



- Final Technical Report -

Building Industry Research Alliance (BIRA)

Budget Periods One, Two and Three
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TABLE OF CONTENTS

DISCLAIMER.....	31
ACKNOWLEDGEMENTS.....	31
ABSTRACT.....	32
INTRODUCTION AND SUMMARY	35
INDUSTRY PARTNERSHIPS.....	35
SUMMARY OF ACTIVITIES	37
TASK 1: BUILDING AMERICA – SYSTEM RESEARCH MANAGEMENT AND TECHNICAL SUPPORT	60
SUBTASK 1.1 PRESENTATION SCHEDULE AND TECHNICAL REPORTS FOR CY 2008 – CY 2010	60
SUBTASK 1.2 MONTHLY STATUS REPORTS, UPCOMING EVENT REPORTING, TECHNICAL HIGHLIGHTS.....	70
SUBTASK 1.3 QUARTERLY ACTIVITY	70
SUBTASK 1.5 FIELD TESTS AND PLANNING	71
SUBTASK 1.6 PUBLICATIONS.....	72
SUBTASK 1.6.1 SUMMARY OF CODE BARRIERS REPORT	76
Codes – Washington State	76
Quadrant Homes.....	77
New Tradition Homes	78
Washington State Energy Code	79
Code and Standards Issues, 2009	80
Code and Standards Issues, 2010	82
Codes – Oregon State	83
Standards	84
SUBTASK 1.7 EXPERTS MEETINGS.....	84
Subtask 1.7.a Miscellaneous Plug Loads (MELs) Expert Meeting.....	85
Objectives.....	85
Summary	85
Conclusions and Next Steps.....	86
Next Steps	86
BIRA Next Steps.....	87
Subtask 1.7.b Solar PV/Thermal Expert Meeting	87
Objectives.....	87
Expert Panelist Introductions	87
Summary	88
ConSol/BIRA	88

NREL	88
Washington State University	88
Florida Solar Energy Center	88
PVT Solar	89
Site Visit-- David Cohan ZEH	89
Conclusions	89
Subtask 1.7.c Panelized Wall Systems Expert Meeting	89
Objectives.....	89
Expert Panelist Introductions	90
Summary	90
Building Science Consortium	90
RAY-CORE	90
Premier Building Systems, INC.....	90
Fintech Precast, INC	91
T-Clear Corporation	91
Amvic Building System	91
Conclusions	91
SUBTASK 1.8 TRAINING	91
TASK 2A: STAGE GATE 1A – INTEGRATED SOLUTIONS FOR SPECIFIC CLIMATE REGIONS AND PERFORMANCE LEVEL.....	93
CLIMATE OVERVIEW	93
Marine Climate	93
Hot/Mixed Dry Climate	94
Cold Climate	95
SUBTASK 2A.1 STAGE GATE 1A EVALUATION PLAN & INITIAL OPTIMIZATION AND ANALYSIS OF TECHNOLOGY PATHWAYS AND PERFORMANCE MAPS IN CA, OR, WA AND UT	96
Key Participants	97
Areas of Investigation	101
Impact of Current Energy Standards (2009 IECC and 2008 California Title-24)	103
Baseline Home Overview	103
SUBTASK 2A.2 SIMULATION AND BUILDER PREFERENCES	104
50% Marine – Budget Period 1	105
“Must Meet” Gate Criteria -- Source Energy Savings	105
50% Marine Strategy.....	108
“Must Meet” Gate Criteria -- Market Coverage	110
“Must Meet” Gate Criteria -- Neutral Cost Target.....	111
“Should Meet” Gate Criteria - Marketability	114
“Should Meet” Gate Criteria - Builder Commitment.....	114
“Should Meet” Gate Criteria - Gaps Analysis.....	114
50% Hot/Dry – Budget Period 1.....	116
“Must Meet” Gate Criteria -- Source Energy Savings	116

"Must Meet" Gate Criteria -- Market Coverage	118
"Must Meet" Gate Criteria -- Neutral Cost Target.....	118
"Should Meet" Gate Criteria -- Marketability.....	122
"Should Meet" Gate Criteria -- Builder Commitment	122
"Should Meet" Gate Criteria -- Gaps Analysis	122
40% Cold – Budget Period 1.....	122
"Must Meet" Gate Criteria -- Source Energy Savings	123
"Must Meet" Gate Criteria -- Neutral Cost Target.....	125
"Should Meet" Gate Criteria -- Marketability.....	128
"Should Meet" Gate Criteria -- Builder Commitment	128
"Should Meet" Gate Criteria -- Gaps Analysis	128
50% Marine Budget Period 2	129
"Must Meet" Gate Criteria -- Source Energy Savings	129
"Should Meet" Gate Criteria -- Least Cost	140
"Should Meet" Gate Criteria -- Marketability.....	140
"Should Meet" Gate Criteria -- Gaps Analysis	140
50% Hot/Dry Budget Period 2.....	141
"Must Meet" Gate Criteria -- Source Energy Savings	141
"Must Meet" Gate Criteria -- Neutral Cost Target.....	146
"Should Meet" Gate Criteria -- Least Cost	152
"Should Meet" Gate Criteria -- Marketability.....	152
"Should Meet" Gate Criteria -- Gaps Analysis	152
50% Cold Budget Period 2.....	153
"Must Meet" Gate Criteria -- Source Energy Savings	153
"Must Meet" Gate Criteria -- Neutral Cost Target.....	157
"Should Meet" Gate Criteria -- Least Cost	160
"Should Meet" Gate Criteria -- Marketability.....	160
"Should Meet" Gate Criteria -- Gaps Analysis	160
Gate 1A 60% Marine Budget Period 3	161
"Must Meet" Gate Criteria - Source Energy Savings	161
Neutral Cost Target.....	167
"Should Meet" Gate Criteria - Least Cost	171
"Should Meet" Gate Criteria - Marketability	171
"Should Meet" Gate Criteria - Gaps Analysis.....	171
Gate 1A 60% Hot/Mixed-Dry Budget Period 3	172
"Must Meet" Gate Criteria - Source Energy Savings	172
"Must Meet" Gate Criteria - Neutral Cost Target	178
"Should Meet" Gate Criteria -- Least Cost	183
"Should Meet" Gate Criteria -- Marketability.....	183
"Should Meet" Gate Criteria - Gaps Analysis.....	183
TASK 2B: STAGE GATE 1B – SYSTEM PERFORMANCE EVALUATIONS	185

SUBTASK 2B.1- SYSTEMS EVALUATION PLANS IN BUILDER PROTOTYPES IN MULTIPLE CLIMATE ZONES		185
Citihouse II		187
Citihouse III		187
Kennecott.....		188
Reno Project.....		189
Idaho Project.....		189
Heat Pump Water Heater (HPWH) Evaluation Plan Budget		190
Overview		192
“Must Meet” Gate Criteria - Source Energy Savings and Whole Building Benefits.....		193
Research Question 1A.....		193
Research Question 1B.....		194
“Must Meet” Gate Criteria - Performance-Based Code Approval.....		194
Research Question 4A.....		194
“Should Meet” Gate Criteria - Cost Advantage		195
Research Question 2A.....		195
Research Question 2B.....		195
Research Question 2C.....		196
Research Question 2D.....		196
“Should Meet” Gate Criteria - Reliability Advantage.....		196
Research Question 3A.....		196
“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment.....		197
Research Question 5A.....		197
Research Question 6A.....		197
Research Question 6B.....		197
Research Question 7A.....		198
Research Question 7B.....		198
“Should Meet” Gate Criteria - Gaps Analysis.....		198
Research Question 8A.....		198
Proposed Test and Analysis Procedure & Schedule		199
Analysis of HPWH system		199
SUBTASK 2B.2- STAGE GATE 1B REPORT: RESULTS OF RESEARCH ON SYSTEMS FOR PROTOTYPE HOMES		200
CSIPS Budget Period 1 (2008)		202
Key Results		202
Gate Status.....		203
Conclusions		203
“Must Meet” Gate Criteria -- Source Energy and Whole Building Benefits		204
“Must Meet” Gate Criteria -- Performance Code Based Approval.....		205
“Should Meet” Gate Criteria -- Prescriptive Based Code Approval.....		206
“Should Meet” Gate Criteria -- Cost Advantage		206
“Should Meet” Gate Criteria -- Reliability Advantage		207
“Should Meet” Gate Criteria -- Manufacturer/Supplier/Builder Commitment		208

“Should Meet” Gate Criteria -- Gap Analysis	209
Combined Solar: Photovoltaic and Thermal (PVT Solar) Budget Period 1 (2008)	210
Key Results	210
Gate Status.....	210
Conclusions	210
“Must Meet” Gate Criteria -- Source Energy and Whole Building Benefits	211
“Must Meet” Gate Criteria -- Performance Code Based Approval.....	212
“Should Meet” Gate Criteria -- Prescriptive Based Code Approval.....	213
“Should Meet” Gate Criteria -- Cost Advantage	213
“Should Meet” Gate Criteria -- Reliability Advantage	214
“Should Meet” Gate Criteria -- Manufacturer/Supplier/Builder Commitment	214
“Should Meet” Gate Criteria -- Gap Analysis	215
SunCache Budget Period 1 (2008)	216
Key Results	216
Gate Status.....	217
Conclusions	217
“Must Meet” Gate Criteria -- Source Energy and Whole Building Benefits	217
“Must Meet” Gate Criteria -- Performance Code Based Approval.....	218
“Should Meet” Gate Criteria -- Prescriptive Based Code Approval.....	218
“Should Meet” Gate Criteria -- Cost Advantage	218
“Should Meet” Gate Criteria -- Reliability Advantage	219
“Should Meet” Gate Criteria -- Manufacturer/Supplier/Builder Commitment	219
“Should Meet” Gate Criteria -- Gap Analysis.....	220
Miscellaneous Electric Loads (MELs) Budget Period 1 (2008)	220
Research Goals.....	221
Individual component efficiency improvements.....	221
Whole House Control Systems	222
Occupant behavior changes.....	222
MELs Categories.....	224
MELs Reduction Strategies	224
Test and Analysis Objectives.....	226
Systems Tested	227
Test Methods/Technical Approach.....	228
Systems	228
Surveys	229
Must Meet Criteria -- Source Energy and Whole Buildings Benefits.....	229
Home Entertainment	229
Home Office	231
“Must Meet” Criteria -- Performance Code Based Approval	233
“Should Meet Criteria” -- Prescriptive-based code approval	233
“Should Meet Criteria” -- Cost effectiveness.....	233
“Should Meet Criteria” -- Reliability Advantage	234
“Should Meet Criteria” -- Manufacturer commitment.....	234

“Should Meet Criteria” -- Gaps Analysis	234
Conclusions	235
SIP Systems - Status Report Budget Period 2 (2009)	236
Key Results	236
Gate Status.....	237
Conclusions	237
Builder/Project Overview	237
“Must Meet” Gate Criteria -- Source Energy Savings and Whole Building Benefits	238
“Must Meet” Gate Criteria -- Performance-Based Code Approval	239
“Should Meet” Gate Criteria -- Prescriptive-Based Code Approval.....	240
“Should Meet” Gate Criteria -- Cost Advantage	240
“Should Meet” Gate Criteria -- Reliability Advantage	241
“Should Meet” Gate Criteria -- Manufacturer/Supplier/Builder Commitment	241
“Should Meet” Gate Criteria -- Gaps Analysis	241
DESIGN:	242
SUBMITTALS:.....	242
Ground Coupled Heat Pump - Status Report Budget Period 2 (2009)	243
Key Results	244
Gate Status.....	245
Conclusions	245
Builder/Project Overview	245
“Must Meet” Gate Criteria -- Source Energy Savings and Whole Building Benefits	246
“Must Meet” Gate Criteria -- Performance-Based Code Approval	247
“Should Meet” Criteria -- Prescriptive-Based Code Approval	248
“Should Meet” Criteria -- Cost Advantage.....	249
“Should Meet” Criteria -- Reliability Advantage	249
“Should Meet” Criteria -- Manufacturer/Supplier/Builder Commitment	250
“Should Meet” Criteria -- Gaps Analysis	250
Home Energy Management Systems Budget Period 2 (2009)	250
Key Results	250
Gate Status.....	250
Conclusions	251
Overview	251
Individual Component Efficiency Improvements	252
Home Energy Management Systems.....	252
Occupant Behavior Changes	253
System Description	253
Interim Status.....	255
“Must Meet” Criteria -- Source Energy and Whole Buildings Benefits	256
“Must Meet” Criteria -- Performance Code Based Approval	256
“Should Meet” Criteria -- Prescriptive-based code approval	256
“Should Meet” Criteria -- Cost effectiveness.....	257
“Should Meet” Criteria -- Reliability Advantage	257

“Should Meet” Criteria -- Manufacturer commitment.....	257
“Should Meet” Criteria -- Gaps Analysis	257
Conclusions	257
Heat Pump Water Heater -- AirTap™ - Status Report Budget Period 2 (2009)	258
Key Results	259
Gate Status.....	259
Conclusions	259
“Must Meet” Gate Criteria -- Source Energy Savings and Whole Building Benefits	260
“Must Meet” Gate Criteria -- Performance-Based Code Approval	260
“Should Meet” Gate Criteria -- Prescriptive-Based Code Approval.....	261
“Should Meet” Gate Criteria -- Cost Advantage	261
“Should Meet” Gate Criteria -- Reliability Advantage	263
“Should Meet” Gate Criteria -- Manufacture/Supplier/Builder Commitment	263
“Should Meet” Gate Criteria -- Gaps Analysis	264
Marine Climate Solar Thermal - Status Report Budget Period 2 (2009).....	264
Key Results	265
Gate Status.....	268
Conclusions	268
Combined Solar: Photovoltaic and Thermal (PVT Solar) Budget Period 2 (2009)	269
Key Results	269
Gate Status.....	270
Conclusions	270
“Must Meet” Gate Criteria -- Source Energy and Whole Building Benefits	270
“Must Meet” Gate Criteria -- Performance Code Based Approval	272
“Should Meet” Gate Criteria -- Prescriptive Based Code Approval	272
“Should Meet” Gate Criteria -- Cost Advantage	273
“Should Meet” Gate Criteria -- Reliability Advantage	273
“Should Meet” Gate Criteria -- Manufacturer/Supplier/Builder Commitment	274
“Should Meet” Gate Criteria -- Gap Analysis	275
PVT Budget Period 3 (2010)	276
Key Results	276
Gate Status.....	276
Conclusions	277
“Must Meet” Gate Criteria - Source Energy Savings and Whole Building Benefits.....	277
Gold Medallion “Parade of Homes” at Daybreak PVT Installation	277
Garbett Homes “Solaris Collection” at Daybreak PVT Installations	279
“Must Meet” Gate Criteria - Performance-Based Code Approval.....	280
“Should Meet” Gate Criteria - Prescriptive-Based Code Approval	280
“Should Meet” Gate Criteria - Cost Advantage	281
“Should Meet” Gate Criteria - Reliability Advantage.....	283
“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment.....	284
“Should Meet” Gate Criteria - Gaps Analysis.....	284

Home Energy Management Systems (HEMs) - Verve Living Systems Budget Period 3 (2010)	286
Key Results	287
Gate Status	287
Conclusions	287
Project Overview and Background	287
Individual Component Efficiency Improvements	288
Home Energy Management Systems (HEMs)	289
Occupant Behavior Changes	289
Research Study Approach	291
“Must Meet” Gate Criteria - Source Energy and Whole Buildings Benefits	293
Baseline Data	293
“Must Meet” Gate Criteria - Performance-Based Code Approval	298
“Should Meet” Gate Criteria - Prescriptive Code Based Approval	298
“Should Meet” Gate Criteria - Cost Advantage	299
“Should Meet” Gate Criteria - Reliability Advantage	300
“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment	300
“Should Meet” Gate Criteria - Gaps Analysis	301
Conclusions	301
Ground Coupled Heat Pump (GeoX) Budget Period 3 (2010)	301
Key Results	302
Gate Status	302
Conclusions	302
Project Overview	302
Ground Source Heat Pump	303
Project Status	304
“Must Meet” Gate Criteria - Source Energy Savings	304
“Must Meet” Gate Criteria - Performance-Based Code Approval	306
“Should Meet” Gate Criteria - Prescriptive-Based Code Approval	306
“Should Meet” Gate Criteria - Cost Advantage	307
“Should Meet” Gate Criteria - Reliability Advantage	308
“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment	308
“Should Meet” Gate Criteria - Gaps Analysis	308
High R-Wall (SIPs) - Status Report Budget Period 3 (2010)	308
Key Results	308
Gate Status	309
Conclusions	309
Introduction	309
Structurally Insulated Panels (SIPs)	309
Project/Builder Overview	310
“Must Meet” Gate Criteria - Source Energy Savings and Whole Building Benefits	310
“Must Meet” Gate Criteria - Performance-Based Code Approval	312
“Should Meet” Gate Criteria - Prescriptive-Based Code Approval	312

“Should Meet” Gate Criteria - Cost Advantage	313
“Should Meet” Gate Criteria - Reliability Advantage.....	314
“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment.....	314
“Should Meet” Gate Criteria - Gaps Analysis.....	314
“Should Meet” Gate Criteria – Quality Control Integration	315
Solar Thermal Budget Period 3 (2010).....	318
Key Results	319
Gate Status.....	319
Conclusion	319
Introduction	319
Market Background	319
Current Market	320
Study Summary	321
Maintenance and Operation.....	322
Installation	323
Code Related Issues	323
Return on Investment	324
Case Studies	324
Martha Rose Construction	325
Design and Installation Issues.....	328
Fish Singer Place.....	329
Cohan Residence	330
Shirey Residence – Ideas House	333
OASys - Final Report Budget Period 3 (2010)	334
Key Results	336
Gate Status.....	337
Conclusion	337
“Must Meet” Gate Criteria - Source Energy and Whole Building Benefits.....	338
“Must Meet” Gate Criteria - Performance Code Based Approval	340
“Should Meet” Gate Criteria - Prescriptive Based Code Approval	340
“Should Meet” Gate Criteria - Cost Advantage	341
“Should Meet” Gate Criteria - Reliability Advantage.....	343
“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment.....	344
“Should Meet” Gate Criteria - Gap Analysis	345
Heat Pump Water Heater (HPWH) Budget Period 3 (2010)	350
Key Results	352
Gate Status.....	352
Conclusions	352
“Must Meet” Gate Criteria - Source Energy and Whole Building Benefits.....	353
“Must Meet” Gate Criteria - Performance-Based Code Approval.....	355
“Should Meet” Gate Criteria - Prescriptive Based Code Approval	356
“Should Meet” Gate Criteria - Cost Advantage	356
“Should Meet” Gate Criteria - Reliability Advantage.....	357

"Should Meet" Gate Criteria - Manufacturer/Supplier/Builder Commitment.....	357
"Should Meet" Gate Criteria - Gaps Analysis.....	357
SUBTASK 2B.3 EXPERT MEETINGS (1 MINIMUM).....	358
Objectives.....	359
Overview	360
Expert Panel	361
Open Discussion.....	362
Consumer Electronics	362
Feedback	363
Controls.....	364
Conclusions and Next Steps.....	364
Expert's Meeting Action Items.....	364
BIRA Next Steps.....	365
SUBTASK 2B.5 WSU HEAT PUMPS	365
Scope of Report.....	365
Background and Summary of STAC Project	366
Background	366
Description of STAC Project	366
Findings and Conclusions.....	367
"Must Meet" Criteria - Source Energy and Whole Buildings Benefits.....	368
"Must Meet" Criteria - Performance-Based Code Approval	369
"Should Meet" Criteria -- Prescriptive-Based Code Approval	369
"Should Meet" Criteria -- Cost Advantage.....	369
"Should Meet" Criteria -- Reliability Advantage	369
"Should Meet" Criteria -- Manufacturer/Supplier/Builder Commitment	370
"Should Meet" Criteria -- Gaps Analysis	370
TASK 3: STAGE GATE 2 -- PROTOTYPE HOUSE EVALUATIONS	372
3.1 DESIGN, ANALYSIS, AND TEST PLANS FOR STAGE GATE 2 HOUSE PROJECTS IN MULTIPLE CLIMATES (MARINE, HOT/DRY, AND COLD)	372
New Tradition Homes: 50% Marine Prototype Evaluation Plan.....	374
Background	374
"Parade Home" Location	375
Climate	376
Utility Providers	376
Overall Test and Analysis Objective.....	377
NTH 50% Prototype Performance Measurement Plans	377
"Must Meet" Gate Criteria - Source Energy Savings	378
"Must Meet" Gate Criteria - Prescriptive-Based Code Approval.....	378
"Must Meet" Gate Criteria - Quality Control Requirements	378
"Should Meet" Gate Criteria - Cost Neutrality	378
"Should Meet" Gate Criteria - Quality Control Integration	380

“Should Meet” Gate Criteria - Gap Analysis	380
Proposed Test and Analysis Schedule.....	380
Description of Test Results Required by Industry Partners.....	381
Artisans Group: 50% Marine Prototype Evaluation Plan.....	381
Background	381
“Passive House” Location	382
Climate	383
Utility Provider	383
Overall Test and Analysis Objective.....	384
“Must Meet” Gate Criteria- Source Energy Savings	384
“Must Meet” Gate Criteria - Prescriptive-Based Code Approval.....	385
“Must Meet” Gate Criteria - Quality Control Requirements	385
“Should Meet” Gate Criteria - Cost Neutrality	385
“Should Meet” Gate Criteria - Quality Control Integration	386
“Should Meet” Gate Criteria - Gap Analysis	387
Proposed Test and Analysis Schedule.....	387
Description of Test Results Required by Industry Partners.....	387
3.2 STAGE GATE 2 PROTOTYPE HOUSE REPORT: PERFORMANCE EVALUATIONS IN	
PREPRODUCTION PROTOTYPES	388
Artistic Homes - Albuquerque, NM BP2 (2009)	389
Key Results	390
Gate Status.....	391
Conclusion.....	391
Builder/Project Overview	391
“Must Meet” Gate Criteria -- Source Energy Savings	392
“Must Meet” Gate Criteria -- Prescriptive-Based Code Approval	393
“Must Meet” Gate Criteria -- Quality Control Requirements.....	394
“Should Meet” Gate Criteria -- Neutral Cost Target.....	394
“Should Meet” Gate Criteria -- Quality Control Integration.....	395
“Should Meet” Gate Criteria -- Gaps Analysis	395
Geos “Solar Cottages” BP2 (2009)	395
Key Results	396
Gate Status.....	396
Conclusions	396
“Must Meet” Gate Criteria -- Source Energy Savings	397
“Must Meet” Gate Criteria -- Prescriptive-Based Code Approval	399
“Must Meet” Gate Criteria -- Quality Control Requirements.....	399
“Should Meet” Gate Criteria -- Neutral Cost Target.....	399
“Should Meet” Gate Criteria -- Quality Control Integration.....	400
“Should Meet” Gate Criteria -- Gaps Analysis	400
Snow Creek Cottages BP2 (2009).....	401
Key Results	402
Gate Status.....	403

Conclusions	403
“Must Meet” Gate Criteria -- Source Energy Savings	405
“Must Meet” Gate Criteria -- Prescriptive-Based Code Approval	408
“Must Meet” Gate Criteria -- Quality Control Requirements	408
“Should Meet” Criteria -- Neutral Cost Target.....	409
“Should Meet” Gate Criteria -- Quality Control Integration	410
DESIGN:	411
SUBMITTALS:	411
Gold Medallion 50% Prototype BP2 (2009)	412
Key Results	412
Gate Status.....	414
Conclusions	414
“Must Meet” Gate Criteria -- Source Energy Savings	414
“Must Meet” Criteria -- Prescriptive-Based Code Approval	415
“Should Meet” Criteria -- Neutral Cost Target.....	416
“Should Meet” Criteria -- Quality Control Integration	416
“Should Meet” Criteria -- Gaps Analysis	416
Forest City, HI – 50% Hot/Humid Mololani Prototype BP3 (2010)	416
Key Results	417
Gate Status.....	417
Conclusions	417
Builder/Project Overview	417
Location.....	418
Climate	419
Utility Provider	419
Detailed Description of Test Home	420
“Must Meet” Gate Criteria - Source Energy Savings	421
“Must Meet” Gate Criteria - Prescriptive-Based Code Approval.....	421
“Must Meet” Gate Criteria - Quality Control Requirements	422
“Should Meet” Gate Criteria - Cost Neutrality	423
“Should Meet” Gate Criteria - Quality Control Integration	423
“Should Meet” Gate Criteria - Gap Analysis	424
Snow Creek Cottages BP3 (2010).....	424
Key Results	424
Gate Status.....	425
Conclusions	425
Introduction	425
Background	426
Location.....	427
Utility Provider	428
Detailed Description of Prototype Houses	429
Prototype Home Status.....	430
Stage Gate 2 Research Objective	431

“Must Meet” Gate Criteria -- Source Energy Savings and Whole Building Benefits	431
“Must Meet” Gate Criteria - Prescriptive-Based Code Approval.....	433
“Must Meet” Gate Criteria -- Quality Control Requirements.....	433
“Should Meet” Criteria -- Neutral Cost Target.....	434
“Should Meet” Gate Criteria -- Quality Control Integration.....	435
“Should Meet” Gate Criteria -- Gaps Analysis	435
Marine - New Tradition Homes 50% Prototype Report (BP3 (2010)).....	436
Key Results	436
Gate Status.....	436
Conclusions	436
Introduction	437
Background	437
“Parade Home” Location	438
Climate	439
Utility Providers	439
“Must Meet” Gate Criteria - Source Energy Savings and Whole Building Benefits.....	440
“Should Meet” Gate Criteria - Prescriptive-Based Code Approval.....	440
“Must Meet” Gate Criteria - Quality Control Requirements	441
“Should Meet” Gate Criteria - Gaps Analysis.....	441
“Should Meet” Gate Criteria - Neutral Cost Target	442
“Should Meet” Gate Criteria - Quality Control Integration	445
3.3 STAGE GATE 2 PROTOTYPE HOUSE REPORTS: NORTHERN MARINE HOUSE STUDIES AT	
50% WHES - 2 MINIMUM.....	446
New Traditions Homes – Kent Model 2264 – Vancouver, WA BP1 (2008)	447
“Must Meet” Gate Criteria -- Source Energy Savings	448
“Must Meet” Gate Criteria -- Prescriptive-Based Code Approval	450
“Must Meet” Gate Criteria -- Quality Control Requirements.....	450
“Should Meet” Gate Criteria -- Neutral Cost Target	451
“Should Meet” Gate Criteria - Quality Control Integration	453
“Should Meet” Gate Criteria - Gaps Analysis.....	453
Martha Rose BP1 (2008)	454
“Must Meet” Gate Criteria -- Source Energy Savings	455
“Must Meet” Gate Criteria -- Prescriptive-Based Code Approval	458
“Must Meet” Gate Criteria -- Quality Control Requirements.....	458
“Should Meet” Gate Criteria - Neutral Cost Target	459
“Should Meet” Gate Criteria -- Quality Control Integration	464
“Should Meet” Gate Criteria -- Gaps Analysis	464
David Cohan 50% Marine Prototype - Portland, OR BP2 (2009)	465
Key Results	465
Gate Status.....	465
Conclusions	465
Background	466
“SIPs House” Location.....	466

Climate	468
Utility Providers	469
“Must Meet Criteria” -- Source Energy Savings	469
“Must Meet Criteria” -- Prescriptive-Based Code Approval	471
“Must Meet Criteria” -- Quality Control Requirements	471
“Should Meet Criteria” -- Cost Neutrality	472
“Should Meet Criteria” -- Quality Control Integration	476
“Should Meet Criteria” -- Gap Analysis	476
Gold Medallion 50% Prototype – Completion Report BP3 (2010)	477
Key results	477
Gate Status	477
Conclusions	477
Introduction	478
Project Overview	478
Advanced Systems Overview	478
“Must Meet” Gate Criteria - Source Energy Savings	479
“Must Meet” Gate Criteria - Prescriptive-Based Code Approval	480
“Must Meet” Gate Criteria - Quality Control Requirements	480
“Should Meet” Gate Criteria - Neutral Cost Target	480
“Should Meet” Gate Criteria - Quality Control Integration	480
“Should Meet” Criteria - Gaps Analysis	481
TASK 4: STAGE GATE 3 -- COMMUNITY SCALE EVALUATIONS	482
SUBTASK 4.1 EVALUATION PLANS FOR INITIAL COMMUNITY SCALE PROJECTS OF TEN OR MORE HOMES WITH 40-50% IN EFFICIENCY SAVINGS	482
SUBTASK 4.2 STAGE GATE 3 CASE STUDIES: 40-50% INITIAL COMMUNITY SCALE PROJECTS	483
New Traditions - Community Overview BP1 (2008)	486
“Must Meet” Gate Criteria -- Source Energy Savings	487
“Must Meet” Gate Criteria - Market Coverage	490
“Must Meet” Gate Criteria - Neutral Cost Target	490
“Should Meet” Gate Criteria -- Marketability	493
“Should Meet” Gate Criteria -- Builder Commitment	496
“Should Meet” Gate Criteria -- Gaps Analysis	497
“Should Meet” Gate Criteria -- Quality Assurance	498
Quadrant - Community Overview BP1 (2008)	498
“Must Meet” Gate Criteria -- Source Energy Savings	499
“Must Meet” Gate Criteria -- Market Coverage	502
“Must Meet” Gate Criteria -- Neutral Cost Target	503
“Should Meet” Gate Criteria -- Marketability	506
“Should Meet” Gate Criteria -- Builder Commitment	509
“Should Meet” Gate Criteria -- Gaps Analysis	510

"Should Meet" Gate Criteria -- Quality Assurance	511
Ruhoff Homes BP1 (2008)	512
Community Overview	512
"Must Meet" Gate Criteria -- Source Energy Savings	513
"Must Meet" Gate Criteria -- Market Coverage	516
"Must Meet" Gate Criteria -- Neutral Cost Target.....	516
"Should Meet" Gate Criteria --Marketability.....	520
"Should Meet" Gate Criteria -- Builder Commitment	522
"Should Meet" Gate Criteria -- Gaps Analysis	523
"Should Meet" Gate Criteria -- Quality Assurance	523
Schneider Family Homes BP1 (2008)	524
Community Overview	524
"Must Meet" Gate Criteria -- Source Energy Savings	524
"Must Meet" Gate Criteria -- Market Coverage	527
"Must Meet" Gate Criteria -- Neutral Cost Target.....	527
"Should Meet" Gate Criteria -- Marketability.....	531
"Should Meet" Gate Criteria -- Builder Commitment	533
"Should Meet" Gate Criteria -- Gaps Analysis	534
"Should Meet" Gate Criteria -- Quality Assurance	535
Tom Walsh & Co. BP1 (2008)	535
Community Overview	535
"Must Meet" Gate Criteria -- Source Energy Savings	536
"Must Meet" Gate Criteria -- Market Coverage	539
"Must Meet" Gate Criteria -- Neutral Cost Target.....	539
"Should Meet" Gate Criteria -- Marketability.....	543
"Should Meet" Gate Criteria -- Builder Commitment	545
"Should Meet" Gate Criteria - Gaps Analysis.....	546
"Should Meet" Gate Criteria - Quality Assurance	546
Snow Creek Cottages – Park City, UT – 50% Cold BP2 (2009)	547
Key Results	547
Gate Status.....	547
Conclusions	548
Community Overview	548
Location.....	549
"Must Meet" Gate Criteria -- Source Energy Savings	549
"Must Meet" Gate Criteria -- Market Coverage	551
"Must Meet" Gate Criteria -- Neutral Cost Target.....	552
"Should Meet" Gate Criteria -- Marketability.....	555
Should Meet" Gate Criteria -- Builder Commitment	555
Should Meet" Gate Criteria -- Gaps Analysis	555
Should Meet" Gate Criteria -- Quality Assurance	556
Green One Construction Services - Sage Green – Portland, OR BP2 (2009)	556
Key Results	556

Gate Status.....	556
Community Overview	557
“Must Meet” Gate Criteria -- Source Energy Savings	557
“Must Meet” Gate Criteria -- Market Coverage	559
“Must Meet” Gate Criteria -- Neutral Cost Target.....	559
“Should Meet” Gate Criteria -- Marketability.....	562
“Should Meet” Gate Criteria -- Builder Commitment	562
“Should Meet” Gate Criteria -- Gaps Analysis	563
“Should Meet” Gate Criteria -- Quality Assurance	563
Mololani -- Kaneohe, HI -- 50% Hot Humid BP2 (2009)	563
Key Results	564
Gate Status.....	564
Conclusions	564
Community Overview	564
“Must Meet” Gate Criteria -- Source Energy Savings	565
“Must Meet” Gate Criteria -- Market Coverage	568
“Must Meet” Gate Criteria -- Neutral Cost Target.....	568
“Should Meet” Gate Criteria -- Marketability.....	572
“Should Meet” Gate Criteria -- Builder Commitment	572
“Should Meet” Gate Criteria -- Gaps Analysis	573
“Should Meet” Gate Criteria -- Quality Assurance	574
Artistic Homes -- NM/CO -- 50% Cold and Hot/Mixed Dry BP2 (2009)	574
Key Results	574
Gate Status.....	574
Conclusions	575
Community Overview	575
“Must Meet” Gate Criteria -- Source Energy Savings	575
“Must Meet” Gate Criteria -- Market Coverage	577
“Must Meet” Gate Criteria -- Neutral Cost Target.....	577
“Should Meet” Gate Criteria -- Marketability.....	577
“Should Meet” Gate Criteria -- Market Coverage.....	580
“Should Meet” Gate Criteria -- Builder Commitment	580
“Should Meet” Gate Criteria -- Gaps Analysis	580
“Should Meet” Gate Criteria -- Quality Assurance	581
Waikulu -- Oahu, HI -- 50% Hot Humid BP2 (2009)	581
Key Results	581
Gate Status.....	581
Conclusions	582
Overview	582
“Must Meet” Gate Criteria -- Source Energy Savings	583
“Must Meet” Gate Criteria -- Market Coverage	585
“Must Meet” Gate Criteria -- Neutral Cost Target.....	585
“Should Meet” Gate Criteria -- Marketability.....	589

“Should Meet” Gate Criteria -- Builder Commitment	589
“Should Meet” Gate Criteria -- Gaps Analysis	590
“Should Meet” Gate Criteria -- Quality Assurance	591
DR Horton –Makalae at Sea Country – 50% Hot-Humid BP3 (2010).....	591
Key Results	591
Gate Status.....	591
Conclusions	592
Overview	592
“Must Meet” Gate Criteria -- Source Energy Savings	594
“Must Meet” Gate Criteria -- Market Coverage	600
“Must Meet” Gate Criteria -- Neutral Cost Target.....	600
“Should Meet” Gate Criteria -- Marketability	603
“Should Meet” Gate Criteria -- Builder Commitment	604
“Should Meet” Gate Criteria -- Gaps Analysis	604
“Should Meet” Gate Criteria -- Quality Assurance	605
Visionary Home Builders – Tierra Del Sol – 50% Hot/Mixed-Dry Community BP3 (2010) .	606
Key Results	606
Gate Status.....	606
Conclusions	606
Overview	607
“Must Meet” Gate Criteria -- Source Energy Savings	609
“Must Meet” Gate Criteria -- Market Coverage	614
“Must Meet” Gate Criteria -- Neutral Cost Target.....	614
“Should Meet” Gate Criteria -- Marketability	619
“Should Meet” Gate Criteria -- Market Coverage	619
“Should Meet” Gate Criteria -- Builder Commitment	620
“Should Meet” Gate Criteria -- Gaps Analysis	620
“Should Meet” Gate Criteria -- Quality Assurance	620
Green One Construction Services - Sage Green 50% Marine Community Completion Report BP3 (2010).....	622
Key Results	622
Gate Status.....	622
Conclusion	622
Project Overview and Background	622
Community Overview	623
“Must Meet” Gate Criteria -- Source Energy Savings	623
“Must Meet” Gate Criteria -- Market Coverage	625
“Must Meet” Gate Criteria -- Neutral Cost Target.....	625
“Should Meet” Gate Criteria -- Marketability	629
“Should Meet” Gate Criteria -- Builder Commitment	629
“Should Meet” Gate Criteria -- Gaps Analysis	629
“Should Meet” Gate Criteria -- Quality Assurance	630
SUBTASK 4.2.A – STAGE GATE 3: DEVOTED CASE STUDY (40% MARINE JOULE MILESTONE)	630

Mediterranean Villas --Community Overview	630
Key Results	631
Gate Status.....	631
“Must Meet” Gate Criteria -- Source Energy Savings	632
“Must Meet” Gate Criteria -- Market Coverage	633
“Must Meet” Gate Criteria -- Neutral Cost Target.....	634
“Should Meet” Gate Criteria -- Marketability.....	637
“Should Meet” Gate Criteria -- Builder Commitment	639
“Should Meet” Gate Criteria -- Gaps Analysis	640
“Should Meet” Gate Criteria -- Quality Assurance	640
SUBTASK 4.3 STAGE GATE 3 REPORT: 40% INITIAL COMMUNITY SCALE PROJECTS IN MARINE CLIMATE	641
Key Results	641
Project Overview.....	641
“Must Meet” Gate Criteria -- Source Energy Savings	642
“Must Meet” Gate Criteria -- Market Coverage	645
“Must Meet” Gate Criteria -- Neutral Cost Target.....	646
“Should Meet” Gate Criteria -- Marketability.....	647
“Should Meet” Gate Criteria -- Market Coverage.....	653
“Should Meet” Gate Criteria -- Builder Commitment	655
“Should Meet” Gate Criteria -- Gaps Analysis	656
“Should Meet” Gate Criteria -- Quality Assurance	657
SUBTASK 4.4 STAGE GATE 3: INITIAL COMMUNITIES UPDATE REPORT - MULTIPLE CLIMATES	658
Cold Climate	659
City of Park City, UT (Developer)	659
Devoted Home Builders	660
Oregon DOE High Performance Home builder partner (new project)	661
Artistic Homes	661
Salt Lake County Affordable Housing	662
GEOS.....	662
Hot/Mixed-Dry Climate.....	663
K Street LLC	663
DMB (Developer)	663
I-Build	663
Rancho Mission Viejo (Developer).....	664
Habitat for Humanity	664
PepperViner	665
Coldwell Banker	665
Forest City (Developer)	665
Newland Communities.....	666
City of Henderson, NV (Developer)	666
Artistic Homes.....	666

Zero Energy Net Homes (SMUD Project)	667
Marine Climate	668
Howland Homes.....	668
Tom Walsh	668
Ruhoff Home Builders.....	669
New Tradition Homes	669
The WJM Studio	669
Hot/Humid Climate	670
Forest City	670
TASK 5: STAGE GATE FINAL PROJECT CLOSEOUT	671
O BEL SOLE! ESTATES	671
Key Results	671
Gate Status.....	671
Conclusions	671
Lancaster – Location, Demographics, Housing Market Data.....	672
Partnerships/History	673
Homes and Community Overview	674
“Must Meet” Gate Criteria -- Source Energy Savings	675
“Must Meet” Gate Criteria -- Neutral Cost Target.....	677
Should Meet” Gate Criteria -- Quality Control Integration	680
Should Meet” Gate Criteria -- Marketability	681
Should Meet” Gate Criteria -- Builder Commitment	683
Should Meet” Gate Criteria -- Home Owner Satisfaction / Energy Bills.....	684
Energy Bills Savings	684
Energy Efficiency Performance and Benefits.....	685
Should Meet” Gate Criteria -- Gaps Analysis	686
TASK 6: POST-STAGE GATE RESULTS, BEST PRACTICES DOCUMENTATION AND RESOURCE DEVELOPMENT	688
SUBTASK 6.1 REVIEW & PROVIDE FEEDBACK TO BEST PRACTICES DRAFTED REPORTS BY PNNL & ORNL.....	688

TABLE OF FIGURES

Figure 1. Map of BIRA Research Activity and Climate Regions.....	37
Figure 2. Map of Targeted Marine Climate Regions.....	94
Figure 3. Map of Targeted Hot/Dry Climate Regions	95
Figure 4. BIRA Cold Climate/High Desert Regions	96
Figure 5. California Code (CZ3) vs. Building America Benchmark	106
Figure 6. Oregon Code vs. Building America Benchmark	106
Figure 7. Washington Code vs. Building America Benchmark.....	107
Figure 8. Estimated Annual Energy Costs for 50% Marine Strategy.....	113
Figure 9. Infrared Picture of a Kitchen Can Light in a New Tradition Home.....	115
Figure 10. BA Benchmark vs. CA Title-24 (Hot/Dry Climate Zone)	116
Figure 11. Estimated Annual Energy Costs for 50% Strategy	120
Figure 12. BEopt Analysis for Kennecott Land Current Construction Practice	123
Figure 13. Comparison of IECC 2006, Kennecott Sustainability, Energy Star and As-Built.....	124
Figure 14. Cost Comparison for Four Design Options.....	126
Figure 15. Whole-House Energy Savings in Title-24 Region	130
Figure 16. Whole-House Energy Savings in IECC Region	130
Figure 17. End-Use Energy Loads for 2008 Title-24 and 50% WHES	131
Figure 18. End-Use Energy Load for 2009 IECC and 50% WHES.....	132
Figure 19. Annual Net Savings for 50%WHES (upgraded from 2008 Title-24)	135
Figure 20. Annual Net Savings for 50%WHES (upgraded from 2009 IECC)	136
Figure 21. Whole-House Energy Savings in Title-24 Region	142
Figure 22. Whole-House Energy Savings in IECC Region	142
Figure 23. End-Use Energy Loads for 2008 Title-24 and 50% WHES	143
Figure 24. End-Use Energy Load for 2009 IECC and 50% WHES.....	144
Figure 25. Annual Net Savings for 50% WHES (upgraded from 2008 Title-24)	147
Figure 26. Annual Net Savings for 50% WHES (upgraded from 2009 IECC)	148
Figure 27. Whole-House Energy Savings	154
Figure 28. End-Use Energy Loads.....	155
Figure 29. End-Use Energy Load as Percentage of Total	155
Figure 30. Annual Net Savings for 50% WHES	157
Figure 31. WHES in Title-24 region	162
Figure 32. Whole-House energy savings in 2009 IECC region	162
Figure 33. End-use energy loads for 2008 Title-24 and 60% WHES	163
Figure 34. End-use energy load for 2009 IECC and 60% WHES	164
Figure 35. Annual net cost savings for 60%WHES (upgraded from 2008 Title-24)	167
Figure 36. Annual net cost savings for 60%WHES (upgraded from 2009 IECC)	168
Figure 37. WHES in Title-24 region	173
Figure 38. WHES in IECC region	174
Figure 39. End-use energy loads for 2008 Title-24 and 60% WHES	175
Figure 40. End-use energy load for 2009 IECC and 60% WHES	175
Figure 41. Annual net cost savings for 60% WHES (upgraded from 2008 Title-24)	179

Figure 42. Annual net cost savings for 60% WHES (upgraded from 2009 IECC)	179
Figure 43. Gold Medallion Parade Home 40%+ PVT.....	189
Figure 44. General Electric online savings calculator	191
Figure 45. 40% High Efficiency Home vs. Building America Benchmark (Hot/Mixed Dry).....	221
Figure 46. Estimated Average Source Energy Savings for Whole House Control Systems in Each of the Major Climate Zones	223
Figure 47. LCG3 Smart Strip Power Strip	227
Figure 48. Isole IDP-3050 Plug Load Control.....	228
Figure 49. Estimated Average Source Energy Savings for Whole House Control Systems in Each of the Major Climate Zones	251
Figure 50. Collector inlet fluid temperature above ambient.....	267
Figure 51. F-chart vs. Actual solar from BTU meter (2009)	268
Figure 52. Estimated average source energy savings for whole house control systems in each of the major Climate zones	288
Figure 53. Verve System wiring schematic	291
Figure 54. Baseline utility bill data for Farmington, NM prototype (w/o VERVE)	295
Figure 55. Baseline utility bill data for Albuquerque, NM prototype (w/o VERVE).....	295
Figure 56. Total estimated MELs consumption	298
Figure 57. Btu meter	323
Figure 58. Drain-back and propylene glycol active indirect	324
Figure 59. Martha Rose Construction SDHW systems.....	325
Figure 60. Homestead's Btu metered performance compared to F-chart simulation.....	326
Figure 61. Redesign of Martha Rose's solar thermal system - Homestead.....	327
Figure 62. IR photo of heat loss from gas heated 120°F solar tank at Homestead.....	327
Figure 63. Solar thermal piping installation at Homestead	328
Figure 64. Solar pump cycling in April 2008 for Homestead	328
Figure 65. Diagram of Fish Singer Place solar two-tank DHW system.....	329
Figure 66. Typical two-tank SDHW drain-back SDHW approved in Oregon.....	330
Figure 67. Drain-back and solar tanks.....	331
Figure 68. Solar panel tilted on flat roof.....	331
Figure 69. Impact of inlet temperature of flat plate, evacuated tube and	332
Figure 70. Estimated solar heating performance in Oregon vs. other climates.....	333
Figure 71. Shirey Zero Energy Idea House with evacuated tube panels on left.....	334
Figure 72. Gold Medallion's Newport House.....	335
Figure 73. Community Development Corporation's Webster Cottages house.....	336
Figure 74. Cooling performance of OASys during a 104.2 degree day in Gold Medallion's Newport House	346
Figure 75. Relative humidity levels during a 104.2 degree day in the Gold Medallion Newport House	347
Figure 76. Cooling performance of OASys during a 36.95% outdoor relative humidity day in the Gold Medallion's Newport House.....	348
Figure 77. Cooling performance of OASys during a 36.95% outdoor relative humidity day in the Gold Medallion's Newport House.....	349

Figure 78. DOE Buildings Energy Data Book Table 2.1.6	350
Figure 79. DOE Buildings Energy Data Book Table 2.4.3	351
Figure 80. Graph showing energy input to output in MBtus.....	355
Figure 81. UPC Table 5-1	356
Figure 82. Comparison of MELs Use BA Benchmark Home vs. 40% Energy Efficient Home	359
Figure 83. NTH “Parade Home” location	375
Figure 84. NTH “Parade Home”	376
Figure 85. AG “Passive House” location.....	382
Figure 86. AG “Passive House”	383
Figure 87. Front view of the Albuquerque House	390
Figure 88. BEopt Source Energy Use “Solar Cottage” with BA Benchmark and IECC Standard as the Reference Homes	398
Figure 89. Cost Neutrality for “Deer” Model	409
Figure 90. Cost Neutrality for “Fox” Model	410
Figure 91. Monthly comparison of energy consumption and production.	413
Figure 92. Comparison of net energy production and consumption with the values from Rocky Mountain Power bills.	413
Figure 93. Prototype home location	419
Figure 94. Mololani Unit 110 home	420
Figure 95. 13-Unit Snow Creek Development Fox A (#10) on left & Deer A (#11) on right	427
Figure 96. Snow Creek Cottages Development Area Located at 6,800 elevation in Cold Climate Designation	428
Figure 97. Average electricity rates by state indicating that Utah charges the least amount for power in the nation	429
Figure 98. Snow Creek Cottages, Unit 10 (left) and 11 (right) with PV and Evacuated Tube Solar Hot Water	430
Figure 99. NTH “Parade Home” location	438
Figure 100. NTH “Parade Home”	439
Figure 101. BEopt Source Energy Use Kent 2264 with BA Benchmark as the Reference House	449
Figure 102. BEopt Source Energy Use Martha Rose with BA Benchmark as the Reference House	456
Figure 103. BEopt Source Energy Use Martha Rose with Washington Code House as the Reference House	456
Figure 104. BEopt Energy Costs: Martha Rose with Washington Code House as the Reference House	460
Figure 105. David Cohan’s “SIPs House” Location	467
Figure 106. David Cohan “SIPs House”	467
Figure 107. Completed Home	468
Figure 108. WHES versus Benchmark	471
Figure 109. BEopt Source Energy Use Kent 2264 with the BA Benchmark as the Reference House	488
Figure 110. BEopt Energy Cost Kent 2264 with the BA Benchmark as the Reference House ...	491

Figure 111. Source Energy Use Marketing Material for New Tradition Homes	495
Figure 112. Energy Cost Marketing Material for New Tradition Homes	496
Figure 113. BEopt Source Energy Use Olympic 2011 with the BA Benchmark as the Reference House.	500
Figure 114. BEopt Energy Cost Olympic 2011 with the BA Benchmark as the Reference House	503
Figure 115. Source Energy Use Marketing Material for Quadrant Homes.....	507
Figure 116. Energy Cost Marketing Material for Quadrant Homes.....	508
Figure 117. Energy Cost Comparison Marketing Material for Quadrant Homes	508
Figure 118. Cost Effectiveness Marketing Materials for Quadrant Homes.....	509
Figure 119. BEopt Source Energy Use Fidalgo Townhome with the BA Benchmark as the Reference House	514
Figure 120. BEopt Energy Cost Fidalgo Townhome with the BA Benchmark as the Reference House	517
Figure 121. Source Energy Use Marketing Material for Ruhoff Home Builders.....	521
Figure 122. Energy Cost Marketing Material for Ruhoff Home Builders.....	522
Figure 123. BEopt Source Energy Use E381 with the BA Benchmark as the Reference House .	525
Figure 124. BEopt Energy Cost E381 with the BA Benchmark as the Reference House	528
Figure 125. Source Energy Use Marketing Material for Schneider Family Homes	532
Figure 126. Energy Cost Marketing Material for Schneider Family Homes.....	533
Figure 127. BEopt Source Energy Use Roseburg 1884 with the BA Benchmark as the Reference House	537
Figure 128. BEopt Energy Cost Roseburg 1884 with the BA Benchmark as the Reference House	540
Figure 129. Source Energy Use Marketing Material for Tom Walsh & Co.	544
Figure 130. Energy Cost Marketing Material for Tom Walsh & Co.....	545
Figure 131. Snow Creek Cottages Site Map	549
Figure 132. EnergyGauge Source Energy Use-“Deer” Model	550
Figure 133. Cost Neutrality- “Deer” Model	552
Figure 134. BEopt Source Energy Use Unit C with the BA Benchmark as the Reference House	558
Figure 135: BEopt Energy Cost Unit C with the BA Benchmark as the Reference House	560
Figure 136. BEopt Source Energy Use – Average of 4 Cardinal Orientations 110 with the BA Benchmark as the Reference House.....	566
Figure 137. BEopt Energy Cost 110 with the BA Benchmark as the Reference House	569
Figure 138. BEopt Source Energy Use – average of 4 cardinal orientations 1651 with the BA Benchmark as the Reference House	583
Figure 139. BEopt Energy Cost 1651 with the BA Benchmark as the Reference House	586
Figure 140. Community map	592
Figure 141. Computer rendering - Model 3 prototype (1,360 sq. ft.)	593
Figure 142. Computer rendering- Model 5 prototype (1,244 sq. ft.)	594
Figure 143. Icynene® thermal break illustration	598
Figure 144. Estimated annual source energy- Model 3.....	599

Figure 145. Estimated annual source energy- Model 5	599
Figure 146. Estimated annual incremental costs – Model 3	601
Figure 147. Estimated annual incremental costs- Model 5	601
Figure 148. Estimated annual energy costs- Model 3	602
Figure 149. Estimated Annual Energy Costs- Model 5.....	603
Figure 150. Area map of the Tierra Del Sol community, located on Del Ray Court, Stockton, CA 95215	608
Figure 151. Computer rendering of Exterior View of Unit 101, a Tierra Del Sol floor plan.	609
Figure 152. Tierra Del Sol estimated annual source energy for the BA Benchmark, Title 24, Builder’s Practice, and 50% WHES (labeled prototype)	614
Figure 153. Tierra Del Sol estimated annual incremental costs for the BA Benchmark and the prototype without PV	617
Figure 154. Tierra Del Sol estimated annual incremental costs for the BA Benchmark and the prototype with PV	617
Figure 155. Tierra Del Sol estimated annual energy costs for BA Benchmark, Title 24, builder’s practice and 50% WHES	618
Figure 156. BEopt source energy use for Unit C with the BA Benchmark as the reference house	624
Figure 157. BEopt energy cost for Unit C with the BA Benchmark as the reference house	626
Figure 158. EnergyGauge Source Energy Use Marsala 1772 with the BA Benchmark as the Reference House	632
Figure 159. EnergyGauge Energy Cost Marsala 1772 with the BA Benchmark as the Reference House	634
Figure 160. Source Energy Use Marketing Material for Devoted Builders	638
Figure 161. Energy Cost Marketing Material for Devoted Builders.....	639
Figure 162. Source Energy Use Marketing Material for Quadrant Homes.....	649
Figure 163. Energy Cost Marketing Material for Quadrant Homes.....	650
Figure 164. Energy Cost Comparison Marketing Material for Quadrant Homes	651
Figure 165. Cost Effectiveness Marketing Materials for Quadrant Homes.....	652
Figure 166. 40% Marine Community Distribution	653
Figure 167. Housing Permits Comparison for California, Oregon, and Washington	654
Figure 168. Climate Zones of the Western US	659
Figure 169. O Bel Sole – Lancaster Area Map	672
Figure 170. Aerial View of O Bel Sole Site.....	674
Figure 171. BEopt Source Energy Use Plan B with the BA Benchmark as the Reference House	675
Figure 172. BEopt Energy Cost Plan B with the BA Benchmark as the Reference House	677
Figure 173. Source Energy Use Marketing Material for K Street	682
Figure 174. Energy Cost Marketing Material for K Street.....	683

LIST OF TABLES

Table 1. BIRA's List of Partners by Type	37
Table 2. Field Test Opportunities	40
Table 3. System Evaluation Plans	44
Table 4. Summary of Stage Gate 1B Advanced Systems Analysis for BP1	44
Table 5. Summary of Stage Gate 1B Advanced Systems Analysis for BP2	45
Table 6. Summary of Stage Gate 1B Advanced Systems Analysis for BP3	46
Table 7. Stage Gate 2 Design, Analysis and Test Plans	49
Table 8. Prototype House Evaluation	50
Table 9. Summary of Northern Marine Prototype House Studies	51
Table 10. Summary of Northern Marine Prototype House Studies	51
Table 11. Summary of Northern Marine Prototype House Studies	51
Table 12. Evaluation Plans – Initial Community Scale Projects	52
Table 13. 40-50% Initial Community Scale Project in the Multiple Climates	53
Table 14. Summary of Initial Community Scale Projects	54
Table 15. Summary of Initial Community Scale Projects	55
Table 16. 40 %Marine Case Study Communities	57
Table 17. List of Conferences and Presentations CY 2008	65
Table 18. List of Conferences and Presentations CY 2009	68
Table 19. List of Conferences and Presentations CY 2010	69
Table 20. BA Database Updates BP2	70
Table 21. BA Database Updates BP3	70
Table 22. Additional Measures	72
Table 23. Publications Budget Period 1 (2008)	73
Table 24. Publications Budget Period 2 (2009)	74
Table 25. Publications Budget Period 3 (2010)	75
Table 26. Additional Measures	80
Table 27. Percent Improvement of the 2006 WSEC (with amendments) over 2009 IECC	81
Table 28. Percent improvement of the 2009 WSEC over 2006 WSEC	83
Table 29. Key Technology Pathway Evaluation Participants Budget Period 1 (2008)	98
Table 30. Key Technology Pathway Evaluation Participants Budget Period 2 (2009)	99
Table 31. Key Technology Pathway Evaluation Participants Budget Period 3 (2010)	100
Table 32. Technology Pathways -- Areas of Investigation	102
Table 33. Simulation and Builder Preferences Major Loads and Climate Strategies	105
Table 34. Code Energy Features	108
Table 35. 50% Marine Strategy Features	108
Table 36. Incremental Energy Savings per Feature (in % Whole House savings)	110
Table 37. 50% Marine Strategy Costs	111
Table 38. 50% Marine Strategy Savings Summary - California	112
Table 39. 50% Marine Strategy Savings Summary - Oregon	112
Table 40. 50% Marine Strategy Savings Summary - Washington	113
Table 41. Net Annual Cash Flow Summary	114

Table 42. Energy Efficiency Features Summaries – Hot/Dry	117
Table 43. 50% Hot/Dry Strategy Costs.....	119
Table 44. 50% Hot/Dry Strategy Savings Summary	119
Table 45. 50% Strategy Cost Savings	122
Table 46. Comparison of Major Features	124
Table 47. Feature Cost Comparison.....	126
Table 48. Available Incentives.....	127
Table 49. Average 2008 Title-24 and 50% WHES Features Summaries.....	133
Table 50. Average 2009 IECC and 50% WHES Features Summaries.....	133
Table 51. Average Cost Savings for 50% WHES in Title- 24 Region	138
Table 52. Average Cost Savings for 50% WHES in IECC Region	139
Table 53. Average 2008 Title-24 and 50% WHES Features Summaries.....	145
Table 54. Average 2009 IECC and 50% WHES Features Summaries.....	145
Table 55. Average Cost Savings for 50% WHES in Title- 24 Region	150
Table 56. Average Cost Savings for 50% WHES in IECC Region	151
Table 57. Comparison of Major Features	153
Table 58. Cash Flow for 50% WHES	159
Table 59. Average 2008 Title-24 and 60% WHES features summaries	165
Table 60. Average 2009 IECC and 60% WHES features summaries.....	165
Table 61. Average cost savings for 60% WHES in Title-24 region	169
Table 62. Average cost savings for 60% WHES in IECC region.....	170
Table 63. Average 2008 Title-24 and 60% WHES features summaries	176
Table 64. Average 2009 IECC and 60% WHES features summaries.....	177
Table 65. Average cost savings for 60% WHES in Title- 24 region.....	181
Table 66. Average cost savings for 60% WHES in IECC region.....	182
Table 67. Prototype Opportunities	187
Table 68. Preliminary test and analysis schedule	199
Table 69. Summary of Stage Gate 1B Advanced Systems Analysis for BP1.....	200
Table 70. Summary of Stage Gate 1B Advanced Systems Analysis for BP2.....	201
Table 71. Summary of Stage Gate 1B Advanced Systems Analysis for BP3.....	202
Table 72. Analytical Peak Cooling Load (Btuh) for CSIPs vs. Standard Constructions	204
Table 73. Ultimate Loading Strength - 4" Thick ProTEC CSIP Panel.....	207
Table 74. Average Daily Peak PVT Production Reno, Nevada Installation	211
Table 75. Home Entertainment - Unit Electrical Consumption	226
Table 76. Home Office - Unit Electrical Consumption	227
Table 77. Home Entertainment Center with IDP-3050 Results	230
Table 78. Home Entertainment Center with LCG-3 Results	231
Table 79. Home Office Center with IDP-3050 Results	232
Table 80. Home Office Center with LCG-3 Results	233
Table 81. Home Entertainment - Unit Electrical Consumption	255
Table 82. Home Office - Unit Electrical Consumption	255
Table 83. Installation Costs	262
Table 84. Solar Thermal system comparison	267

Table 85. Average Daily Peak PVT Production Reno, Nevada Installation	271
Table 86. 2008 Gold Medallion PVT Production	278
Table 87. Garbett Homes “Solaris Collection” Estimated PVT Production.....	280
Table 88. Gas and Electricity Rates for South Jordan, Utah	281
Table 89. PVT Production Annual Savings	282
Table 90. 2008 Gold Medallion PVT payback time comparison #1	282
Table 91. 2008 Gold Medallion PVT payback time comparison #2	282
Table 92. Baseline utility bill data for Farmington, NM prototype (w/o VERVE)	294
Table 93. Baseline utility bill data for Albuquerque, NM prototype (w/o VERVE)	294
Table 94. Home entertainment – Unit electrical consumption (per unit).....	296
Table 95. Home office – Unit electrical consumption (per unit)	296
Table 96. Kitchen – Electrical consumption (per unit).....	297
Table 97. Other household appliances – Electrical consumption (per unit)	297
Table 98. Hard wired - Electrical consumption (per unit).....	297
Table 99. Total estimated electrical consumption	297
Table 100. Potential range of MELs (kWh/yr).....	298
Table 101. PNM (New Mexico) utility rates.....	299
Table 102. Cost of Verve equipment for Albuquerque prototype	300
Table 103. Cost of Verve equipment for Farmington prototype.....	300
Table 104. ROI for Verve Living System in Albuquerque prototype.....	300
Table 105. ROI for Verve Living System in Farmington prototype	300
Table 106. Snow Creek Cottages unit description details (Fox and Deer Models)	303
Table 107. Cost data provided by Elliott Workgroup and Park City	314
Table 108. Monthly water usage and energy equivalency	339
Table 109. Table 4.1a, ASHRAE 62.2	341
Table 110. Estimated contracted cost of various cooling equipment.....	341
Table 111. Electricity usage and savings of OASys and various SEER units	342
Table 112. Sample of rebates currently being offered	342
Table 113. Estimated payback periods	343
Table 114. Ratio of energy input to equivalent energy output	354
Table 115. Stage Gate 2 Design, Analysis and Test Plans	374
Table 116. Portland, OR annual climate data	376
Table 117. Portland, OR temperature data	376
Table 118. Utility rates.....	377
Table 119. 50% WHES “Parade Home” base case features	377
Table 120. Available incentives.....	380
Table 121. Olympia, WA annual climate data.....	383
Table 122. Utility rates.....	383
Table 123. 50% WHES “Passive House” base case features	384
Table 124. Available incentives.....	386
Table 125. Prototype House Evaluation	389
Table 126. Albuquerque WHES Summary.....	392
Table 127. Farmington WHES Summary	393

Table 128. Source Energy Savings for the “Solar Cottage” Floor Plan.....	399
Table 129. Current Utility Rates for Arvada, Colorado	400
Table 130. “Deer” WHES Summary.....	406
Table 131. “Fox” WHES Summary.....	406
Table 132. Kaneohe, HI annual climate data	419
Table 133. Utility rates	420
Table 134. 50% Hot/Humid design feature comparison	422
Table 135. Verified equipment and infiltration results for Mololani homes.....	423
Table 136. Description of Snow Creek Cottages Prototypes (Unit #10 and #11)	429
Table 137. Cost data for Snow Creek Prototypes	434
Table 138. 50% WHES “Parade Home” base case features.....	437
Table 139. Portland, OR annual climate data	439
Table 140. Portland, OR temperature data	439
Table 141. Clark Public Utilities & Northwest Natural Gas rates.....	440
Table 142. Available incentives.....	443
Table 143. Economic analysis and cost neutrality	444
Table 144. Summary of Northern Marine Prototype House Studies.....	446
Table 145. Summary of Northern Marine Prototype House Studies	447
Table 146. Summary of Northern Marine Prototype House Studies	447
Table 147. Source Energy Savings for the Kent 2264 Floor Plan	449
Table 148. Current Utility Rates for Vancouver, Washington	451
Table 149. Neutral Cost Analysis for the Kent 2264 Floor Plan.....	452
Table 150. Source Energy Savings for the Martha Rose Homestead Plan.....	457
Table 151. Current Utility Rates for Shoreline, Washington	459
Table 152. Energy Feature Incremental Cost Information for MRC Homestead Plan.....	461
Table 153. Neutral Cost Analysis for the Homestead Floor Plan.....	463
Table 154. Portland, OR Annual Climate Data	468
Table 155. Portland, OR Temperature Data	469
Table 156. Portland General Electric – Time of Use Electricity Rates	469
Table 157. Portland General Electric – Time of Use Schedule.....	469
Table 158. 50% WHES “SIPs House” Base Case Features	470
Table 159. Available Incentives.....	474
Table 160. Incremental Builder Cost.....	474
Table 161. Neutral Cost Analysis for the Cohan “SIPs House”	475
Table 162. Evaluation Plans – Initial Community Scale Projects	483
Table 163. 40-50% Initial Community Scale Project in the Multiple Climates	484
Table 164. Summary of Initial Community Scale Projects	485
Table 165. Summary of Initial Community Scale Projects	486
Table 166. Source Energy Savings for the Kent 2264 Floor Plan	489
Table 167. Current Utility Rates for Vancouver, Washington	491
Table 168. Neutral Cost Analysis for the Kent 2264 Floor Plan.....	493
Table 169. Source Energy Savings for the Olympic 2011 Floor Plan	501
Table 170. Simulation Comparison for Quadrant Homes BEopt 0.8.6 / Energy Gauge USA 2.7	502

Table 171. Current Utility rates for Kent, Washington	504
Table 172. Neutral Cost Analysis for the Olympic 2011 Floor Plan	505
Table 173. Source Energy Savings for the Fidalgo Townhome Floor Plan.....	515
Table 174. Current Utility rates for Eugene, Oregon	517
Table 175. Neutral Cost Analysis for the Fidalgo Townhome Floor Plan	519
Table 176. Source Energy Savings for the E381 Floor Plan.....	526
Table 177. Current Utility Rates for Burien, Washington	529
Table 178. Neutral Cost Analysis for the E381 Floor Plan	530
Table 179. Source Energy Savings for the Roseburg 1884 Floor Plan	538
Table 180. Current Utility Rates for Portland, Oregon	541
Table 181. Neutral Cost Analysis for the Roseburg 1884 Floor Plan	542
Table 182. Source Energy Savings for the “Deer” Model	551
Table 183. Current Utility Rates for Wanship, Utah	552
Table 184. Neutral Cost Analysis for the “Deer” Floor Plan	554
Table 185. Source Energy Savings for Unit C	558
Table 186. Current Utility Rates for Portland, Oregon	560
Table 187. Modeled annual energy and dollar savings for Sage Green Unit C	561
Table 188. Source Energy Savings for the 110 Floor Plan	567
Table 189. Feature comparison between Forest City Pre and Post Building America	567
Table 190. Current Utility Rates for Oahu, HI	569
Table 191. Detailed Incremental Cost of Energy Efficient Features for 110 Unit.....	570
Table 192. Neutral Cost Analysis for the 110 Floor Plan	571
Table 193. Albuquerque WHES Summary (Hot/Mixed Dry)	576
Table 194. Farmington WHES Summary (Cold)	576
Table 195. True Cost of Ownership after Base and 7 Years.....	579
Table 196. True Cost of Ownership after 17 and 30 Years	579
Table 197. Source Energy Savings for the 1651 Floor Plan	584
Table 198. Feature comparison between Forest City Pre and Post Building America	585
Table 199. Current Utility Rates for Oahu, HI	586
Table 200. Detailed incremental cost of energy efficient features for 1651 unit	587
Table 201. Neutral Cost Analysis for the 1651 Floor Plan	588
Table 202. Project Snapshot	593
Table 203. Floor plan information	594
Table 204. Model 3 WHES summary	595
Table 205. Model 5 WHES summary.....	596
Table 206. Building features	597
Table 207. Tierra Del Sol community information.....	608
Table 208. Tierra Del Sol utility provider and marginal costs.....	609
Table 209. Annual source energy and estimated source energy savings of the BA Benchmark, Title 24, builder’s practice and Tierra Del Sol homes	610
Table 210. Tierra Del Sol building features for code compliance, builder’s practice and 50% WHES.....	612
Table 211. Source energy savings for Unit C	625

Table 212. Current utility rates for Portland, Oregon	627
Table 213. Modeled annual energy and dollar savings for Sage Green Unit C	628
Table 214. Source Energy Savings for the Marsala 1772 Floor Plan.....	633
Table 215. Current Utility Rates for Pasco, Washington	635
Table 216. Neutral Cost Analysis for the Marsala 1772 Floor Plan	636
Table 217. 40% Marine Communities.....	642
Table 218. 40% Marine Source Energy Savings	642
Table 219. 40% Marine Market Coverage	645
Table 220. 40% Marine Neutral Cost Target.....	646
Table 221. Source Energy Savings for the Plan B Floor Plan.....	676
Table 222. Current Utility Rates for Lancaster, California	678
Table 223. Neutral Cost Analysis for the Plan B Floor Plan	679
Table 224. Actual Electric Bills	685

Disclaimer

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Abstract

This final report was compiled from the detailed annual reports that were submitted for efforts in 2008 and 2009, and from individual task reports from 2010. Reports, case studies, and presentations derived from this work are available through the Building America website: http://www1.eere.energy.gov/buildings/building_america/. The BIRA team is led by ConSol, a leading provider of energy solutions for builders since 1983. In partnership with over fifty builders, developers, architects, manufacturers, researchers, utilities, and agencies, research work was performed in California, Colorado, Utah, New Mexico, Washington, Oregon, and Hawaii and five (5) climate regions (Hot-Dry, Marine, Hot-Humid, Cold, and Hot/Mixed Dry). In addition to research work, the team provided technical assistance to our partners whose interests span the entire building process. During the three year budget period, the BIRA team performed analyses of several emerging technologies, prototype homes, and high performance communities through detailed computer simulations and extensive field monitoring to meet the required climate joule milestone targets.

Executive Summary

BIRA's work for the contract included research in all five of the Building America Stage Gate processes. The Stage Gate research performed met the targeted climate milestones. BIRA also supported the Best Practices Documentation and Resource Development process throughout the contract period. The BIRA team responded thoughtfully and quickly to the requests of PNNL, ORNL, NREL and the DOE. Much of BIRA's work in this area has been in tandem with other deliverables, such as Stage Gate Research Reports.

Stage Gate 1A

Gaps and pathways analyses were performed in three climate targets: 50% Marine, 50% Hot/Mixed Dry, and 40% and 50% Cold. In the Marine and Hot/Dry climates, BIRA compared the latest versions of two major energy standards – California's 2008 Energy Code, Part 6 (Title-24) and the 2009 International Energy Conservation Code (IECC) with the BA benchmark at the 50% WHES level. Cold climate analysis of technology pathways were completed at the 50% WHES level with input from builder partners. Analyses were completed and the results evaluated against the Stage Gate 1A criteria to identify potential technology pathways. Pathways were further refined based on feedback from area builders, resulting in feasible strategies in each climate zone that can achieve the target savings.

In 2010, additional analyses were performed in two climate targets: 60% Marine and 60% Hot/Mixed-Dry. In the Marine and Hot/Dry climates, BIRA compared the latest versions of two major energy standards - California's 2008 Energy Code, Part 6 (Title-24) and the 2009 International Energy Conservation Code (IECC) with the BA benchmark at the 60% WHES level.

Stage Gate 1B

System performance evaluations were conducted in three climate targets - Cold, Hot/Mixed-Dry and Marine - using Concrete Structural Insulated Panel (CSIP) wall systems, the OASys evaporative cooling system, Ground Coupled Heat Pumps (GCHP), Home Energy Management Systems (HEMs)/Miscellaneous Electric Load (MELS) reduction, Heat Pump Water Heater (HPWH), PV Thermal (PVT) combination systems, and solar thermal system. Final results and interim results-to-date are reported for these systems.

Stage Gate 2

Prototype house evaluations plans were developed for homes targeted at 40% Cold, 50% Cold, 50% Hot/Mixed Dry, 50% Hot-Humid and 50% Marine. Interim evaluations were completed for fifteen (15) prototype 50% Cold, 50% Marine, 50% Hot/Mixed Dry, and 50% Hot-Humid homes. A completion report was generated for one prototype location in the Cold climate. Results-to-date are reported for all homes.

Stage Gate 3

Initial community scale evaluation plans were developed for five (5) 40% Marine communities, three (3) 50% communities in Hawaii (Hot-Humid), one (1) in Utah (Cold), one (1) in Oregon (Marine) and one (1) in New Mexico (Hot-Dry/Cold), and two (2) Hot/Mixed-Dry communities. The BIRA team completed all five of the required 40% Marine community case studies as well as the Stage Gate 3 40% Marine Joule Milestone. One 50% Hot/Mixed Dry community case study was completed in 2008. An initial communities update was completed covering the status of three Cold climate communities, nine Hot/Mixed Dry communities, and three Marine communities.

The BIRA team also completed one (1) 40% Cold community case study in Pasco, Washington which contributed to the 2009 40% Cold Joule Milestone. In addition, BIRA has provided the preliminary documentations to the FSEC BA Team for the 2010 40% Hot-Humid Joule Milestone. An initial community update was completed covering the status of five Cold climate communities, nine Hot/Mixed Dry communities, seven Hot-Humid communities and four Marine communities

The BIRA team completed one Stage Gate Final Project Closeout for the O Bel Sole! Estates community in Lancaster, CA, estimated at the 66.7% WHES level. Using energy simulations, targeted utility bill analysis and feedback from project stakeholders, BIRA investigated and identified the benefits and lessons learned from this project for homebuilders, homebuyers, utilities, and other stakeholders to understand the collective benefits that near-zero energy homes offer.

INTRODUCTION AND SUMMARY

BIRA is one of six (6) U.S. Department of Energy (DOE) sponsored Building America Program (BAP) teams (www.buildingamerica.gov) that perform cost-shared activities to develop and deploy systems engineering based solutions to enhance the energy efficiency, comfort, and durability of new homes built in the U.S.A.

The BIRA team is led by ConSol, a leading provider of energy solutions for the builder since 1983. As a BAP team for the last five years, the BIRA team has been responsible for the addition of over 10,000 BAP homes to the program (over ¼ of the BAP homes built over the ten-year life of the program), more near-zero energy communities than any other BAP team, and the only post-occupancy communities with full utility data reported to the BAP.

BIRA's multifaceted approach to the BAP goal of marketable, cost-effective net-zero energy homes by 2020, has met with success due to the market connections available through team lead ConSol, and the technical support provided by over 50 members of the BIRA team. Through a program of strategic relationships that encompasses the entire home building process, BIRA leveraged its partners' ongoing research and development programs to:

Identify key systems and technologies needed to obtain 50% and greater WHES, and move these new and improved systems through Stage-Gate 1 as quickly as possible;
Build greater than 50% WHES prototypes in Marine, Hot/Mixed Dry, Cold, Hot-Humid and Mixed-Humid climate regions to meet or exceed Joule Milestones for Stage-Gate 2;
Build 40% WHES initial community-scale projects in Marine, and 50% initial-community-scale projects in Marine, Hot/Mixed Dry, Cold, Hot-Humid, and Mixed Humid climate areas to meet or exceed Joule Milestones for Stage-Gate 3; Evaluate post-occupancy 40% WHES community-scale projects in Hot/Mixed Dry, Hot/Humid, and Marine climate regions for Stage-Gate 3;

The overall objective of the BIRA program is to conduct cost-shared research that accelerates the nationwide development of cost effective, production ready energy technologies that can be widely implemented by site builders to achieve 40% to 100% whole-house energy savings (WHES) through a combination of energy efficiency and renewable energy measures. BIRA employs BA systems engineering principles to enhance the energy efficiency, comfort, durability, indoor air quality, insurability, affordability, marketability and construction productivity of U.S. housing. In addition to more traditional industry partners, BIRA also works with utilities, local governments, state governments, and other stakeholders to identify and encourage use of benefits that derive from BAP advanced housing which improve marketability and cost-effectiveness.

Industry Partnerships

BIRA has enlisted and partnered with over 100 industry partners, including more than twenty-five production builders, to work together to fulfill its objectives, leading to marketable near-

zero energy homes (ZEH). BIRA has used BAP support to perform systems research, build and evaluate prototype homes, and perform community scale research to evaluate and improve cost-effectiveness of building near-zero energy communities.

In addition, BIRA has disseminated research findings to industry stakeholders throughout the nation as Building America goals are met. Support from the DOE Building America Program has leveraged BIRA partners to commit and provide in-kind support in excess of \$1,630,000 in the form of donated labor, prototype homes and community-scale projects. Table 1 contains a partial list of BIRA partners.

Home Builders / Developers	Agencies / Firms / Utilities	Suppliers/Manufacturers
Artistic Homes	Arizona Department of Commerce/Energy	DOW Chemical
Centex Homes	Building Industry Institute	Freus
Clarum Homes	California Energy Commission	GE Energy
Forest City Military Communities		Lennox
Gold Medallion Homes		Rinnai
Holmes Homes		Owens Corning
Holton Homes	Energy Trust of Oregon	Sharp
Lennar		SIPA
Liberty Homes	Lawrence Berkeley National Lab	Speakman
Garbett homes	Nevada State Office of Energy	Well Home
Morrison Homes		Solar City
NC Investments	Oakridge National Laboratory	Premier Building Systems
Needham Homes	Oregon DOE	Innovative Openings
New Tradition Homes		Cardinal Glass
Kennecott Land Development		Carrier
	Sacramento Municipal Utilities District	Lennox Industries
Pardee Homes	Southern California Edison	Mitsubishi
Pinnacle Homes	TaylorMade	Dwelltek
Premier Homes		
	Washington State	

Home Builders / Developers	Agencies / Firms / Utilities	Suppliers/Manufacturers
	University	
Quadrant Homes	University of Utah	
Rainey Homes	Salt Lake County	
Ruhoff Home Builders	City of Park City	
Schneider Family Homes	Utah Clean Energy	
SunStar		
Tom Walsh & Co.		

Table 1: BIRA's List of Partners by Type

BIRA research activities are primarily on the western US coast and include California, Washington, Oregon, Idaho, Utah, Nevada, Arizona, New Mexico, Texas, and Hawaii.

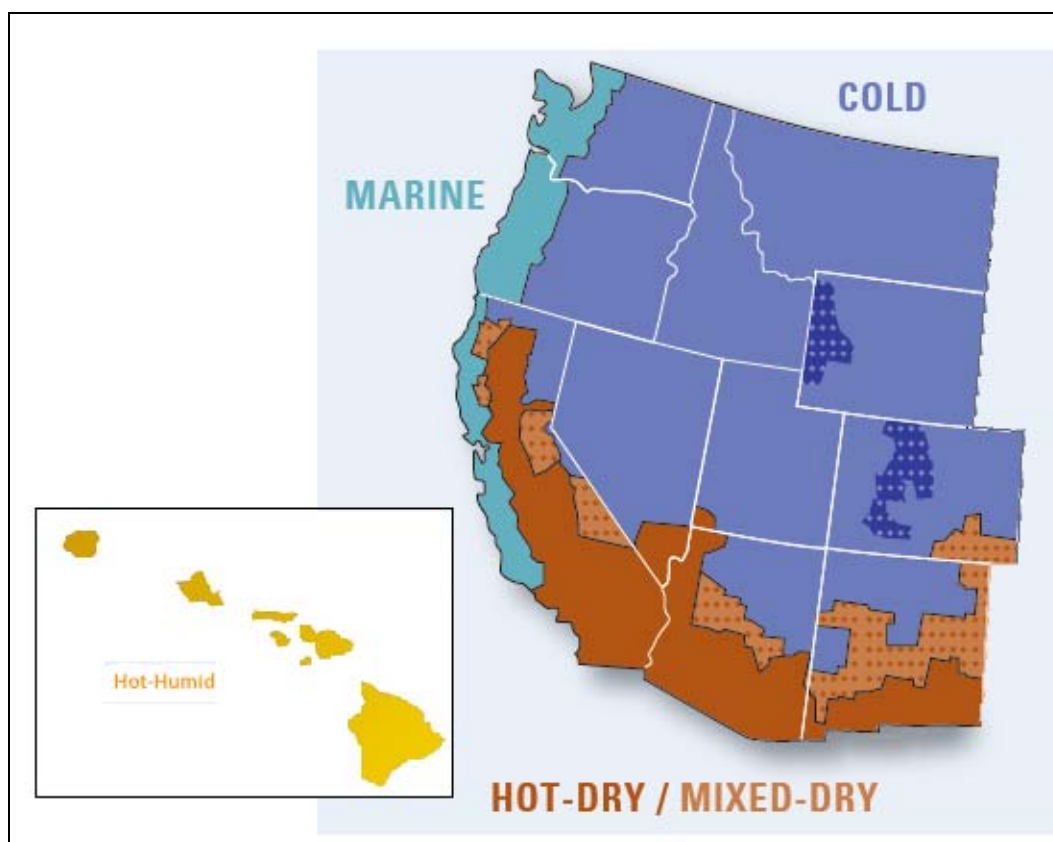


Figure 1. Map of BIRA Research Activity and Climate Regions

Summary of Activities

The BIRA research strategy is to leverage its partners' abilities and expertise to move as quickly and effectively to highly-marketable, highly-energy efficient community-scale projects as possible. This includes working closely with our manufacturing partners to improve individual

systems efficiencies and costs, to move projects as quickly as possible to market by building demand, to improve whole-house integration, and to produce community-scale BAP projects, all in a coordinated effort to achieve Joule Milestone goals. What sets BIRA apart is its realization that solving the challenge of marketable, cost-effective net-zero energy communities extends beyond the single home and its components and their costs, to include community-scale effects that can impact marketability and cost-effectiveness. These effects include utilities and their rates, tariffs and efficiency programs, local jurisdictions' processes and fees, and state and federal incentives and programs. All of these factors play important roles in the marketability and cost-effectiveness of BAP homes so BIRA works with all of them and at many levels.

The BIRA team conducted activities in seven (7) major task areas:

- Task 1 Building America - System Research Management and Technical Support
- Task 2A: Stage Gate 1A - Integrated Solutions for Specific Climate Regions and Performance Levels
- Task 2B: Stage Gate 1B - System Performance Evaluations
- Task 3: Stage 2 - Prototype House Evaluations
- Task 4: Stage Gate 3 - Community Scale Evaluations
- Task 5: 2009 Post-Stage Gate Results, Best Practices Documentation and Resource Development
- Task 6: Post-Stage Gate Results, Best Practices Documentation and Resource Development

The activities in each area are summarized below:

Task No.1 Building America – System Research Management and Technical Support

Subtask 1.1 Presentation Schedule and Technical Reports for CY 2008-2010

BIRA delivered several technical reports and/or presentations to ensure broad dissemination of Building America Research results. These technical reports and presentations covered topics ranging from, but not limited to, ducts in conditioned space, peak cooling, and vented crawlspaces. A deliverable with schedules of conference presentations and technical reports was reported to Building America. Refer to Table 17 for a complete list of presentations given by BIRA or partners of BIRA.

Subtask 1.2 Monthly Status Reports, Upcoming Event Reporting, Technical Highlights

BIRA has produced eight monthly executive summary of significant progress at each gate level, summary of upcoming team events and activities, and highlight describing recent notable technical accomplishments.

Subtask 1.3 Quarterly Activity

BIRA has produced quarterly reports (March, June, October, and December) which highlight the technical achievements as required for HQ. These quarterly reports detail the progress made in the system, prototype home, and community evaluations for each budget period.

Subtask 1.4 BA Technical Working Group Participation

BIRA has and participated in all BA technical working group discussions. These included posting of comments, conference calls, training sessions, and WebEx set up by NREL and other participating Building America teams.

Subtask 1.5 Field Tests and Planning

The BIRA team worked on 15 prototype home opportunities for field test and evaluation from varying climate zones during the three budget periods. Each home incorporated advanced technologies ranging from advanced wall systems to multipurpose renewable energy sources. Details of the prototype homes evaluated are in Table 2 below.

House/Location	Builder/Contact	Design Features	Climate
Citihouse II Fresno, CA	AlvisProjects, Inc. Marlin Alvis	– SunCache Solar Water Heating – CSIP Walls	50% Hot/Mixed
Citihouse III Fresno, CA	AlvisProjects, Inc./Marlin Alvis	– ICF Walls – PVT	50% Hot/Mixed
Kennecott Land Salt Lake City, UT	Gold Medallion	– PVT	40-50% Cold
Reno Project Reno, NV	Sweeney Architecture & Idea Development	– ICF Walls – Others TBD	40-50% Cold
Idaho Project Southwest Idaho	Chuck Miller Construction	– Residential Economizer – Heat Pump	50% Cold
Snow Creek Cottages Park City, UT	City of Park City	– SIP Walls – GSHP	50% Cold
Webster School Cottages	Salt Lake County Affordable Housing	– Solar thermal – Solar PV	50% Cold

House/Location	Builder/Contact	Design Features	Climate
Magna, UT	Project	– OAsys evaporative-cooling – MELS reduction	
GEOS Project Arvada, CO	GEOS	– All electric – Passive solar – Innovative HVAC – Community GSHP	50% Cold
Forest City Military Housing Oahu, Hawaii	Forest City Hawaii	– Solar thermal systems – Verve lighting system	50% Hot Humid
Habitat for Humanity Las Cruces, NM	Habitat for Humanity	– Solar thermal – Solar PV	50% Hot/Mixed Dry
Pepper Viner, Tucson, AZ	Pepper Viner	– SIP – Solar thermal – Solar PV	50% Hot/Mixed Dry
Mololani Net-ZEH Oahu, Hawaii	Forest City Military Housing	– High performance A/C system (21 SEER)Verve HEMs – Solar thermal w/ storage backup – 6.0kW PV system	50+% Hot-Humid
Oroville Lab Home Oroville, CA	Cleantech Innovative Center (CIC)	– Solar thermal/PV – Slab edge insulation – Ground coupling – HEMs	50% Hot/Mixed-Dry
Utah Lab Home South Jordan, UT	Garbett Homes	– SIPs Walls – Compressorless cooling – Passive solar design – Solar thermal	50+% - Cold
Tierra del Sol Community Stockton, CA	Visionary Home Builders	– Modular wall system – Solar thermal & PV	50+% Hot/Mixed-Dry

Table 2: Field Test Opportunities

Subtask 1.6 Publications (at least 6)

BIRA and its partners identified a comprehensive list of planned publications based on Building America research results. Eight publications were accepted and have been published in *Home Energy Magazine* and *Transactions*.

Subtask 1.6.1 Summary of Code Barriers Report

In working with Washington State University, BIRA generated a report identifying Codes and Standards issues in Washington. Among the issues addressed were duct sealing when outside of conditioned space, improving the 2009 Washington State Energy Code (WSEC) to 30% better than the 2006 WSEC, and developing a method of test for air leakage in HVAC equipment.

ASHRAE Std 193 2010, *Method of Test For Determining the Air Leakage Rate of HVAC Equipment*, has established a method of test (MOT) for HVAC equipment rated below 3000 CFM including residential air handlers, packaged rooftop equipment, coil boxes, filter boxes, etc. Std 193 was adopted in three years, and represents challenges on behalf of the committee to balance the needs of manufacturers with the analytical needs of others performing research.

Subtask 1.7 Experts Meetings

BIRA conducted two Experts Meetings in Budget Period Two, one for solar PV/thermal and another for panelized wall systems.

Subject	Location	Date	Budget Period
Miscellaneous Electric Loads	Asilomar, CA	8/19/08	1
Solar PV and Solar Thermal	Vancouver, Wa	8/20/09	2
Alternative Wall Systems	Sacramento, CA	11/13/09	2

Solar PV/Thermal Experts Meeting

The objective of the solar PV/thermal systems experts meeting was to focus on areas of investigation of the above, and methods to improve net energy benefits, marketability, total costs, and production home building viability of the PV and solar thermal systems. The objective included bringing BA stakeholders and other relevant experts together to determine where we are as a research community, where we need to go and how we are going to get there.

As team lead on PV and solar thermal integration, BIRA identified further key issues and proposed approaches to solve them. This was accomplished through the Experts Meeting process and directed research with the goal of developing systems integration practices that resulted in wider use of these renewable energy technologies at lower costs.

Panelized Wall Systems Experts Meeting

The overall objective of this meeting was to introduce and bring in wall industries to provide product information based on case studies and lessons learned, while not limited to energy

savings benefits, building and health code issues, learning curve of subcontractors, drawbacks, cost-effectiveness and marketability of the systems.

BIRA worked with Building Science Corporation (BSC), the BA team lead for wall systems, to identify further key issues and propose approaches to solve them. This was accomplished through the experts meeting process and directed research with the goal of identifying promising alternative wall systems that targeted the result for wider use in the building industry, in addition to saving time and money beyond conventional stick frame wall systems.

Subtask 1.8 Training

The BIRA team was trained in TRNSYS, EnergyPlus, BEopt, Micropas and Energy Gauge. Systems, prototypes, and communities in all three stage gates are modeled using a combination of these software programs.

Subtask 1.9 Review and Provide Comments to Best Practices Guide reports/drafts by PNNL/NREL/DOE

The BIRA team has reviewed and successfully provided comments, pictures, and other research needs to the Best Practices Guide reports/drafts by PNNL/NREL/DOE related to the 40% Marine joule milestone

Task 2A: Stage Gate 1A – Integrated Solutions for Specific Climate Regions and Performance Levels

Subtask 2A.1 Stage Gate 1A Evaluation Plan & Initial Optimization and Analysis of Technology Pathways and Performance Maps in CA, OR, WA and UT

BIRA identified the following climate regions for further analysis of technology pathways. Plans for the evaluation process were developed and builders were identified based on who would provide feedback on identified technologies and their integration into their building practices.

- 50% Marine
- 50% Hot/Mixed Dry
- 40% Cold
- 60% Marine
- 60% Hot/Mixed-Dry

Technical pathways were determined for each of the milestones above. The specified packages were also compared to the Benchmark and applicable energy codes.

Subtask 2A.2 Simulation and Builder Preferences

BIRA completed the analysis of technology pathways in the following climate regions and WHES goals. Builders provided feedback on the pathways and how they would integrate into their building practices.

- 50% Marine
- 50% Hot/Mixed Dry
- 40% Cold
- 50% Cold
- 60% Marine
- 60% Hot/Mixed-Dry

Task 2B: Stage Gate 1B – System Performance Evaluations

This section documents BIRA's efforts in providing design and technical assistance to develop the necessary high-performance systems for prototype high performance homes.

Subtask 2B.1- Systems Evaluation Plans in Builder Prototypes in Multiple Climate Zones

BIRA identified 10 system evaluation opportunities in Cold, Marine, Hot/Dry and Hot/Mixed Dry climate zones. These opportunities were further developed, working with the builders and manufacturers, to be included in a house design package. Plans were developed for each of these systems to instrument, monitor and analyze data for evaluating their performance relative to the Stage Gate 1B "Must Meet" and "Should Meet" criteria.

System	System Type	Target Climate Zone	Budget Period No.
Concrete Structural Insulated Panels (CSIPs)	Advanced Wall System	Hot/Dry and Hot/Mixed-Dry	1,3
MELs	Miscellaneous Electric Loads	All	1
PVT	Heating/Water Heating/Solar Generation/Cooling	All	1,2
SunCache	Heating	Hot/Dry and Marine	1
High R-value Wall (SIP)	Advanced Wall System	Cold, Marine	2
OASys Cooling Systems	Cooling	Cold, Hot/Mixed Dry	2
Ground Coupled Heat Pumps	Heating	Cold	2

System	System Type	Target Climate Zone	Budget Period No.
Home Energy Management	MELS/HEM	All	2
Heat Pump Water Heater	Water Heating	All	2,3
Solar Thermal	Heating/Water Heating/Solar Generation	Marine, Cold	2

Table 3: System Evaluation Plans

Subtask 2B.2- Stage Gate 1B Report: Results of Research on Systems for Prototype Homes - 4 Systems Minimum

BIRA performed systems evaluations and performance analysis relative to the Stage Gate 1B criteria. Three of the systems are scheduled for continued analyses and one system did not satisfy the Stage Gate 1B criteria.

Advanced System	System Status BP1 (2008)
CSIPs	CSIPs are still in Gate 1B. They have analytically shown to provide a better thermal envelope than standard R-19 walls, but did not shift the peak load to off-peak utility rates. The thicker the interior layer of the CSIP, the lower the peak load.
MELs	Gate 1B research for MELs will continue into 2009, expanding the test group and testing bigger and more sophisticated systems, as well as developing integrated MELs systems into projects like Home of the Future.
PVT	PVT remains at the Gate 1B and is awaiting more cost data and feedback from contractors. Diverse actual application data from various climate regions is still needed, which will be obtained either from the manufacturer or through test monitoring.
SunCache	The SunCache system remains in Stage Gate 1B. While some actual operational data has been provided by Eric Lee of Harpiris Energy, additional data monitoring is needed to further determine energy savings.

Table 4: Summary of Stage Gate 1B Advanced Systems Analysis for BP1

Advanced System	System Status BP2 (2009)
High R-Value Walls (SIP Walls)	Performance still needs to be evaluated since construction of the homes are not yet complete
OASys Cooling Systems	Additional summer data is needed to accurately evaluate source energy and whole building benefits.
Ground Coupled Heat Pumps	Performance still needs to be evaluated since construction of the homes are not yet complete
Home Energy Management	Baseline performance data is now being collected from installed systems; After six months, the system's features will be fully activated to provide the most energy savings possible for evaluation.
Heat Pump Water Heater	AirTap™ has provided substantial site energy savings over the propane fired water heater. However this particular product fails the Stage Gate 1B criteria based on warranty and cost.
Solar Thermal	This ongoing work is examining three solar thermal systems and remains at Stage Gate 1B pending more thermal monitoring data, simulation analysis, cost data and stakeholder feedback.
PVT	PVT theoretically completed the Stage Gate 1B Criteria. Actual system performance testing to continue in 2010.

Table 5: Summary of Stage Gate 1B Advanced Systems Analysis for BP2

Advanced System	System Status BP3 (2010)
High R-Value Walls (SIP Walls)	Performance of the advanced wall system has been analyzed and is included in the system performance interim report.
OASys Cooling Systems	The OASys system successfully satisfied criteria for Stage Gate 1B. Refer to the completion report for more details related to performance results.
Ground Coupled Heat Pumps	Performance will be evaluated in 2011 as monitoring equipment installation was completed late November.
Home Energy Management	The baseline performance data has been collected for a full year without the installation of the HEMs. As of October 2010, the HEMs have been activated and are currently gathering data from the utility bills in order to quantify the energy savings impacted by the HEMs itself.
Heat Pump Water Heater	The heat pump water heater manufactured by General Electric (GE) was installed in an existing home earlier this year. Currently BIRA has gathered a minimum of two (2) month's data. Refer to the heat pump water heater interim report for further details.

Advanced System	System Status BP3 (2010)
Solar Thermal	The solar thermal system performance analysis has been completed and is referenced in the completion report satisfying criteria for Stage Gate 1B.
PVT	The PVT report has been completed but is not ready to move forward from Stage Gate 1B

Table 6: Summary of Stage Gate 1B Advanced Systems Analysis for BP3

Subtask 2B.5 WSU Heat Pumps

As with any piece of equipment, proper heat pump installation is integral to its functionality. Over the past decade, utilities and energy offices in the Pacific Northwest have been troubled by the underperformance of heat pumps installed through their incentive programs. Heat pump sizing, installation and commissioning protocols and standards have been established and incrementally improved with each subsequent performance study. The latest such study, performed through State Technology Advancement Collaborative (STAC) and with Building America support, strove to improve these standards not only through field inspections, diagnostics and monitoring, but also through laboratory testing, software modeling and the development of additional training aids. The STAC heat pump project also performed a cost survey for heat pump commissioning to help evaluate current incentive programs.

The STAC study, along with its predecessors, found that heat pump performance can be degraded by a variety of factors. The primary failure modes include poor duct installation, incorrect control settings and improper refrigerant charge and airflow. These studies repeatedly demonstrated that heat pumps require clear sizing, installation and commissioning protocols. Additionally, in order for these protocols to be widely adopted and properly performed, the standards must be supported with effective training methods and materials and thorough quality assurance protocols.

As heat pumps are increasingly turned to as a potential source of efficiency, the need for proper sizing, installation and commissioning practices becomes ever more critical. The STAC project, along with similar research efforts, has not only demonstrated the complexity of the issue, but also the potential effect a successful heat pump commissioning program can have. The studies have concentrated on the Pacific Northwest, a heating-dominated region. This type of research needs to be replicated in cooling-dominated and mixed regions in order to be applicable to all heat pump installations. Once established, these protocols can enhance the effectiveness, and therefore the reputation, and therefore the market penetration, of air-source heat pumps in the housing market. The benefits could realistically extend to related equipment, such as other types of heat pumps and air conditioners, as these industry practices are enhanced.

Task 3: Stage 2 – Prototype House Evaluations

Subtask 3.1 Design, Analysis, and Test Plans for Stage Gate 2 House Projects in Multiple Climates (Marine, Hot/Dry, and Cold)

The overall objective of these evaluations was to determine how well the advanced systems in these home integrate with production building practices and whether the homes meets the Stage Gate 2 “Must Meet” and “Should Meet” criteria.

The 16 homes identified for Stage Gate 2 Design, Analysis and Test Plans are shown in the table below. These plans identify the advanced features, milestone target, climate region, and the test/analysis plans for each home throughout all three budget periods.

House/Location	Builder/Contact	Advanced Features	Target WHES/Climate
<i>Budget Period 1 (2008)</i>			
Citihouse II Fresno, CA	AlvisProjects, Inc. Marlin Alvis	SunCache Solar Water Heating, CSIP Walls	50% Hot/Mixed
“Newport” South Jordan, UT	Kennecott Land Gold Medallion	PVT, SIP and Oasys Evap Cooler	40% Cold
“Liverpool” South Jordan, UT	Kennecott Land Liberty Homes	N/A	40% Cold
“Carmichael” South Jordan, UT	Kennecott Land Holmes Homes	N/A	40% Cold
“Craftsman” South Jordan, UT	Kennecott Land Rainey Homes	Bosch Solar Hot Water System	40% Cold
NextGen, Las Vegas, NV	NextGen	ICF Walls, 2 Speed Heat Pump hybrid system, LED lightings, electric tankless WH	50% Hot/Mixed Dry
Kent Model 2294 Vancouver, WA	New Tradition Homes	Ducts in Conditioned Space	50% Marine
Martha Rose	Martha Rose	Ducts in Conditioned Space	50% Marine
<i>Budget Period 2 (2009)</i>			
Artistic Homes Albuquerque, NM	Artistic Homes Tom Wade, Principal, Artistic Homes Tom@ArtisticHomes.com	PVT system, Verve whole house lighting, outlet control system, with feedback display	50% Hot/Mixed Dry
Snow Creek Cottages	R & O Builders Ogden, Utah	SIPs exterior walls and roof, PVs,	50% Cold

House/Location	Builder/Contact	Advanced Features	Target WHES/Climate
Park City, UT	933 Wall Ave. 84404 (801) 627-1403 Fax (801) 399-1480	geothermal systems, solar hot water, HRV	
GEOS Solar Cottage Arvada, CO	GEOS Homes Norbert Klebl norbert@discovergeos.com	Earthlinked DX GSHP for space heating, cooling and DHW, RecoupAerator 200DX ERV with EarthTubes	50% Cold
David Cohan SIPs House Portland, OR	David Cohan	SIP walls, solar water heating, high efficiency mini-split ductless heat pumps, green roof design	50% Marine
Forest City, HI NZEH Kaneohe Marine Base	Forest City, HI Will Boudra, Development Manager Forest City Hawaii Military Communities, LLC WilliamBoudra@forestcity.net	Verve Living Systems lighting controls and demand response, solar hot water	50% Hot-Humid
Forest City, HI Mololani Waikulu, Kaneohe Marine Base	Forest City, HI Will Boudra, Development Manager Forest City Hawaii Military Communities, LLC WilliamBoudra@forestcity.net	All around energy efficiency package, Verve Living Systems lighting controls and demand response, solar hot water	50%+ Hot-Humid
<i>Budget Period 3 (2010)</i>			
New Tradition Homes "Parade Home" Ridgefield, WA	New Tradition Homes Steve Tapio, Quality Control Warranty Manager and Building Science Team Leader Steve.tapio@newtraditionhomes.com (360) 448-4714	Tankless HW, Two (2) high efficiency mini-split heat pumps, Heat recovery ventilator (HRV)	50% Marine
Artisan Groups Olympia, WA	Artisan Groups Tessa Smith tessa@artisansgroup.com (360) 870-6280	Tankless WH, Solar Hot Water, Energy recovery ventilator (ERV)	50% Marine

Table 7: Stage Gate 2 Design, Analysis and Test Plans

Subtask 3.2 Stage Gate 2 Prototype House Report: Performance Evaluations in Preproduction Prototypes

The BIRA team completed the Stage Gate 2 prototype house performance evaluations for 23 homes shown in the table below during the three Budget Periods; all of which are at varying stages of completion.

House/Builder	Stage Gate 2 Status
<i>Budget Period 1 (2008)</i>	
Citihouse II Alvis Projects, Inc.	On hold
"Newport" Gold Medallion	Completed
"Liverpool" Liberty Homes	Completed
"Carmichael" Holmes Homes	Completed
"Craftsman" Rainey Homes	Completed
Kent Model 2294 New Traditions	In construction during this Budget Period
NextGen, Las Vegas, NV	NextGen
NextGen	Completed
Martha Rose	Completed
<i>Budget Period 2 (2009)</i>	
Artistic Homes (2 homes)	Both homes are still in Stage Gate 2. One home is still under construction and both homes have yet to have any data collected to verify energy savings
GEOS Homes Solar Cottage	In Process. Construction is expected during the first quarter of 2010.
Gold Medallion	In progress
Cohan Residence	Constructed and awaiting monitoring data
Snow Creek (2 homes)	Under construction. Monitoring sensors are being installed.
Forest City, HI	Under construction

House/Builder	Stage Gate 2 Status
Mololani	
Forest City, HI NZEHS (2 homes)	Scheduled to be built in early 2010.
<i>Budget Period 3 (2010)</i>	
Snow Creek Cottages (2 units) Park City, UT (Cold)	These homes remain at Stage Gate 2. The two homes are currently being monitored. Data has been collected for approximately 3 months. For additional details outlining results, please refer to the Snow Creek Cottages Interim report.
Net-ZEH Mololani Oahu, HI (Hot-Humid)	The Net-ZEH prototype home performance has been evaluated and results are included in the Stage Gate 2 report satisfying criteria for this gate.
New Tradition Homes Ridgefield, WA (Marine)	The study conducted on the New Traditions Home, located in the Marine Climate, has been completed and satisfies criteria for Stage Gate 2.

Table 8: Prototype House Evaluation

Subtask 3.3 Stage Gate 2 Prototype House Reports: House Studies at 50% WHES - 4 minimum

The BIRA team was tasked with evaluating four Prototype Homes during the three year budget period. Each Prototype Home was evaluated based on Building America's Stage Gate 2 "Must Meet" and "Should Meet" criteria.

The BIRA team evaluated the New Traditions Homes' Kent Model 2264 home in Vancouver, WA and the Martha Rose Construction's The Homestead in Seattle, Washington during Budget Period One to determine if they meet the Building America 50% whole house energy savings goal when compared to the Building America Benchmark for the Marine Climate Zone.

House/Builder	% WHES / Climate Zone	Stage Gate 2 Status
Kent Model 2264 / New Traditions Homes	51% Marine	NTH expects to construct the prototype upon sale of a custom upgrade package, likely within budget period 2. Based on the energy cost savings from BEopt and incremental costs estimated by NTH, it has been determined that the homeowner can expect to see approximately \$1,276 per year net cost savings versus the Building America Benchmark with a net \$752 annual positive cash flow.
Homestead / Martha Rose Construction	59% Marine	Based on the energy cost savings from BEopt and incremental costs estimated by MRC, it was been determined that the homeowner can

House/Builder	% WHES / Climate Zone	Stage Gate 2 Status
		expect to see approximately \$1,595 per year in energy cost savings based on the advanced features plus an additional \$181 per year from PV generation, for a net annual utility bill savings of \$1,776.

Table 9: Summary of Northern Marine Prototype House Studies

Budget Period 1

In Budget Period Two, the BIRA team evaluated another Northern Marine Prototype Home to determine if they met the Building America 50% whole house energy savings goal when compared to the Building America Benchmark for the Marine Climate Zone. The David Cohan

“SIP” House was evaluated based on Building America’s Stage Gate 2 “Must Meet” and “Should Meet” criteria.

House/Builder	% WHES / Climate Zone	Stage Gate 2 Status
SIP House / David Cohan	51.2%% Marine	In Process. Refer to interim report for more details.

Table 10: Summary of Northern Marine Prototype House Studies

Budget Period 2

The BIRA team evaluated one (1) Cold Prototype Home in 2010 to determine if it met the Building America 50% whole house energy savings goal when compared to the Building America Benchmark for the Cold Climate Zone. The Gold Medallion House was evaluated based on Building America’s Stage Gate 2 “Must Meet” and “Should Meet” criteria.

Prototype Home	Stage Gate 2 Status
Gold Medallion Home South Jordan, UT (Cold)	The Gold Medallion home has successfully completed the Stage Gate 2 Criteria. Refer to the completion report for more details related to prototype results.

Table 11: Summary of Northern Marine Prototype House Studies

Budget Period 3

Task 4: Stage Gate 3 – Community Scale Evaluations

Subtask 4.1 Evaluation Plans for Initial Community Scale Projects of Ten or More Homes with 40-50% in Efficiency Savings

The BIRA team completed the evaluation plans for qualified initial community scale projects

shown in the table below:

Community/Location	Builder	Number of Homes	% WHES/Climate Zone
O Bel! Sole Lancaster, CA	K Street LLC	58 completed	54% Hot/Dry
Landover Commons Vancouver, WA	New Traditions	94	44.1% Marine
Kentlake Highlands Kent, WA	Quadrant	9 completed 10 in process	41.7% Marine
Crescent Village Eugene, OR	Ruhoff	16 completed 8 in process	44.1% Marine
Village at Miller's Creek Burien, WA	Schneider Family Homes	37	47.4% Marine
New Columbia Portland, OR	Tom Walsh and Co	22	43.5 % Marine
Snow Creek Park City, UT	Park City	13	50% Cold
Mololani Kaneohe, HI	Forest City Military Communities, LLC	244	50% Hot Humid
Mediterranean Villas Pasco, WA	Devoted Builders	200	40% Cold
Sage Green Portland, OR	Green One Construction	18	50% Marine
Artistic Homes NM / CO	Artistic Homes	12	50% Cold 50% Hot/Mixed Dry
Waikulu Kaneohe, HI	Forest City Military Communities, LLC	165	40% Hot Humid
DR Horton Oahu, HI	DR Horton	10	50%+ Hot-Humid
Tierra del Sol Stockton, CA	Visionary Home Builders	22	50% Hot/Mixed-Dry

Table 12: Evaluation Plans – Initial Community Scale Projects

Subtask 4.2 Stage Gate 3 Case Studies: 40-50% Initial Community Scale Projects

The BIRA team completed all of the necessary case studies for qualified initial community scale projects required for completing the Building America 2008-2010 Joule Milestones: 40% Marine and 40% Hot-Humid. The communities are summarized in the table below.

Community/Location	Builder	Number of Homes	% WHES/Climate Zone
Landover Commons	New Traditions	94	44.1% Marine

Community/Location	Builder	Number of Homes	% WHES/Climate Zone
Vancouver, WA			
Kentlake Highlands Kent, WA	Quadrant	10 completed 9 in process	41.7% Marine
Crescent Village Eugene, OR	Ruhoff	16 completed 8 in process	44.1% Marine
Village at Miller's Creek Burien, WA	Schneider Family Homes	37	47.4% Marine
New Columbia Portland, OR	Tom Walsh and Co	22	43.5 % Marine
Snow Creek Park City, UT	Park City	13	50% Cold
Mololani Kaneohe, HI	Forest City Military Communities, LLC	244	50% Hot Humid
Sage Green Portland, OR	Green One Construction	18	>50% Marine
Mediterranean Villas Pasco, WA	Devoted Builders	12	40% Cold
Artistic Homes NM / CO	Artistic Homes	165	50% Cold 50% Hot/Mixed Dry
Waikulu Kaneohe, HI	Forest City Military Communities, LLC	13	40% Hot Humid
DR Horton Oahu, HI	DR Horton	10	50%+ Hot-Humid
Tierra del Sol Stockton, CA	Visionary Home Builders	22	50% Hot/Mixed-Dry

Table 13: 40-50% Initial Community Scale Project in the Multiple Climates

The following tables below summarize the Initial Community Scale Project findings during the contract period.

Community	Key Result	Gate Status BP1
Landover Commons	44.1% Marine	As of May 2008, New Tradition expected at least ten of these tax credit homes to be complete in the Landover Commons community by September. Based on the energy cost savings from BEopt and incremental costs from New Tradition Homes, it was determined that the homeowner can expect

Community	Key Result	Gate Status BP1
		to see approximately \$700 per year net cost savings compared to the Building America Benchmark.
Kentlake Highlands	41.7% Marine	The Kentlake Highlands community met Building America's 40% initial communities goal for the Marine Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria.
Crescent Village	44.1% Marine	There are at least 16 homes built at the 40% level, with another eight to be completed by the end of the year. Based on the energy cost savings from BEopt and incremental costs from Ruhoff Home Builders, it was determined that the homeowner can expect to see approximately \$319 per year net cost savings compared to the Building America Benchmark.
Village at Miller's Creek	47.4% Marine	All 37 of the homes in Village at Miller's Creek have been completed. Based on the energy cost savings from BEopt and incremental costs from Schneider Family Homes, it was determined that the homeowner should expect approximately \$830 per year net cost savings relative to the Building America Benchmark.
New Columbia	43.5 % Marine	There were 22 homes of this level completed in the New Columbia community. Based on the energy cost savings from BEopt and incremental costs from Tom Walsh & Co., it was determined that the homeowner can expect to see approximately \$750 per year net cost savings compared to the Building America Benchmark.

Table 14: Summary of Initial Community Scale Projects

Community	Key Result	Gate Status BP2	Gate Status BP3
Snow Creek	>50% Cold Climate	Qualifies as a Building America 50% Community in the Cold Climate Zone with all plans averaging 54.8% WHES	N/A
Mololani	>50% Hot Humid Climate	Qualifies as a Building America 50% Community in	N/A

Community	Key Result	Gate Status BP2	Gate Status BP3
		the Hot-Humid Climate Zone with 52.9% WHES	
Sage Green	>50% Marine Climate	Qualifies as a Building America 50% Community in the Marine Climate Zone with 50.1% WHES	This project fulfills all “must meet” and “should meet” criteria for Stage Gate 3.
Mediterranean Villas	40% Marine Climate	Qualifies as a Building America 40% Community in the Marine Climate Zone with 48.5% WHES	N/A
Artistic Homes	>50% Cold and Hot/Mixed-Dry Climate	Qualifies as a Building America 50% Community in the Cold and Hot/Mixed Dry Climate Zone with 55.7% WHES without PV	N/A
Waikulu	>50% Hot Humid Climate	Qualifies as a Building America 50% Community in the Hot-Humid Climate Zone with 51.4% WHES	N/A
DR Horton Oahu, HI	50%+ Hot-Humid N/A	N/A	Qualifies as a Building America 50% community in the Hot-Humid climate zone while satisfying stage Stage Gate 3 criteria.
Tierra del Sol Stockton, CA	50% Hot/Mixed-Dry	N/A	Qualifies as a Building America 50% Community in the Hot/Mixed-Dry climate zone. This community meets all Stage Gate 3 criteria.

Table 15: Summary of Initial Community Scale Projects

40% Case Study – Hot-Humid (Forest City)

The BIRA team completed one (1) case study for 40% efficiency in the Hot-Humid climate zone satisfying stage gate 2 criteria. The report presents evaluation results of the Forest City Military Communities LLC – Naval Computer and Telecommunications Area Master Station (NCTAMS) Community. The community evaluation was based on the Building America Stage Gate 3 “Must Meet” and “Should Meet” criteria for Initial Community Scale Evaluations.

Subtask 4.3 Stage Gate 3 Report: 40% Initial Community Scale Projects in Marine Climate

The Stage Gate 3 process evaluated the performance of final production building designs using energy simulations, financial analyses, and quality assurance techniques. The objective of this study was to provide a concise summary of communities meeting 40% energy efficiency savings relative to the Building America Benchmark in the Marine Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria. Detailed case studies for each community were provided in reports detailing BIRA work on Task 4.2. These case studies are valuable resources for specific information on each community in regards to each of the Stage Gate criteria.

The Marine Climate Zone is a thin strip of land stretching down the West Coast from the Canadian border to Santa Barbara, California. The three largest metropolitan areas in the region are Seattle, Washington; Portland, Oregon; and San Francisco, California. Although temperatures are reasonably mild, the space conditioning requirements for this climate zone is dominated by heating. Both the number of heating degree days and the amount of precipitation increase moving north along the coast. This creates two sub-climates within the Marine Climate Zone, the Northern Marine Climate Zone and the Southern Marine Climate Zone.

The Northern Marine Climate Zone is distinct from the Southern Marine Climate Zone not only due to increased heating degree days and precipitation, but also due to differing construction practices. Northern Marine builders typically build with 2x6 walls on top of crawlspaces while Southern Marine builders typically build with 2x4 walls on a slab. The five case studies detail five different Northern Marine communities. The reasons for this distribution are thoroughly discussed in the Market Coverage "Should Meet" criteria section of this report. The table below lists the five communities studied their WHES level, and the builders and locations of the communities.

Community/Location	Builder	Number of Homes	% WHES/Climate Zone
Landover Commons Vancouver, WA	New Traditions	94	44.1% Marine
Kentlake Highlands Kent, WA	Quadrant	10 completed 9 in process	41.7% Marine
Crescent Village Eugene, OR	Ruhoff	16 completed 8 in process	44.1% Marine
Village at Miller's Creek Burien, WA	Schneider Family Homes	37	47.4% Marine
New Columbia Portland, OR	Tom Walsh and Co	22	43.5 % Marine

Table 16: 40 %Marine Case Study Communities

All five communities studied qualify as Building America 40% Communities in the Marine Climate Zone. This assessment was based on energy analyses performed using BEopt 0.8.6, incremental costs based on builder estimates, and additional information acquired first hand from the builders.

An energy analysis performed on a representative home from each community shows an energy savings of at least 40% when compared to the Building America Benchmark. All five communities featured at least ten homes at this level of savings by September. Based on the energy cost savings from BEopt and incremental costs from each of the builders, it was determined that homeowners in each community expected to see positive cash flow compared to homes built to code and/or to the Building America Benchmark.

All five builders took full advantage of programs such as Northwest ENERGY STAR and Built Green to help with their marketing efforts. In addition, builders provided exceptional customer service and education on energy efficient features to keep their homes marketable. Although all five of the builders studied were from the Northern Marine Climate Zone, BIRA developed a strategy for builders looking to build at the 40% level in the Southern Marine Climate Zone (California), but was not successful in recruiting any builders for this Stage Gate. Each of the participating builders was committed to continuing to build at current Building America levels while also finding new energy efficiency features that they can integrate into their current building practices. BIRA continued to work with these builders and others to move from the 40% target to 50%; this effort included efforts so that future designs in the Northern Marine Climate Zone more commonly featured external foam insulation and the use of open-web trusses. To ensure that quality homes were built, all five builders depended on the protocols of Northwest ENERGY STAR and the extensive support of their superintendents.

All five of the communities studied met Building America's 40% initial communities goal for the Marine Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria.

Subtask 4.4 Stage Gate 3: Initial Communities Update Report - Multiple Climates

This report provided a concise summary of BA Gate 3 Community opportunities that were likely prospects for research from 2008 through 2010.

BIRA had 25 community-level projects lined up spanning three climate zones. Redundancy in a particular climate zone was viewed as a benefit, as market conditions at the time did not guarantee that all projects would proceed as planned.

Cold Climate:

- City of Park City – Snow Creek, Park City, Utah
- Devoted Home Builders - Mediterranean Villas, Pasco, WA
- DOE High Performance Home, Bend, Oregon
- Artistic Homes – Hart Valley, Aztec, New Mexico
- Salt Lake County Affordable Housing, Utah
- GEOs, Arvada, Colorado

Marine Climate:

- Howland Homes – Issaquah Highlands, Issaquah, Wa
- Tom Walsh
- Ruhoff Home Builders – Wiley Creek, Eugene, OR
- New Tradition Homes – Serena Estates, Vancouver, WA
- The WJM Studio – Mirror Lake Highlands, Federal Way, WA

Hot/Mixed-Dry Climate:

- K Street LLC – O Bel Sole, Lancaster, CA
- DMB (Developer)
- I-Build – Hurricane, UT
- Rancho Mission Viejo (Developer) – The Ranch, Mission Viejo, CA
- Habitat for Humanity – Alamogordo, NM
- PepperViner – Sunny Pointe, Tucson, AZ
- Coldwell Banker – Davis, CA
- Forest City (Developer)
- Newland Communities
- City of Henderson, NV (Developer)
- Artistic Homes – Anasazi Ridge, Sundance Estates, Yucatan Del Este, Albuquerque, NM
- Zero Net Homes (SMUD Project)

Hot/Humid Climate

- Forest City – Military Housing, Oahu, HI

Task 5: Stage Gate Final Project Closeout

In Budget Period Two, the BIRA team completed one Stage Gate Final Project Closeout report for the O Bel Sole! Estates community based on the Building America's (BA) Stage Gate Final Project Close Out Criteria. The performance of an occupied BA community was documented using energy simulations, targeted utility bill analysis and feedback from project stakeholders. The benefits and lessons learned from this project were documented for homebuilders, homebuyers, utilities, and other stakeholders to understand the collective benefits that near-zero energy homes offer.

The O Bel Sole! Estates community, at 66.7% whole house energy savings (WHES), relative to the BA Benchmark, is an example of smart design, improved construction practice, and high efficiency, "off-the shelves" equipment. This building strategy allowed the cost neutrality target to be exceeded with approximately \$1,457.58 annual cost savings for the homeowner.

In BP3, the BIRA team was not tasked with any final project closeout reports.

Task 6: Post-Stage Gate Results, Best Practices Documentation and Resource Development

Subtask 6.1 Review & Provide Feedback to Best Practices drafted reports by PNNL & ORNL

BIRA's support of Best Practices Documentation and Resource Development is an ongoing, dynamic process. BIRA strived to respond thoughtfully and quickly to the requests of PNNL and ORNL, and has strong relationships and lines of communications with key personnel at each lab. In preparation for the 2009 update to the Marine Best Practices/Builders Challenge Guide, BIRA worked closely with PNNL earlier in the year to align 40% Marine Joule reporting (G3 report and case studies) with the needs of guides. BIRA's outreach in designing reporting format for new G3 reporting criteria proved helpful as the documents were well received and facilitated PNNL's work in 2009 to update the Marine Guide. BIRA continued to be an essential contributor to Hot Mixed/Dry and Marine reporting and best practices.

BIRA also worked closely with ORNL on BIRA project documentation and the Builders Challenge. BIRA contributed significant time working with builders in Cold, Marine and Hot Mixed/Dry climates to educate and promote participation of the Builders Challenge.

Detailed Task Reports

Task 1: Building America – System Research Management and Technical Support

Subtask 1.1 Presentation Schedule and Technical Reports for CY 2008 – CY 2010

In 2008 – 2010, BIRA delivered several technical reports and/or presentations to ensure broad dissemination of Building America Research results. A deliverable with schedules of conference presentations and technical reports was submitted to NREL.

In addition, BIRA used the following deliverables for conferences or journal articles:

Budget Period 1 (2008)

Task 2.B.2 - MELs Research Results on Controls Targeting Home Entertainment and Office Areas

Task 2.B.2.a - PVT System Research and Performance at the Kennecott Land Project in Utah

Task 3.1.a - Performance of the New Oasys HVAC system in the Kennecott Land Project in Utah

Task 3.1.b - Performance of the Plenum Crawlspace Approach in Hot/Dry zone

Budget Period 2 (2009)

- Task 2B.2.b - New Oasys HVAC system at Gold Medallion Homes in UT
- Task 2B.2.d – VERVE lighting control system at Artistic Homes in New Mexico
- Task 2B.2.g - PVT System Research and Performance at the Gold Medallion Project in Utah
- Task 3.1.e - Forest City Retrofit of the Eisenhower home

The following abstracts were accepted for Publications:

- Moving Ducts into Conditioned Space; Getting to Code in the Pacific Northwest
- Vented and Conditioned Crawlspace Performance in Marine and Cold Climates of the Pacific Northwest
- Applications for Large Communities: What is Net- Zero Energy?
- Battle of the Walls, Peak-Cooling

Budget Period 3 (2010)

The following abstracts were accepted for Publications:

- Moving Ducts into Conditioned Space; Getting to Code in the Pacific Northwest
- Battle of the Walls, Peak-Cooling

Conference	Location	Dates	Subject	Presenter	Audience	Paper/ Presentation
SDG&E: Energy Efficiency and Solar Communities	San Diego, California	4/22	Case Studies, Energy Efficiency and Solar	Steve Vang	Utilities; builders; engineers; educators; and other consultants.	Presentation
SWEEP Energy Efficiency Workshop in Western States	Salt Lake City, UT	4/30	Introduction to ZEH	Rob Hammon	Industry and utility; architects; builders; engineers; local, state, and federal agency personnel; energy researchers and educators; and consultants.	Presentation
SWEEP Energy Efficiency Workshop in Western States	Phoenix, AZ	5/7	Introduction to ZEH	Rob Hammon	Industry and utility; architects; builders; engineers; local, state, and federal agency personnel; energy researchers and educators; and consultants.	Presentation

Conference	Location	Dates	Subject	Presenter	Audience	Paper/ Presentation
SWEEP Energy Efficiency Workshop in Western States	Las Vegas, NV	6/10	Introduction to ZEH	Rob Hammon	Industry and utility; architects; builders; engineers; local, state, and federal agency personnel; energy researchers and educators; and consultants.	Presentation
SWEEP Energy Efficiency Workshop in Western States	Albuquerque, AZ	6/18-20	Introduction to ZEH	Rob Hammon	Industry and utility; architects; builders; engineers; local, state, and federal agency personnel; energy researchers and educators; and consultants.	Presentation
PCBC	San Francisco, CA	6/25-27	Green Affordable Housing One Innovative Home At A Time	Rob Hammon, Abe Cubano, Marlin Alvis, Steve Sotomayor	Home builders, city, state and national officials, suppliers	Presentation

Conference	Location	Dates	Subject	Presenter	Audience	Paper/ Presentation
Data Not Dogma Conference	Goldendale, WA	7/21 - 22	Presenting Building America Work in PNW	Ryan Kerr	Home builders, city, state and national officials and suppliers	Presentation
Kennecott Parade of Homes	Kennecott, UT	August (1st week)	Kennecott "Daybreak" Project Parade of Homes in Utah	Abe Cubano Rob Hammon Steve Vang	Home builders, city, state and national officials	Presentation by Kennecott
ACEEE	Pacific Grove, California	8/17- 22		Ryan Kerr Rob Hammon Steve Vang	Industry and utility; architects; builders; financial and insurance professionals; clean-tech investors; manufacturers of building products, appliances and equipment; building owners and operators; engineers; local, state, and federal agency personnel; energy researchers and educators; and consultants.	Presentation & Paper
ACEEE	Pacific Grove,	8/17-	Moving Ducts Inside	Michael	Industry and	Presentation &

Conference	Location	Dates	Subject	Presenter	Audience	Paper/ Presentation
	California	22	Conditioned Space	Lubliner, Ryan Kerr	utility; architects; builders; engineers; local, state, and federal agency personnel; energy researchers and educators; and consultants.	Paper
Solar Power 2008	San Diego, CA	10/14- 15	Solar and Efficiency Powers Homes	Rob Hammon	Industry and utility; architects; builders; engineers; local, state, and federal agency personnel; energy researchers and educators; and consultants.	Presentation
EEBA	Phoenix, AZ	10/23	High Performance Track	Duncan Prael, Ryan Kerr	Industry and utility; architects; builders; engineers; local, state, and federal agency personnel; energy researchers and educators; and	Presentation

Conference	Location	Dates	Subject	Presenter	Audience	Paper/ Presentation
					consultants.	
EEBA	Phoenix, AZ	10/23	Buildings and Systems Research - How to Keep Your Cool in Desert Climates	David Springer, Steve Vang	Industry and utility; architects; builders; engineers; local, state, and federal agency personnel; energy researchers and educators; and consultants.	Presentation

Table 17: List of Conferences and Presentations CY 2008

Conference	Location	Dates	Subject	Presenter	Audience	Paper/Presentation
NAHB - Int'l Bldrs Show	Las Vegas	1/20- 1/23	Energy Value Housing Awards - Judge	David Hales	Utilities; Builders; Engineers; Educators; Consultants; Researchers	Building America Booth
Solar Forum	Anaheim Convention Center	1/29	Cooling strategies for hot climates. Builder tests strategies for reducing cooling loads	Rob Hammon	Utilities; Builders; Engineers; Educators; Consultants; Researchers	Presentation
ASHRAE Annual Meeting	Winter Conference - Chicago	1/24- 1/28	ASHRAE HVAC	Chaired Std 193 mtg (Mike	Builders, Engineers, Consultants, Architects,	Presentation

Conference	Location	Dates	Subject	Presenter	Audience	Paper/Presentation
				Lubliner)	Designers, Contractors	
ACI Northwest	Portland, Oregon	2/4-2/5	1.Vented & Conditioned crawlspaces 2.Duct in Conditioned Space 3.High R-Value wall construction	David Hales Brady Peeks	Utilities; Builders; Engineers; Educators; Consultants; Researchers	Presentation
RESNET - Building Performance Conference	Astor Crowne Plaza Hotel - New Orleans	2/16- 2/18	Building Performance	HUD-code panel w/EPA, DOE & HUD (Mike Lubliner)	Builders, Engineers, Consultants, Architects, Designers, Contractors	Presentation
NAHB's Multifamily Pillars of the Industry Conference...	Hotel Del Coronado, San Diego, CA	3/17- 3/18	Green Building: A Cost/Benefit Analysis	Rob Hammon	Utilities; Builders; Engineers; Educators; Consultants; Researchers	Presentation
2009 Water Conservation Showcase	Pacific Energy Center, 851 Howard Street, San Francisco, CA	3/24	Saving 20,000 gallons: Case Studies in Water Conservation	Justin Dunning	Building Designers, Engineers,	Presentation
Session with Cities on ENERGY	Ramada Inn, Fresno, CA	3/26	Approaches for Developing Community-based Energy Programs	Ethan Sprague	San Joaquin Valley Energy Organization, HUD, cities	Presentation

Conference	Location	Dates	Subject	Presenter	Audience	Paper/Presentation
Green Home Expo	Sacramento Convention Center	4/3	Stimulus Package Federal Grants and Tax Breaks for Building Green	Mike Hodgson & Ethan Sprague	Builders, Engineers, Consultants, Architects, Designers, Contractors	Presentation
BIPV Summit	Hilton Del Mar, San Diego, CA	4/6-4/8	Assessing BIPV Activity in the Home Builder Market	Rob Hammon	PV manufacturers, architects/designers, developers/builders, building engineers, contractors	Panel Discussion
Coachella Energy Summit	Palm Springs Convention Center	4/17	Promoting Climate Action Planning, Energy Efficiency and Sustainability through Incentives	Mike Hodgson	Regional leaders in government, energy, and the private sector	Panel Discussion
ACI Home Performance Conference	Hyatt Regency - Kansas City, MO	4/27-5/1		HUD Code Panel, David Hales	PV manufacturers, architects/designers, developers/builders, building engineers, contractors	Panel Discussion
California Green Builder Workshop	SCE's Customer Technology Application Center (CTAC), Irwindale, CA	5/7	Examines state and national green building programs, updates on the California building regulations, as well as details on CGB rater certification.	Justin Dunning	Builders, Raters and local jurisdictions	Presentation

Conference	Location	Dates	Subject	Presenter	Audience	Paper/Presentation
West Coast Energy Management Congress	Long Beach Convention Center, Long Beach, CA	6/10-6/11	Peak Communities	Rob Hammon	PV manufacturers, architects/designers, developers/builders, building engineers, contractors	Presentation/Paper
BIRA Experts Meeting: Solar PV/Thermal	Vancouver, WA	8/20/09	Solar Thermal/PV	Steve Vang, Mike Lubliner and Matt Fung	PV manufacturers, architects/designers, developers/builders, building engineers, contractors	Presentation
EEBA 2009	Denver, CO	9/28-30/09	EEBA	Rob Hammon	PV manufacturers, architects/designers, developers/builders, building engineers, contractors	Presentation/Tour Guide
BIRA Experts Meeting: Alternative Wall Systems	Sacramento, CA	11/13/09	Alternative Wall Systems	Steve Vang	PV manufacturers, architects/designers, developers/builders, building engineers, contractors	Presentation

Table 18: List of Conferences and Presentations CY 2009

Conference	Location	Dates	Subject	Presenter	Audience	Paper/Presentation
NAHB - Int'l Builders Show	Las Vegas, NV	1/20-1/23	Energy Value Housing Awards - Judge	David Hales	Utilities; Builders; Engineers; Educators; Consultants; Researchers;	Building America Booth

Conference	Location	Dates	Subject	Presenter	Audience	Paper/Presentation
					Contractors	
ASHRAE Winter Meeting	Orlando, FL	1/25-1/28	Poster: Moving Ducts into Conditioned Space; Getting to Code in the Pacific Northwest	David Hales	Utilities; Builders; Engineers; Educators; Consultants; Researchers; Contractors	Poster Peer Reviewed paper Published in Transactions
PCBC	SF, CA	6/11	Energy Retrofit Series Seminar: overview, training, becoming a retrofit contractor	Mike Hodgson	Builders; Consultants; Researchers; Contractors; Raters	Publicized three-hour seminar series at major builders' conference
Buildings XI International Conference	Clearwater Beach, FL	12/5-9	Crawlspace Performance in Marine & Cold Climates of the Pacific Northwest	David Hales	Utilities; Builders; Engineers; Educators; Consultants; Researchers; Contractors	Paper/Presentation Peer reviewed Published in Transactions

Table 19: List of Conferences and Presentations CY 2010

Subtask 1.2 Monthly Status Reports, Upcoming Event Reporting, Technical Highlights

BIRA produced eight monthly executive summaries of significant progress at each gate level, summaries of upcoming team events and activities, and highlights describing recent notable technical accomplishments for BP1, BP2 and BP3.

Subtask 1.3 Quarterly Activity

BIRA produced four (March, June, October and December) technical highlights (quarterly reports) as required for each of BP1, BP2 and BP3.

The Building America Database was updated on a quarterly basis with a total of 439 total homes for BP2 and 294 total homes for BP3:

Climate Zone	Community	Number of Homes
Hot-Dry	Artistic Community	12
Hot-Humid	Mololani	244
	Waikulu	165
Marine	David Cohan	1
	Martha Rose	4
	Shirey	1
Cold	Snow Creek Cottages	12
Total Homes:		439

Table 20: BA Database Updates BP2

Climate Zone	Community	Number of Homes
Hot/Mixed-Dry	Tierra del Sol – Visionary Home Builders	22
Hot-Humid	Mololani	244
	DR Horton	10
Marine	Sage Green	5
Cold	Snow Creek Cottages	13
Total Homes:		294

Table 21: BA Database Updates BP3

Subtask 1.5 Field Tests and Planning

The BIRA team worked on 15 prototype home opportunities for field test and evaluation from varying climate zones during the three budget periods. Each home incorporated advanced technologies ranging from advanced wall systems to multipurpose renewable energy sources. Details of the prototype homes evaluated are shown in Table 22 below.

House/Location	Builder/Contact	Design Features	Climate
Citihouse II Fresno, CA	AlvisProjects, Inc. Marlin Alvis	– SunCache Solar Water Heating – CSIP Walls	50% Hot/Mixed
Citihouse III Fresno, CA	AlvisProjects, Inc./Marlin Alvis	– ICF Walls – PVT	50% Hot/Mixed
Kennecott Land Salt Lake City, UT	Gold Medallion	– PVT	40-50% Cold
Reno Project Reno, NV	Sweeney Architecture & Idea Development	– ICF Walls – Others TBD	40-50% Cold
Idaho Project Southwest Idaho	Chuck Miller Construction	– Residential Economizer – Heat Pump	50% Cold
Snow Creek Cottages Park City, UT	City of Park City	– SIP Walls – GSHP	50% Cold
Webster School Cottages Magna, UT	Salt Lake County Affordable Housing Project	– Solar thermal – Solar PV – OAsys evaporative-cooling – MELS reduction	50% Cold
GEOS Project Arvada, CO	GEOS	– All electric – Passive solar – Innovative HVAC – Community GSHP	50% Cold
Forest City Military Housing Oahu, Hawaii	Forest City Hawaii	– Solar thermal systems – Verve lighting system	50% Hot Humid
Habitat for Humanity Las Cruces, NM	Habitat for Humanity	– Solar thermal – Solar PV	50% Hot/Mixed Dry
Pepper Viner, Tucson, AZ	Pepper Viner	– SIP – Solar thermal – Solar PV	50% Hot/Mixed Dry
Mololani Net-ZEH Oahu, Hawaii	Forest City Military Housing	– High performance A/C system (21	50+% Hot-Humid

House/Location	Builder/Contact	Design Features	Climate
		SEER)Verve HEMs – Solar thermal w/ storage backup – 6.0kW PV system	
Oroville Lab Home Oroville, CA	Cleantech Innovative Center (CIC)	– Solar thermal/PV – Slab edge insulation – Ground coupling – HEMs	50% Hot/Mixed-Dry
Utah Lab Home South Jordan, UT	Garbett Homes	– SIPs Walls – Compressorless cooling – Passive solar design – Solar thermal	50+% - Cold
Tierra del Sol Community Stockton, CA	Visionary Home Builders	– Modular wall system – Solar thermal & PV	50+% Hot/Mixed-Dry

Table 22: Additional Measures

Subtask 1.6 Publications

The following is a list of special publications in BP1 2008, BP2 2009 and BP3 2010 by BIRA and its partners that: are comprehensive in nature; are based substantially on Building America research results; and are not otherwise undergoing peer review through an established conference, journal, or NREL report review process.

	Conference or Journal	Status	Expected Title or Subject	Author	Audience
1	Home Energy	Published May 2008	Green Production Building – Moving Ducts Inside	Ryan Kerr	Home builders, Home buyers
2	Home Energy	Published January 2008	Zero Peak Homes: Real Homes, Real Savings	Ryan Kerr	Home builders, Home buyers, Solar Industry
3	Home Energy, Solar Today and/or Others	Accepted	Green Affordable Housing One Innovative Home at a Time	Abe Cubano	Home builders, Home buyers, Renewable Energy Industry

Table 23: Publications Budget Period 1 (2008)

Conference or Journal	Status	Expected Title or Subject	Author	Audience
Home Energy	Published November 2010	Battle of the Walls, Peak Reduction	Steve Vang	Home builders, Home buyers
Home Energy / Others	Accepted	Moving Ducts into Conditioned Space: Getting to Code in the Pacific Northwest	David Hales	Home builders, Home buyers,
Home Energy / Others	Published 2010	Vented and Conditioned Crawlspace Performance in Marine and Cold Climates of the Pacific Northwest	David Hales	Home builders, Home buyers,
Home Energy, Solar Today and/or Others	Published 2010	Applications for Large Residential Communities: What is Net-Zero Energy?	Rob Hammon	Home builders, Home buyers, Renewable Energy Industry

Table 24: Publications Budget Period 2 (2009)

Conference or Journal	Status	Expected Title or Subject	Author	Audience
Home Energy	Published November 2010	Battle of the Walls, Peak Reduction	Steve Vang	Home builders, Home buyers
ASHRAE Transactions, 2010	Published 2010	Moving Ducts into Conditioned Space: Getting to Code in the Pacific Northwest	David Hales	Home builders, Home buyers,

Table 25: Publications Budget Period 3 (2010)

Subtask 1.6.1 Summary of Code Barriers Report

The BIRA team explored several issues in Codes and Standards, primarily uncovered during work in the Northern Marine Climate while working on the 40% and 50% Marine WHES.

Codes – Washington State

Over 85%¹ of all homes in Washington have central forced air heating as their primary system. In new construction, problems affecting distribution efficiency represent the single largest system loss in performance based on standard practice.

The current Washington State Energy Code 2006 Ed. only requires sealing of all duct work outside of conditioned space as a prescriptive measure.

- Section 503.10.2 **Seams and Joints:** All low-pressure supply and return duct transverse joints, and enclosed stud bays or joist cavities/space used to transport air, shall be securely fastened and sealed with welds, gaskets, mastics (adhesives), or mastic-plus-embedded-fabric systems installed in accordance with the manufacturer's installation instructions.

EXCEPTIONS:

1. Ducts or building cavities used for air distribution that are located entirely within the conditioned space of the building are exempt from this section.
2. UL 181A listed tapes used with listed rigid fibrous glass ducts may be used as the primary sealant, when installed in accordance with the listing.
3. UL 181B listed tapes used with listed flexible air ducts may be used as the primary sealant, when installed in accordance with the listing.
4. Where enclosed stud bays or joist cavities/spaces are used to transport air sealing may be accomplished using drywall, drywall tape plus joint compound.
5. Tapes installed in accordance with the manufacturer's installation instructions, providing detailed information specific to application on ducts, including approved duct materials and required duct surface cleaning.

A study² conducted in 2001, of a similar prescriptive specification in force at that time found an average effective leakage area of over 40 in² in new homes with ductwork outside of conditioned space. Energy loss from duct leakage was estimated to exceed 20%.

In addition to generalized leakage throughout the systems, areas of specific concern include building cavities allowed by code to be used as part of the return system and leakage associated with the air handler cabinets.

Areas identified by the BIRA team that would improve central forced air distribution

¹ Single-Family Residential New Construction Characteristics and Practices Study; Final Report, March 27, 2007, Table 103.

² Washington State Energy Code Duct Leakage Study Report; November 2001; WSUCEEP01105

performance included:

- Elimination of the use of building cavities as returns,
- Performance testing of duct systems with duct work outside of conditioned space,
- Development of standards and a method of test (MOT) to evaluate air handler cabinet leakage,
- Development of construction practices to bring all the elements of central forced air systems within the conditioned space, and
- Alternative non-ducted systems.

Working with Building America builder partners in Washington, alternative approaches to improve distribution efficiency have been implemented and evaluated. The ENERGY STAR® Homes Northwest new construction program has adopted performance testing standards for duct systems outside of conditioned space and prescriptively eliminated building cavities as part of the return systems. This was used as the baseline for BA builder partners to improve upon (see Task 1.6 - Codes and Standards for more information).

Quadrant Homes

Quadrant Homes, the largest builder in the Washington and a BA partner, was provided design assistance and modeling analysis that convinced them to redesign all of their current models to bring ducts inside conditioned space. As a result, all of their homes when upgraded to a .93 AFUE gas furnace, qualify for a Federal EPACT 2005 tax credit and meet the BA 40% benchmark for Marine climate.

In homes with garages under conditioned living space, minimal duct work was run in the garage ceiling. The original detailing called for the duct work to be placed above the required R-30 floor insulation with the envelope pressure boundary maintained at the dry-walled ceiling below the ducts and at the rim joist. Some jurisdictions interpreted WSEC section 502.1.4.7 to require that the R-30 floor insulation must be placed on top of the ducts in substantial contact with the floor above.

- **502.1.4.7 Floor Insulation:** Floor insulation shall be installed in a permanent manner in substantial contact with the surface being insulated. Insulation supports shall be installed so spacing is no more than 24 inches on center. Foundation vents shall be placed so that the top of the vent is below the lower surface of the floor insulation.

The BA team explored an advisory Code interpretation allowing the original detail but the ultimate performance depends on the floor over the garage being a well-sealed cavity. Additional Code language clarification is needed and anticipated (see below under Washington State Energy Code section).

New Tradition Homes

New Tradition Homes (NTH), an early BA builder partner in the region and among the first Builder Challenge builders in the country, has also modified a number of their designs to bring all of the components of the central forced air systems within conditioned space. Their homes with ducts inside conditioned space qualified for both the Federal EPACT 2005 tax credit and meet the BA 40% benchmark for Marine climate.

Regional builder interest in conditioned crawlspaces was on the rise because of national publicity for systems built and evaluated primarily in the Hot Humid climates of the Southeast. NTH built four speculation homes in Vancouver, Washington, as part of a Washington State University Energy Program (WSUEP) study to evaluate IAQ and energy performance of conditioned crawlspaces in Maritime and Cold climates. Traditional vented crawlspaces dominated the new construction market in the maritime regions of the State. The NTH homes were built to IRC standards for conditioned crawls and monitored for up to 2 years. More detailed results are included in BA reporting on the NTH 40% prototype home.

Part of this evaluation examined the benefits of bringing crawlspace ducts within the conditioned space by extending the conditioned space to include the crawl space. Modeling results³ previously published indicated little or no energy savings unless the duct work was already very leaky. Tracer gas analysis indicated a potential benefit from power venting a conditioned crawl and reducing entrainment of crawlspace air into living space by reversing winter time stack effects between the crawlspace and house. The benefit is dependent on operating a crawlspace exhaust fan continuously and is lost if the fan fails. Without power venting, there is a concern about increased pollutant concentrations because of reduced dilution. The vented crawlspaces had roughly 4 times the ACH to the outside than the power vented conditioned crawls. Measured radon levels in the conditioned crawls were roughly 10 times the concentrations in the vented crawls further confirming concern about dilution of pollutants. From an energy perspective, bringing ducts inside the conditioned envelope appears to be much less problematic than extending a conditioned crawlspace around the ducts.

Code recommendations at the time were being developed for the Marine and Cold climates of Washington to specifically allow conditioned crawlspaces and try to keep them, at worst, energy neutral. Recommendations include:

- Only allowing foam insulation products for perimeter insulation,
- Power venting with a tightly sealed floor,
- Passive or active radon mitigation depending on the site, and
- Not allowing direct return or supply air in the crawlspace.

³ Crawlspace Design in Marine and Cold Climates; Lubliner, et.al. ASHRAE Building Envelopes Conference, December 2007.

These recommendations are seen as very climate specific and are based on the Maritime climate in Washington and cold climates to about 7000 HDD.

Washington State Energy Code

Washington State adopted recommended changes to their Energy Code for ducts in conditioned space. As a result, the Washington State Energy Code was improved significantly in part by work done by the BIRA team.

Changes included general requirements for:

- Minimum 50% CFL lighting,
- Performance testing of all ducts outside of conditioned space, and
- Elimination of building cavities as returns.

In addition, a menu driven performance upgrade to the code to reduce energy use by 30% from the existing standard was proposed with widespread preliminary support. The base case Code home in Washington would be approximately at the current Federal EPACT 2005 tax credit level and meet the BA 40% benchmark for the Marine climate.

Measure		Points	%
1	High efficiency HVAC system: – Gas-fired furnace or boiler with minimum AFUE of 90%, or – Air-source heat pump with minimum HSPF of 8.5	1	10
2	High efficiency duct sealing: – Certified performance tested duct systems	1	9
3	All ducts and air handler are contained within building envelope	2	22
4	High efficiency building envelope: – Wall above grade – R-19+R-5 continuous, and – Vaulted ceilings – R-38A, and – Flat ceilings – R-49, and – Windows – U-0.30	1	10-15
5	Limited floor area – max = 1344 ft ² Max. 15% glazing area	2	40
6	Ground Source Heat Pump Min. COP =3.2	2	
7	Advanced air leakage package with heat recovery ventilation Maximum leakage = 3ACH50	1	20

Measure		Points	%
	HRV min. efficiency = 70%		
8	Solar photovoltaic: – Minimum 2 Watt / sq. ft. conditioned floor space	2	20
9	Solar water heating: – Minimum of 40 ft² of gross collector area	1	10

Table 26: Additional Measures

A total of three (3) points would be required by choosing from the nine (9) package options. Other areas under analysis included possible credit for non-ducted systems such as ductless mini-split heat pumps; credit for heat pump commissioning with specific control requirements; and high performance domestic hot water systems.

Code and Standards Issues, 2009

The Washington State Energy Code (WSEC) is the result of a successful partnership between the code enforcement, building and energy efficiency communities. Over the last 30 years, those partners have maintained the code through extensive negotiation, outreach and advocacy. Since 2006 Building America has played a role in this process in the region by identifying successful measures acceptable to builders to further improve performance.

The Governor set a goal of 30 percent overall energy improvement as a benchmark for the State Building Code Council (SBCC) in the code cycle at the time. In order to achieve this ambitious target, code changes needed to increase the number of options available to builders in the state, while still meeting a substantially increased energy efficiency standard. Under new climate initiatives, however, additional requirements will be imposed on the code development process. These included not just energy efficiency, but climate protection and the development of jobs that are secure and based on efficiency technologies. If achieved this should bring a basic Code home in Washington beyond the recently demonstrated 40% Building America benchmarks for both the marine and cold climates in the state⁴.

Comparison of the WSEC 2006 with amendments to the 2009 IECC shows that the WSEC already exceeds the 2009 IECC standard (see Table 27.)

Prototype Size	Heating System	Climate	
		Seattle	Spokane
1350	Furnace	3%	7%
1350	Heat pump	-6%	1%

⁴ WSEC 2009 went into effect January 1, 2011

2200	Furnace	12%	16%
2200	Heat pump	10%	22%
2688	Furnace	9%	13%
2688	Heat pump	-5%	3%
Total WSEC Improvement		10%	15%

**Table 27: Percent Improvement of the 2006 WSEC
 (with amendments) over 2009 IECC⁵**

The State Building Code Council (SBCC) passed significant amendments to the Washington State Energy Code (WSEC). The changes went into effect July 1, 2010 after they sit through the next legislative session where rare amendments are still possible.⁶

The accepted changes do not go as far as originally proposed, but when the final analysis is complete should produce somewhere between a 15-20% reduction in energy use in new residential buildings. Every new home in Washington built after July 1, 2010 should score a 35% or better reduction against the Building America (BA) benchmark in the marine zone. Assuming Energy Star can maintain a standard of performance 15% beyond Code, Energy Star homes in Washington could benchmark very close to the 50% Marine level.

Work done by the Building America program in the marine climate has gone a long way towards making this possible. Research and cost analysis provided by Building America 40% Marine climate community level case studies provided a strong foundation for the proposed amendments presented to the SBCC.

A number of amendments to the WSEC came directly from issues that were identified in Building America projects in the region. These include requirements on the placement of ducts and insulation and the need to document duct and envelop tightness with testing.

Some significant amendments were also added affecting the performance of existing homes when retrofits are done including duct testing when air handlers are replaced.

A new requirement to post a certificate of the energy features of the residence has real potential to transform the marketing of homes.

Changes to WSEC Residential Sections (unofficial results)

- The residential chapters apply to single family dwellings (IRC definition) and multifamily is located in the commercial sections of the WSEC.

⁵ Analysis was conducted using prototypes developed by the Northwest Planning and Conservation Council and used throughout the region for energy planning.

⁶ WSEC 2009 went into effect January 1, 2011

- Duct testing of existing ducts required when a furnace air handler is replaced (there are exceptions).
- A certificate of energy features of the residence is required to be posted.
- Design temperatures for various Washington locations are now listed in Chapter 3.
- The “substantial contact with the surface being insulated” language has an exception for insulation location in certain types of floor systems in order to keep ducts within the conditioned space. (This comes directly from Issues identified by BA)
- Conditioned and unvented attics are allowed under certain conditions.
- Building air leakage testing (with a blower door) is required. (Influenced by BA)
- Programmable thermostats are required on all primary heating systems.
- Strip heat lock-out devices required on heat pumps when the space conditioning requirements can be met with the heat pump alone.
- Ducts located in ceiling and floor space cannot displace required insulation levels. (Influenced by BA)
- Building cavities cannot be used as ducts. (Influenced by BA)
- Duct testing required for all new HVAC systems with ducts located in unconditioned spaces. (Influenced by BA)
- Residential swimming pool pumps have new efficiency requirements.
- Residences must have 50% high efficacy luminaries (light fixtures).
- Changes to Table 5-1 (Component Performance calculations) to reflect efficiency increases.
- Spray foam with a minimum R-value of 3.6 per inch is deemed to comply with the required R-21 prescriptive requirement when installed in a 5.5 inch cavity.
- Garden type windows must now be double glazed for prescriptive compliance.
- Tables 6-1 and 6-2 have been modified. The final versions will be posted later.
- Chapter 7, Reference Standards has been updated with current standards and a duct testing standard has been added.
- Chapter 8, Acceptable Software has been updated to reflect current available packages.
- Chapter 9, Additional Residential Energy Efficiency Requirements has been added to the WSEC. This is a list of 15 options with various credits for each measure. New homes will have to have one additional credit in addition to the base code requirements.
- Chapter 10, Default U-factors. A number of default U-factors have been added to this chapter.

Code and Standards Issues, 2010

In response to the Governor’s request to improve the energy performance of code built homes in Washington State by 30 percent over 2006 WSEC, the State Building Code Council (SBCC) approved the 2009 WSEC package. This package resulted in roughly a 15 percent energy use improvement⁷ over the 2006 WSEC. Prior to implementation of the 2009 WSEC scheduled for

⁷ 2009 Washington State Energy Code: Analysis of Code Changes Adopted By the Washington State Building Code

July 1 2010, the Governor requested an implementation delay in order to allow the construction industry additional time for economic recovery. The SBCC granted the delay. Implementation of WSEC 2009 went into effect on January 1, 2011.

In order to meet Washington State's long term energy use reduction targets of 70 percent (over 2006 WSEC) by 2031, the State developed a strategic plan for enhancing energy efficiency and reducing greenhouse emissions from homes, buildings, districts and neighborhoods. The necessary code changes that will need to be implemented to achieve these targets will address a number of issues already identified by BA work as obstacles to improved performance including: duct testing; location of ducts in conditioned space; and higher R-value walls with the use of insulated sheathing in addition to cost-effective application of renewables.

Comparison of the 2009 WSEC to the 2006 WSEC shows improvements to the state's energy code for the current code change cycle, with 2006 WSEC being the benchmark for energy savings goals for the state. Comparison of the 2009 WSEC to the BA benchmark shows roughly a 32% savings.

Prototype Size	Heating System	Climate	
		Seattle	Spokane
1350	Gas Furnace	8%	14%
1350	Heat Pump	14%	21%
2200	Gas Furnace	18%	24%
2200	Heat Pump	19%	26%
5001	Gas Furnace	16%	21%
5001	Heat Pump	19%	23%

Table 28. Percent improvement of the 2009 WSEC over 2006 WSEC

Codes – Oregon State

Oregon completed the implementation of a 15% energy code improvement in 2008. Work supported by BA was used to identify cost effective improvements that could be implemented and accepted in the marketplace. Efforts by BA partners in the region have demonstrated effectiveness of improved duct sealing with testing; paths to bringing ducts within conditioned space and high R-value walls with insulated sheathing.

Additional work supported by BA has developed training and demonstrations to transfer high R-value wall technology into the marketplace. Hands-on training launched at Affordable Comfort Northwest has been taken around the state to help builders meet the more stringent code requirements.

Council. Chuck Murray, Washington State Department of Commerce Energy Policy Division. David Baylon, Ecotope. 2009

Regionally the use of insulating foam sheathing to minimize thermal bridging in walls and reach higher performance levels has become a common recommendation to builders attempting to meet stricter energy code requirements and the BA 50% marine benchmark. Because of seismic zone requirements some building jurisdictions have been reluctant to accept insulated sheathing. In order to simplify the use of insulated sheathing, WSU and BIRA supported the Oregon Office of Energy's efforts to obtain engineering test data to satisfy building code requirements. The Department of Wood Science and Engineering at Oregon State University was hired to conduct testing resulting in the report: *Testing of Ply-on-Foam Shear Walls under Cyclic (CUREE) Loading*, October 2009 (See Appendix B of the final report). This has been a successful example of leveraging BA partner efforts to remove a critical code obstacle to better energy performance.

Standards

BA team members from the Northwest continued to actively participate in the development of American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) standards and research. Mike Lubliner of the Washington State University Energy Program (WSUEP) leads these efforts.

ASHRAE Std 193 2010, *Method of Test For Determining the Air Leakage Rate of HVAC Equipment*, has established a method of test (MOT) for HVAC equipment rated below 3000 CFM including residential air handlers, packaged rooftop equipment, coil boxes, filter boxes, etc. Mike Lubliner is the SPC 193 Chair. Programs have been proposed to ASHRAE to further discuss the application of Std 193 2010. While the Standard's immediate use is residential, the applicability to commercial equipment will need to be addressed. This is an area that may warrant additional investigation. The Standard is being considered for adoption by the International Energy Conservation Code (IECC) and the California Energy Commission (CEC). Both Lubliner and Ian Walker, Vice Chair of the Std 193 committee, presented a paper at the American Council for an Energy-Efficient Economy (ACEEE) on Std 193. The Standard is now available for purchase on the American National Standards Institute website, eStandards Store at: www.webstore.ansi.org/RecordDetail.aspx?sku=ANSI%2FASHRAE+Standard+193-2010

Std 193 was adopted in three years, and represents challenges on behalf of the committee to balance the needs of manufacturers with the analytical needs of others performing research. Next steps will include manufacturers testing to the Standard now that it is available, in addition to determining who will be responsible for maintaining results of these tests.

Subtask 1.7 Experts Meetings

BIRA conducted three experts meetings during the contract period:

- Miscellaneous Electric Loads at ACEEE Summer Study for Energy Efficient Buildings in Asilomar, CA

- Solar PV/Thermal Experts' Meeting at the New Tradition Homes office in Vancouver, WA
- Alternative Wall System Experts Meeting at the SMUD facility in Sacramento, CA.

Subtask 1.7.a Miscellaneous Plug Loads (MELs) Expert Meeting

On Tuesday, Aug 19th, 2008, the BIRA team hosted a Miscellaneous Electrical Loads (MELs) Experts' Meeting at the ACEEE Summer Study for Energy Efficiency in Buildings in Asilomar, CA. Twenty-eight people attended, exclusive of the BIRA attendees and panel members.

The Building America Program aims to reach cost-effective Zero Energy Homes by 2020. As we progress toward this goal, we are facing several challenges. Two of these challenges are the influence of occupants on energy consumption and the rising consumption from "plug loads", such as consumer electronics. These challenges are typically not addressed by building scientists, architects and other such design professionals as they work to reduce the more traditional loads of water heating, lighting and space conditioning (heating and cooling).

The Building America Program is on a collision course with MELs, and the 2 kW PV systems installed on homes is not an appropriate mitigation measure for MELs. A 2 kW system that produces roughly 2,500-3,000 kWh a year matches typical yearly MELs use. Building America teams must coordinate future work with the industry, as well as with each other, to collaborate on tasks and to reduce the repetition of each other's work.

Objectives

The primary purpose of this meeting was to join experts of different industries affecting plug loads, and to have an open forum regarding systems, policies and strategies to mitigate MELs loads. The scope of the experts meeting included identifying:

- existing research and practice aimed at MELs reductions
- short (<5 yrs) and long (>10 yrs) term solutions
- opportunities and synergies between industries & technologies
- barriers, challenges and necessary research toward consumer friendly solutions

Summary

The expert's meeting was to focus on past and current research done all research done on MELs, as well as on systems used to control/mitigate MELs loads in homes. It was made clear that even though behavior is an important aspect to reducing MELs, it is not a part of the Building America scope. It was also expressed that while lighting, HVAC and large appliances were not to be included, plug load management and appliance communicating protocols might include controls of these features. Building America defines MELs as:

- Small appliances, i.e. electric razors, coffee makers and toasters
- Large “extra” appliances, i.e. freezers and 2nd/garage refrigerators
- Consumer electronics, i.e. TVs, stereos and home offices
- Hard wired features, i.e. security and alarm systems

Presentations and Discussions included the roles and impacts of the following on MELs:

- 1) Home automation systems
- 2) Consumer electronics
- 3) Consumer behavior

Conclusions and Next Steps

The expert’s meeting went very well and garnished a lot of support from all parties of the industry. Two key partnerships were fostered as a result of the meeting, Douglas Johnson from the Consumer Electronics Association, and Sarah Darby from the Environmental Change Institute – Oxford University Centre for the Environment. Working with Douglas will be instrumental in accessing the consumer electronics industry, and determining a solution from the conceptual stages to reducing MELs. Sarah Darby will provide invaluable information from case studies being performed throughout Europe, which has been progressive in its response to energy efficiency and conservation.

The expert’s meeting exposed many gaps in the MELs area, but it also exposed the numerous possible solutions to combating the problem. Electronics are the biggest problem to MELs, but systems like power strip and house automation controls, feedback devices, and education for behavior change can all be used to mitigate their MELs impact. Unfortunately not enough has been done in the area of MELs, so everyone is eager to begin coordinating research efforts to make an impact in this area. As the Building America Program progresses through its milestones, it will be increasingly important to find a way to mitigate MELs loads.

Next Steps

Expert’s Meeting Action Items

As the expert’s meeting drew to an end, next steps were developed to initiate collaboration and cohesion in research goals:

- Get the word out to builders: tell them how to make MELs areas as efficient as possible.
- Keep up with consumer electronic and controls trends and knowledge
- End load use research (more up to date than the TIAX report)
- Asses the different feedback and control mechanisms – Study “ergonomics”, what’s too much information vs what’s just right
- Develop a owner’s manual for homes

- Implement a ratings system to compare energy bills among community residence. Since monthly utility bills are not usually a conversation piece, this will help home owners compare their bills with the community average and encourage them to reduce their monthly consumption.
- Implement a standard with the appliances and consumer electronics industries to allow for greater customization of individual components. The result of this effort will be electronics with zero phantom loads.
- Increase dialog with Sarah Darby and her UK projects. Follow up with the project's results and coordinate future research efforts.

BIRA Next Steps

Many gaps were identified during the Expert's meeting, and it was very encouraging to see the industry come together to explore different solutions to the growing problem of MELs. BIRA will begin working on two areas that received a lot of discussion during the experts meeting: feedback systems and an energy efficient home "user manual".

Introducing easy to install and simple to use feedback systems into Building America homes has the potential to combat the MELs problem, as well as create more conscientious home owners. The "user manual" will educate home owners on how to efficiently run their homes in a comfortable manner. The two areas work very cohesively as the feedback system provides immediate results from the behavioral changes, and together they will help reach the Zero Energy Home milestone.

Subtask 1.7.b Solar PV/Thermal Expert Meeting

On Wednesday, Aug 19th, 2009, the BIRA team hosted a Solar PV/Thermal Experts' Meeting at the New Tradition Homes office in Vancouver, WA.

Objectives

The objective of this meeting was to focus on methods to improve net energy benefits, marketability, total costs, and production home building viability of the PV and solar thermal systems.

The expert's meeting was to focus on past and current research done on solar PV/thermal. The meeting goal was to identify gaps and high potential opportunities, identify systems integrations practices that will result in wider use of renewables at a lower cost.

Expert Panelist Introductions

The panelists led the discussion with an overview of current work projects in the field of Solar

PV/Thermal. The panelists included:

- Matt Fung, ConSol;
- Tim Merrigan, NREL;
- Mike Lubliner, WSU;
- Silas Mattock MRC,
- Carlos Colon, Florida Solar Energy Center,
- Ram Narayanamurthy, PVT Solar, and
- Robert Delmar, OOE

A full attendees list can be found in Appendix A of the final report.

Summary

ConSol/BIRA

Matt Fung began the discussion by summarizing current research projects of the BIRA team. The BIRA team is currently focused on solar PV/thermal projects in various climate zones.

NREL

Tim Merrigan weighed the pros and cons of solar water heating systems and collectors. The solar water heating systems can be classified into two categories, active and passive.

Both passive solar systems require no pumps or controls which make the systems simple to use. They are both reliable and have a good performance rating. The ICS system is also easy to install and is more efficient as it only delivers water upon use. The weight of the thermosiphon system could be a potential issue since the tank is located above the collector.

The direct forced circulation systems have good performance, are simple to install, and have PV-powered pumps. The advantage of choosing an indirect forced circulation system is due to the freeze protection. However, indirect systems require skill to install, otherwise performance will be reduced.

Washington State University

Mike Lubliner expressed concern with the importance of proper installation, maintenance, and service contract for solar PV/thermal systems. A few case studies were presented demonstrating the importance of proper installation and maintenance.

Florida Solar Energy Center

Carlos Colon, FSEC, discussed results from a one year study on 3 occupied near zero energy

homes. The three homes were all located in different parts of Florida.

FSEC had also been conducting a study on different water heating systems and their efficiencies.

PVT Solar

Ram Narayanamurthy, a representative from Photovoltaic-Thermal (PVT) Solar, discussed the importance for a complete solution for a Zero Energy Home. This included an integrated system combining both solar thermal and PV.

Site Visit-- David Cohan ZEH

BIRA's current prototype home (50%+ WHES) located in Portland, OR is a Zero Energy Home, roughly twenty minutes away from the Expert Meeting site. The speakers and participants visited home. The prototype home is currently still under construction, however, attendees were able to walk through and examine the energy efficient features being installed.

David Cohan, the builder, discussed some of the challenges, lessons learned, and cost associated with this project. Visit their website, <http://www.sipshousepdx.com/> for more information.

Conclusions

The experts meeting went very well and garnished a lot of support from all parties of the industry including manufacturers, subcontractors/installers, builders and other building related stakeholders. The experts meeting also exposed many gaps as well as possible solutions and steps needed to integrate solar thermal and PV into standard home construction.

Subtask 1.7.c Panelized Wall Systems Expert Meeting

On Friday, November 13th, 2009, the BIRA team hosted an Alternative Wall Systems Experts' Meeting at the Sacramento Municipal Utility District (SMUD) office in Sacramento, CA.

As the BA joule milestone goal increases each year and more alternative walls systems are being used in new residential construction, builders are exploring these systems to build with and to meet the desired energy savings level, in addition to saving time and money. Alternative wall systems beyond conventional stick frame constructions are also critical for cooling load reduction during the summer months and heat retention during the winter months.

Objectives

The overall objective of this meeting is to introduce and bring in wall industries to provide

product information based on case studies and lessons learned, while not limited to energy savings benefits, building and health code issues, learning curve of subcontractors, drawbacks, cost-effectiveness and marketability of the systems.

Expert Panelist Introductions

The panelists led the discussion with an overview of current work projects in the field of alternative wall systems. The panelists included:

- Joe Lstiburek, BSC;
- William Bozung, RAY-CORE;
- Bryan Osborn, PBSSIPS;
- Steve Ruminski, Fintech Precast, INC;
- Dick Crawford and Gary Shimotsu, T-Clear Corporation, and
- John Krzic, Amvic Building System

Summary

Building Science Consortium

Joe Lstiburek discussed several case studies BSC has worked on in the past in terms of high R alternative wall systems. He discussed the need for moisture controls in some climate zones when using foam sheathing, as well as other alternative wall products. Best practices guide and apparatus for better moisture control can be found at www.buildingscience.com

RAY-CORE

William Bozung discussed the varying R-values of different exterior walls. Fiberglass batts, cellulose, blown-in fiberglass, expanded polystyrene panel, icynene spray foam, and polyurethane foam panels were compared. By comparing the R-value of a typical fiberglass batt wall and a polyurethane foam panel, it is clear that the R-value's are approximately 58% higher.

Premier Building Systems, INC

Bryan Osborn discussed some characteristics of the Structural Insulated Panels (SIP) which give an advantage above conventional framing. The SIPs system:

- Has superior insulation (6"=R-24, 10"=R-38)
- Is Pre-manufactured and delivered to site
- Reduces labor by 40-50%
- Is stronger than conventional framing
- Reduces builder callbacks with precision CAD Drawings of floor plans

- Eliminates waste by recycling unused materials
- Light weight (4lbs/sq. ft.)
- Installation is easy with typical carpentry tools

SIPs can be used for both wall and roof applications. With accurate installation a SIPs house will have a tighter building envelope.

Fintech Precast, INC

Steve Ruminski began with a brief history of Thermomass. The Thermomass system was developed to rely on continuous fiber, thermally non-conductive, structural, composite connectors and Dow brand Styrofoam insulation products. The precast concrete sandwich walls are an integral insulation system used to create energy efficient and moisture resistance structures for new construction. Concrete is essential to the Thermomass system as the “Thermal Mass Effect” is utilized. The concrete is used to store energy and dampen the interior temperature swings caused by the temperature changes outside.

T-Clear Corporation

Gary Shimotsu and Dick Crawford presented the ProTEC Concrete Structural Insulated Panels (CSIP) wall panel system to the group.

Amvic Building System

John Krzic discussed the basics of using Insulated Concrete Forms (ICF). Two expanded polystyrene (EPS) panels are connected either with steel or plastic ties and steel reinforcement holders. Concrete is then used to fill the center.

The three types of ICFs are: flat wall, waffle grid, and screen grid systems. John focused the presentation on flat walls, since they make the strongest structure.

Conclusions

The experts meeting brought together experts of their respective wall systems to discuss the challenges and solutions that are holding back the industry. The biggest issue/barrier in incorporating these systems into residential homes is the cost. In approaching builders, BIRA suggested in developing a cost analysis document with trade-offs. This approach may make these products more appealing due to other positive trade-offs.

Subtask 1.8 Training

The BIRA team members were trained in TRNSYS, EnergyPlus, BEopt, Micropas and Energy Gauge. BIRA interacted directly with TESS (TRNSYS) and NREL (EnergyPlus and BEopt) to discuss

simulation models and methodologies. Systems, prototypes, and communities in all three Stage Gates are modeled using these software.

Task 2A: Stage Gate 1A – Integrated Solutions for Specific Climate Regions and Performance Level

Climate Overview

The BIRA goals for this budget period were focused primarily on the Marine, Hot/Mixed Dry and Cold climate zones. The following descriptions provide an overview of each of the climate zones and the geographical areas BIRA was focused on.

Marine Climate

The Marine Climate Zone is a thin strip of land stretching down the West Coast from the Canadian border to Santa Barbara, California. The three largest metropolitan areas in the region are Seattle, Washington; Portland, Oregon; and San Francisco, California. Although temperatures are reasonably mild, the climate zone is dominated by heating degree days. Both the number of heating degree days and the amount of precipitation increase moving north along the coast. This creates two sub-climates within the Marine Climate Zone, the Northern Marine Climate Zone and the Southern Marine Climate Zone.

The Northern Marine Climate Zone is distinct from the Southern Marine Climate Zone not only due to increased heating degree days and precipitation, but also due to differing construction practices. Northern Marine builders typically build with 2x6 walls on top of crawlspaces while Southern Marine builders typically build with 2x4 walls on a slab.



Figure 2. Map of Targeted Marine Climate Regions

Hot/Mixed Dry Climate

The Hot/Mixed Dry Climate consists of two previously-separate Climate Zones: Hot/Dry and Mixed/Dry. Hot/Dry is defined as a region that receives less than 20 in. (50 cm) of annual precipitation and where the monthly average outdoor temperature remains above 45°F (7°C) throughout the year; Mixed/Dry is defined as a region that receives less than 20 in. (50 cm) of annual precipitation, has approximately 5,400 heating degree days (50°F basis) or less, and where the average monthly outdoor temperature drops below 45°F (7°C) during the winter months. This accounts for the large heating loads seen in areas such as Sacramento and Redding, California that see relatively cold winter months.

The Hot/Dry Climate Zone spans a large range of actual climate conditions, so this analysis targeted four cities, biased towards regions where eligible communities will more likely occur, to get a more representative understanding of the zone: Redding, CA; Sacramento, CA; Bakersfield, CA and Tucson, AZ. While all four of these cities are within the same Building America climate zone, each experiences a dramatically different winter season.

Partnerships were developed in each of the cities, including Seastar in Redding, Treasure and Premier Homes in Sacramento, K Street LLC in the Bakersfield area, Newland Communities in Phoenix, DMB in Albuquerque and Artistic Homes in Albuquerque. These builders worked with BIRA to develop communities at the 40% WHES level (some already achieving the 50% WHES level) and are committed to finding cost effective methods to further improve their building techniques and achieving greater levels of energy efficiency.

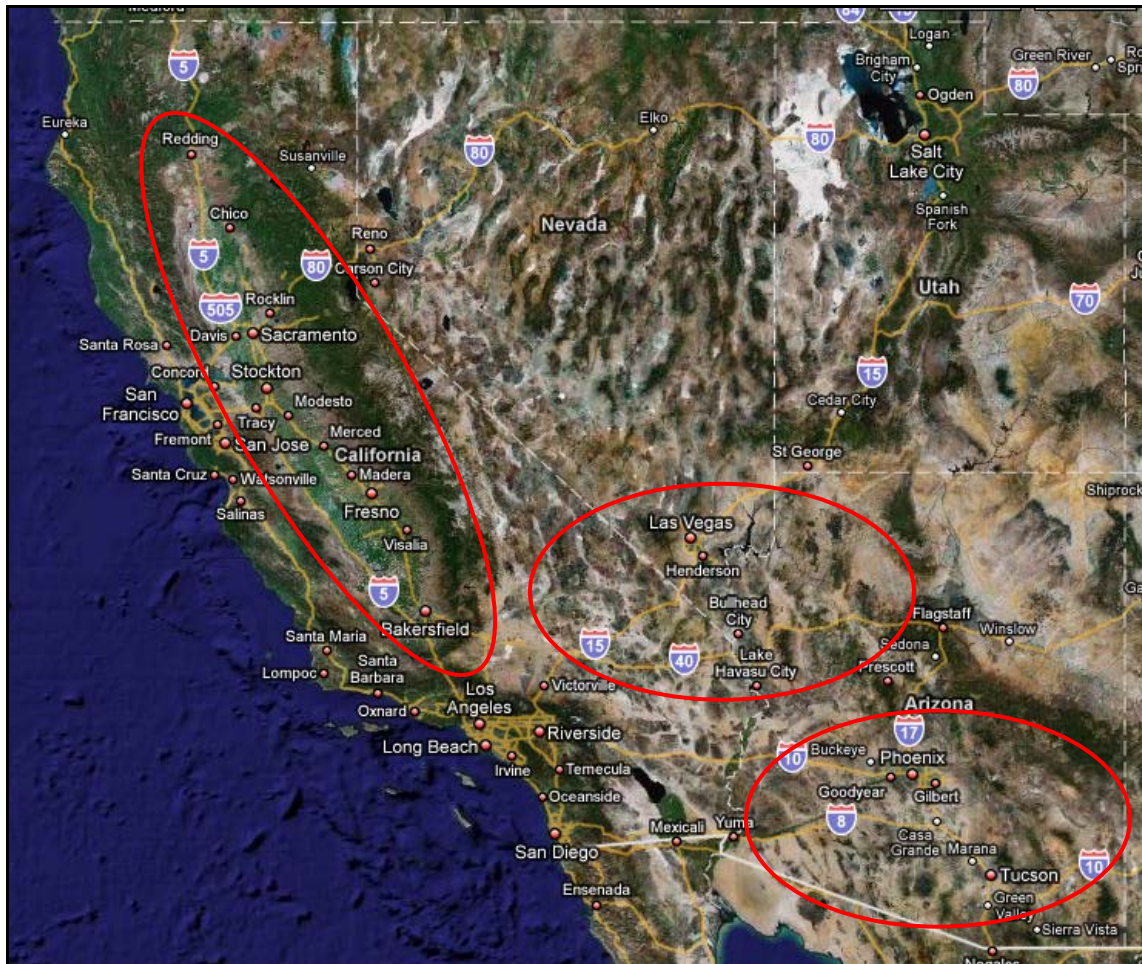


Figure 3. Map of Targeted Hot/Dry Climate Regions

Cold Climate

The Cold Climate is defined as a region with approximately 5,400 heating degree days (65°F basis) or more and fewer than approximately 9,000 heating degree days (65°F basis). This upper limit determines the difference between the Cold and Very Cold Climates. It is therefore expected that heating would account for a significant portion of the overall house load.

BIRA work focused on the high desert regions of the Cold Climate, shown in the figure below. This decision was made as a result of BIRA's involvement in the Kennecott Land Development located near Salt Lake City, Utah. The partnership with Kennecott Land will provide valuable future research opportunities that will be used to determine the effectiveness of the strategies developed for similar regions. In addition, this region also experiences hot/dry conditions during the summer and systems appropriate for use in the Hot Climate zones can also be tested, providing useful year-round data. For this reason, the cooling load is among the loads that were considered for improvement in this effort.

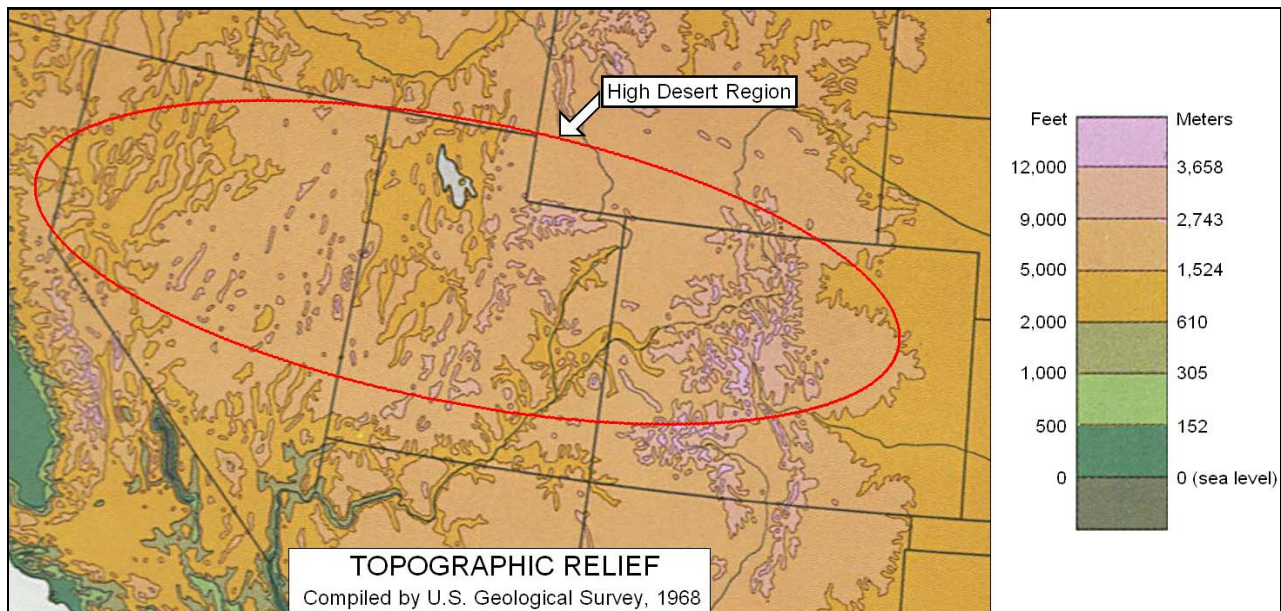


Figure 4. BIRA Cold Climate/High Desert Regions

Since the scope of analysis was narrowed to such specific locations, an accurate analysis was able to be performed on typical building practices for this region. Through discussions with the BIRA builder partners involved in the Kennecott project, it was determined that a typical house at Kennecott Land currently performs at approximately 34% energy savings relative to the BA benchmark. This was good news in that it illustrated a strong local interest in building efficient houses. However, it also provided a more challenging opportunity for cost-effective energy savings since increasing the existing energy savings level from 35% (ENERGY STAR® level) to 40% will generate a small utility savings basis to offset the cost of energy improvements.

Subtask 2A.1 Stage Gate 1A Evaluation Plan & Initial Optimization and Analysis of Technology Pathways and Performance Maps in CA, OR, WA and UT

BIRA developed plans and schedules for the analysis of technology pathways for the following climate zones:

- 50% Marine
- 50% Hot/Mixed Dry
- 40% Cold
- 50% Cold
- 60% Marine
- 60% Hot/Mixed-Dry

Key Participants

The following table summarizes the key participants in these evaluations, by climate zone.

	50% Marine	40% Cold	50% Hot/Mixed Dry
Technical Lead	Adam Neugebauer, ConSol 7407 Tam O'Shanter Drive, Suite 200 Stockton, CA 95210-3370 209.473.5000 ANeugebauer@ConSol.ws	Adam Neugebauer, ConSol 7407 Tam O'Shanter Drive, Suite 200 Stockton, CA 95210-3370 209.473.5000 ANeugebauer@ConSol.ws	Adam Neugebauer, ConSol 7407 Tam O'Shanter Drive, Suite 200 Stockton, CA 95210-3370 209.473.5000 ANeugebauer@ConSol.ws
Builder Partners	Including, but not limited to, the following: Clarum Homes, Rancho Mission Viejo, Summerhill Homes, Tom Walsh Construction, Ruhoff Home Builders, Quadrant Homes and New Tradition Homes.	Gold Medallion Homes 6150 South Redwood Road Taylorsville, UT 84123 801.569.0113 info@goldmedallionhomes.com Holmes Homes Liberty Liberty Homes 9075 South 1300 East Sandy, UT 84094 801.561.2525 Rainey Homes 520 North 900 West Kaysville, Utah 84037 801.927.3000 info@raineyhomes.com IDEA Developments	Including, but not limited to, the following: – Alvis Project (Fresno, CA), – Centex Homes (Pleasanton, CA), – Clarum Homes (Palo Alto, CA), – Forest City (Oahu, HI), – Artistic Homes (Albuquerque, NM), – Homes by Towne (Sacramento, CA), – City of Henderson (Henderson, NV) – Idea Development (Reno, NV), – K Street East (Lancaster, CA) and – Newland Communities (Phoenix, AZ)
Industry Partners	Including, but not limited to: – NREL, – LBNL and – Manufacturers: ▪ PVT Solar, ▪ Icynene, ▪ LP, ▪ Rinnai, ▪ Owens Corning, ▪ Freus	Bosch Water Heating 340 Mad River Park Waitsfield, Vermont 05673 Ecopanel of Utah 6150 South Redwood Road Taylorsville, UT 84123 Speakman Company (OASys) Moe Salem Mechanical Engineer PVT Solar 2550 9th Street, Suite 204B	Including, but not limited to: – NREL, – LBNL and – Manufacturers: ▪ PVT Solar, ▪ Icynene, ▪ LP, ▪ Rinnai, ▪ SIPA, ▪ Owens Corning,

	50% Marine	40% Cold	50% Hot/Mixed Dry
		Berkeley, CA 94710	▪ Freus

Table 29: Key Technology Pathway Evaluation Participants Budget Period 1 (2008)

	50% Marine	50% Cold	50% Hot/Mixed Dry
Technical Lead	Matt Fung, ConSol 7407 Tam O'Shanter Drive, Suite 200 Stockton, CA 95210-3370 209.473.5000 MFung@ConSol.ws	Victoria Doyle, ConSol 7407 Tam O'Shanter Drive, Suite 200 Stockton, CA 95210-3370 209.473.5000 VDoyle@ConSol.ws	Jackson Thach, ConSol 7407 Tam O'Shanter Drive, Suite 200 Stockton, CA 95210-3370 209.473.5000 JThach@ConSol.ws
Builder Partners	Including, but not limited to, the following: – Clarum Homes, – Rancho Mission Viejo, – Summerhill Homes, – Tom Walsh Construction, – Ruhoff Home Builders, – Quadrant Homes and – New Tradition Homes.	Gold Medallion Homes 6150 South Redwood Road Taylorsville, UT 84123 801.569.0113 info@goldmedallionhomes.com – Holmes Homes – Liberty Homes 9075 South 1300 East Sandy, UT 84094 801.561.2525 – Rainey Homes 520 North 900 West Kaysville, Utah 84037 801.927.3000 info@raineyhomes.com – IDEA Developments	Including, but not limited to, the following: – Alvis Project (Fresno, CA), – Centex Homes (Pleasanton, CA), – Clarum Homes (Palo Alto, CA), – Forest City (Oahu, HI), – Artistic Homes (Albuquerque, NM), – Homes by Towne (Sacramento, CA), – City of Henderson (Henderson, NV) – Idea Development (Reno, NV), – K Street East (Lancaster, CA) and – Newland Communities (Phoenix, AZ)
Industry Partners	Including, but not limited to: – NREL,	Bosch Water Heating 340 Mad River Park Waitsfield, Vermont 05673	Including, but not limited to: – NREL,

	50% Marine	50% Cold	50% Hot/Mixed Dry
	– LBNL and – Manufacturers: ▪ PVT Solar, ▪ Icynene, ▪ LP, ▪ Rinnai, ▪ Owens Corning, ▪ Freus	Ecopanel of Utah 6150 South Redwood Road Taylorsville, UT 84123 Speakman Company (OASys) Moe Salem Mechanical Engineer PVT Solar 2550 9th Street, Suite 204B Berkeley, CA 94710	– LBNL and – Manufacturers: ▪ PVT Solar, ▪ Icynene, ▪ LP, ▪ Rinnai, ▪ SIPA, ▪ Owens Corning, ▪ Freus

Table 30: Key Technology Pathway Evaluation Participants Budget Period 2 (2009)

	60% Marine	60% Hot/Mixed-Dry
Technical Lead	Matt Fung, ConSol 7407 Tam O'Shanter Drive, Suite 200 Stockton, CA 95210-3370 209.473.5000 MFung@ConSol.ws	Jackson Thach, ConSol 7407 Tam O'Shanter Drive, Suite 200 Stockton, CA 95210-3370 209.473.5000 JThach@ConSol.ws
Builder Partners	Including, but not limited to, the following: – Tom Walsh Construction – New Tradition Homes – Artisans Group.	Including, but not limited to, the following: – Artistic Homes – Visionary Home Builders
Industry Partners	Including, but not limited to: – NREL, – LBNL – Manufacturers: ▪ PVT Solar, ▪ Icynene, ▪ LP ▪ Rinnai, ▪ Owens Corning, ▪ Freus	Including, but not limited to: – NREL, – LBNL – Manufacturers: ▪ PVT Solar, ▪ Icynene, ▪ LP ▪ Rinnai, ▪ Owens Corning, ▪ Freus

	60% Marine	60% Hot/Mixed-Dry
	SIPA	SIPA

Table 31: Key Technology Pathway Evaluation Participants Budget Period 3 (2010)

Areas of Investigation

For each of the targeted climate zones, the Gate 1A analysis focused on five major areas of investigation, listed below, and how they affect the technology pathways being developed:

Area of Investigation	Research Question
Candidate Efficiency Measures	Which efficiency measures have proven their effectiveness in the target climate? What other efficiency measures (emerging or untested in the target climate) should also be considered?
Technical Approach	Review previous climate research projects. Review relevant case studies. Receive additional input from NREL and builder partners. Compile list of candidate efficiency measures. Review previous research projects from other climates. Review relevant case studies. Receive additional input from NREL, builder partners and manufacturers. This includes possible negative on particular measures. Concerns of construction roadblocks, availability issues, cost overruns, poor performance, etc. should be taken into account. Add to list of candidate efficiency measures. Note any possible roadblocks with particular measures.
Cost (including incentives) and Availability (systems and trained installers)	What are the typical installation costs in the target climate associated with each candidate measure? Are there significant variations in any costs across the climate zone? Are there any availability issues associated with this particular measures? What are the typical utility costs in the target climate? Are there significant variations in any costs across the climate zone?
Technical Approach	Review previous BA cost data. Review relevant BA reports and case studies. Receive additional input from NREL, builder partners and manufacturers. Compile list of measure costs. Note any significant cost variations. Note any significant availability issues. Review previous BA utility cost data. Receive additional input from NREL, builder partners and utilities. Compile list of typical utility costs. Note any significant cost

Area of Investigation	Research Question
	variations.
Local, State and Federal Regulations	Are there any local, state and/or federal regulations which could affect the implementation of specific candidate measures?
Technical Approach	Review relevant BA reports and case studies. Receive input from NREL, builder partners, government agencies and energy offices. Add notes to measure list of any significant regulations.
Identification of Gaps	What are the gaps that should be addressed in order to achieve the target savings level for the target climate? Which of the identified gaps are the most promising targets for later research?
Technical Approach	Review relevant BA reports and case studies. Perform BEopt optimization runs with candidate efficiency measure list. Using BEopt, determine how close to the WHES target can readily be achieved. Using BEopt, identify gaps in the technology pathways (such as loads or costs that could be reduced). Note gaps that could be targeted to achieve the 50% target. Review identified gaps. Determine if any gaps could be addressed using emerging or un-proven measures. Receive input from NREL, builder partners and manufacturers. Identify most promising gaps for Gate 1B research.
Overall Feasibility	Which of the candidate technology pathways are the most feasible and implementable in terms of cost-effectively meeting the WHES target for the climate?
Technical Approach	Review candidate technology pathways and noted cost, availability, utility and regulation issues and identified gaps. Receive input from NREL and builder partners. Select most feasible and implementable technology pathways for Gate 1B and Gate 2 research. Note any concerns, assumptions or questions that must be addressed.

Table 32: Technology Pathways -- Areas of Investigation

Impact of Current Energy Standards (2009 IECC and 2008 California Title-24)

BIRA examined how the latest versions of two major energy standards, California's 2008 Energy Code, Part 6 (Title-24) and the 2009 International Energy Conservation Code (IECC), compare to the Building America (BA) Benchmark.

In Budget Period One, the BIRA team completed Stage Gate 1A research on 50% WHES in the Marine and Hot/Mixed Dry climate zone. Since the 2009 BA Joule Milestone for these climate zone is 60%, BIRA's 2010 Stage Gate 1A examined how the latest versions of two major energy standards – California's 2008 Energy Code, Part 6 (Title-24)⁸ and the 2009 International Energy Conservation Code (IECC)⁹ – compare to the Building America (BA) benchmark at the 60% WHES level. This will be an indicator of how the code-compliant portion of the new construction industry is progressing towards the zero net-energy goals. Note: California Public Utility Commission's goal is consistent with DOE Building America goal – to build net zero energy homes by 2020. In the Cold Climate, BIRA completed these analyses of technology pathways at the 50% WHES level with input from builder partners.

Buildings in California are able to comply with the 2008 Title-24 by either a prescriptive or performance approach. The vast majority of builders use the latter approach, which uses CEC-approved software to determine whether the proposed features of a home will deliver an energy performance equal to or better than a similar home using the standard prescriptive feature set. For Stage Gate 1A analysis, compliance features were developed using CEC-approved software (MICROPAS) and standard building practices for the industry in select climate zones. Once these features were determined for each climate zone, they were entered into EnergyGauge® software to determine how their performance compares to the BA benchmark.

For the 2009 IECC, compliance software was not available in time for this analysis; therefore prescriptive features were used. The 2009 IECC compliance features were derived from the requirements of the residential standards as defined for the relevant climate zones. Once the feature sets were determined, the analysis proceeded similarly to that for Title-24.

Baseline Home Overview

A baseline home was first established for a uniform analysis across all regions in the Marine climate zone. The design was based on typical industry practices in the region. Standard design for a medium sized home includes 2,123 square feet, 18% glazing, two floors, three bedrooms, and two bathrooms. The baseline home was used in all software analyses.

⁸ <http://www.energy.ca.gov/title24/>

⁹ <http://www.energycodes.gov/>

Subtask 2A.2 Simulation and Builder Preferences

BIRA completed the analysis of technology pathways in the following climate regions. Builders provided feedback on the pathways and how they would integrate into their building practices.

- 50% Marine
- 50% Hot/Mixed Dry
- 40% Cold
- 50% Cold
- 60% Marine
- 60% Hot/Mixed Dry

The BIRA team performed Stage Gate 1A research in Budget Period One examining 50% WHES in the Marine and Hot/Mixed Dry climate zone. In Budget Period Two, BIRA completed analyses for the 50% Marine, 50% Hot/Mixed Dry, and 50% Cold climate zones. In Budget Period Three, BIRA completed analyses for the 60% Marine and 60% Hot/Mixed-Dry climate zones. Since the 2010 BA Joule Milestone for these climate zones is 60%, BIRA's 2010 Stage Gate 1A work in the Marine and Hot/Mixed-Dry Climates examined how compliance with 2008 Title-24 and 2009 IECC compares to the BA benchmark and 60% WHES.

These analyses examine the feasibility of building at the Building America 50% Marine, 50% Hot/Mixed Dry, 40% Cold, 50% cold, 60% Marine and 60% Hot/Mixed Dry whole house energy savings (WHES) levels relative to Building America's "Must Meet" and "Should Meet" Gate 1A criteria. These studies were relative to the residential whole building context and technology package. Simulation software and currently available performance data are used to estimate each system's contribution to BA energy performance and neutral cost targets with input from BIRA industry and builder partners.

	50%, 60% Marine	40%, 50% Cold	50%, 60% Hot/Mixed Dry
Major Loads	space heating, water heating, and lighting	heating water heating and lighting	space heating, space cooling, and lighting
Strategies¹⁰	smarter building design, better building practices, and higher efficiency equipment.	smart design, improved construction practices, and high efficiency, "off the shelf" equipment. Cost neutrality is an issue	smarter building design, better building practices and higher efficiency equipment.

¹⁰ In all climates, miscellaneous electric loads (MELs) are technically the third largest energy consumer, However, a viable solution for reducing MELs has not been presented and therefore will not be included in this report.

	50%, 60% Marine	40%, 50% Cold	50%, 60% Hot/Mixed Dry
		due to the existing high standard of construction in some regions and the fairly steep up-front cost of improvements.	
Gate 1A Status	- Analysis Complete 50% WHES Strategy Complete - Strategy Evaluation Complete	- Analysis Complete 40% WHES Strategy Identified - Evaluation In-Process	- Analysis Complete - WHES Strategy Complete - Strategy Evaluation Complete

Table 33: Simulation and Builder Preferences

Major Loads and Climate Strategies

50% Marine – Budget Period 1

“Must Meet” Gate Criteria -- Source Energy Savings

Using BEopt 0.8.7, an energy analysis was performed using standard building features for California, Oregon and Washington. The features simulated were based on each of the state’s energy codes, to determine their code level efficiencies relative to the Building America (BA) benchmark. Each of the homes were modeled as a 2000 sq. ft. single family detached residence, with 2 floors, 2 bedrooms, 2.5 bathrooms, 9 ft. ceilings, gable 6:12 roofs, neighbors at 15ft, 1.50 aspect ratio, no basements, and 18% glazing areas distributed 20%, 40%, 20% and 20% for front, back, left and right respectively.

Results from these simulations indicated that current codes in the Marine climate zone in California (San Francisco/Oakland) produce homes that perform at a 16.3% savings level over the BA benchmark, Oregon 21.8% (Portland??), and Washington 25.3% (Seattle??). These results are presented in Figure 5 - Figure 7.

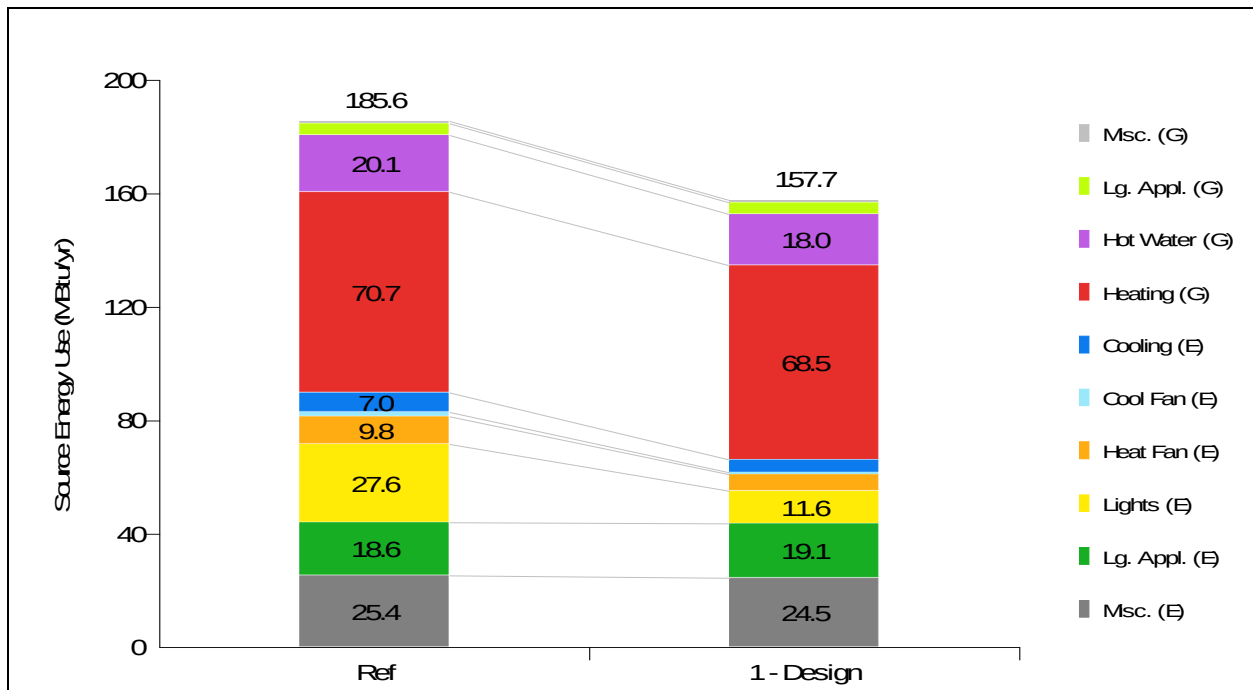


Figure 5. California Code (CZ3) vs. Building America Benchmark

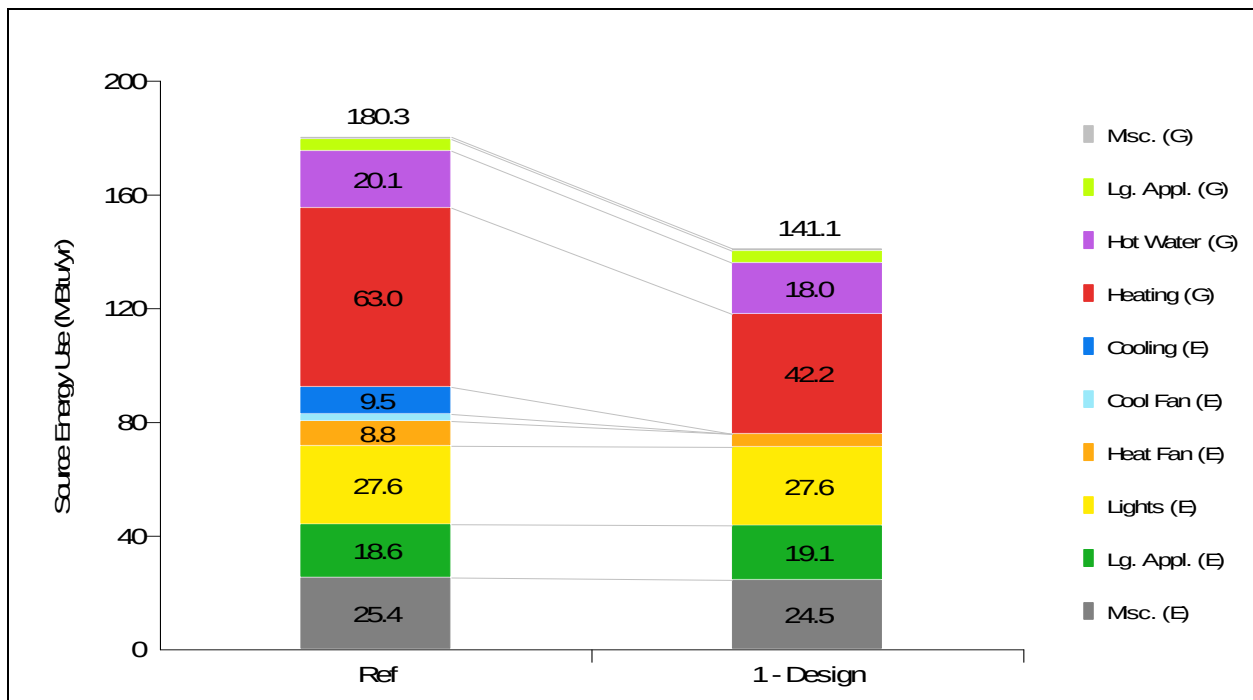


Figure 6. Oregon Code vs. Building America Benchmark

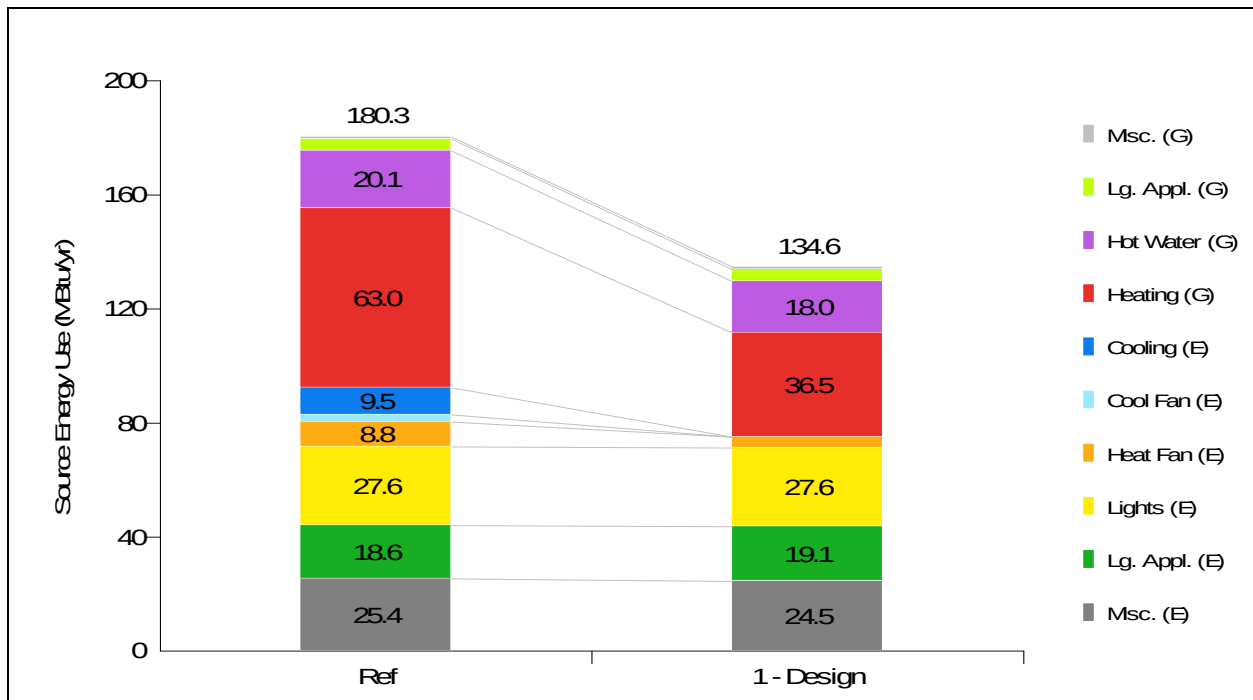


Figure 7. Washington Code vs. Building America Benchmark

Feature	California 2005 Title-24 (CZ3)	Oregon	Washington
Wall insulation	R13	R21 2x6 16" o.c.	R21 2x6 16" o.c.
Ceiling Insulation	R30	R40 (R30 for vaulted)	R40
Below floor insulation	R19	R25	R30
Windows U-Value	.67	.40	.35
Windows SHGC	.40	.29	.29
Roofing material	Asphalt Shingles Medium	Asphalt Shingles Medium	Asphalt Shingles Medium
Radiant Barrier	None	None	None
Infiltration (SLA)	0.00043	0.00035	0.00035
Slab Insulation	None	2ft R10 Perimeter, R5 Gap	2ft R10 Perimeter, R5 Gap
Crawl Space	None	Vented R25 Ceiling	Vented R30 Ceiling
Lighting	80% Hardwire Fluorescent	0% CFL	0% CFL

Feature	California 2005 Title-24 (CZ3)	Oregon	Washington
Cooling	SEER 13	SEER 13	SEER 13
Heating	0.80 AFUE	0.80 AFUE	0.80 AFUE
Ducts	R6	R4.2	R4.2
DHW	NG 0.59 EF	NG 0.59 EF	NG 0.59 EF
% Above Benchmark	16.3%	21.8%	25.3%

Table 34: Code Energy Features

Oregon and Washington have a slightly more stringent energy code, providing 25-35% more savings in the Marine climate zone, however their baseline energy code is still only 25% above the Building America benchmark, at best.

50% Marine Strategy

The following are suggested features to reach the 50% Marine milestone:

	50% Features
Wall insulation	R21 Batts, 2x6 24" o.c. + 1" Foam
Ceiling Insulation	R50
Garage insulation	R30
Windows U-Value	0.325
Windows SHGC	0.511
Roofing material	Asphalt Shingles Medium
Radiant Barrier	None
Infiltration (SLA)	0.00015
Slab	2ft R10 Perimeter, R5 Gap
Appliances	Energy Star
Lighting	80% Fluorescent Hardwired
Air Conditioning	None
Furnace	AFUE 92.5%
Water Heating	NG 0.77 EF Tankless
Ducts	In conditioned space

Table 35: 50% Marine Strategy Features

Leading energy efficiency feature candidates for reducing the loads include improved wall systems. Many energy efficient builders have already upgraded to using advance framing techniques such as 2x6, 24" o.c. wall systems. Increasing their insulation to R-21 batts with 1"

exterior foam will maximize the wall systems' insulation. By providing a better thermal seal, these advanced framing systems greatly reduce conductive heat loss and will serve to decrease heating loads. This also includes an increase in insulation between the garage and 2nd story to R-30 and an increased ceiling insulation level to R-50. The most dramatic improvement will be coming from California, which has the lowest insulation requirements.

Structurally insulated panels (SIPs) are another advanced wall solution, but many builders are hesitant to use them. Their main concern is not its slightly higher unit cost, but rather the unfamiliarity subcontractors have with the features. As such, all of the builders we have talked to are interested in its potential as a quicker and cheaper framing option, however most are not yet willing to take the risk.

Where the foundations are slabs, a substantial amount of heat is lost through an un-insulated slab, resulting in cold, uncomfortable floors. Even if the foundation wall is insulated vertically under the slab, significant heat is still lost from the slab edge that is closest to the cold outside air. A two-foot, R10 perimeter insulation, with R5 gap insulation on the slab can be applied to the foundation wall to reduce losses.

Space and water heating loads can be greatly reduced through improvements to the furnace efficiency and ducting, and to the water heater. Improving the furnace efficiency will naturally reduce heating loads through a more efficient heat distribution. A 92.5% AFUE furnace would improve savings by 2-4% over the 80% AFUE furnaces required by each of the states' codes. Moving the HVAC system into conditioned space is another option that improves the HVAC performance and provides more savings than burying the ducts in attic insulation. For some builders, moving ducts inside can be cheaper than burying them, and for others it is more costly. We have found that to cost effectively bring the HVAC system inside it is necessary to coordinate the architect, subcontractors and superintendents. BIRA's WSU partners have successfully engineered mechanical designs for dropping the ducting into the living space, a significant advantage over sealing the attic and turning its entire volume into a conditioned space. This also removes the need to spray foam the roof trusses to properly insulate it.

Tankless water heating systems have greatly improved the efficiency of water heating, providing immediate hot water without having to constantly heat a large storage tank. Tankless water heaters can provide efficiencies around 80-90%, reducing gas usage. There are also some new tank-type water heaters with >80% efficiency that are cost-competitive with tankless.

Improved building tightness will prevent heat transfer between the conditioned space and the outdoor environment. This can be achieved through properly sealing the wall frame as well as the ducting and improving whole house tightness to at least 0.00015 SLA. In addition, using low U-factor windows with a high SHGC will insulate the glazing while still allowing passive solar to heat the home. The windows should have ratings equal to or lower than U-value of 0.32, and SHGC of 0.51 or higher.

Combined, these features can improve WHES by 34% above California’s 2005 Title-24 code, 30% above Oregon’s code, and 25% above Washington’s code, achieving 50-60% savings above the BA benchmark in the marine climate zone.

	Base	R-21 + 1" Foam	R50 ceiling R 30 garage	2ft R10, R5 Gap Slab Insulation	Ducts in Conditioned Space	0.15 SLA	92.5% AFUE	Gas 77% EF Tankless Water Heater	Windows	80% Fluorescent (removed slab insulation)	Energy Star Appliances
California	16.3	9.7	1.1	1.9	2	8.3	3.7	2.5	1.8	0	6.6
Oregon	21.8	4.1	3	0	3.5	4.7	2.6	2.5	6.2	2.6	1.9
Washington	25.3	4.2	2.6	0	3.1	4.5	2.1	2.5	4	2.8	1.8

Table 36: Incremental Energy Savings per Feature (in % Whole House savings)

“Must Meet” Gate Criteria -- Market Coverage

BIRA chose to focus its work in the “Northern” Marine Climate in the Northwest region, specifically Washington and Oregon due to builder interest there. The primary markets of interest were the Seattle and Portland areas. Partnerships have already been developed in each of the cities, including New Tradition homes and Tom Walsh & Co. in Oregon, and Schneider Family Homes and Quadrant Homes in Washington. These builders worked with BIRA to develop communities at the 40% savings level and are committed to finding cost effective methods to improve their building techniques and achieving higher levels of energy efficiency.

BIRA also had a well- developed working relationship with the Washington State University’s Extension Energy Program. WSU acted as the BIRA team’s lead for Northern Marine climate region and provides support for other climate regions, as well as providing BIRA with Technology Package Research Reports for Marine and Hot/Mixed Dry climates. WSU will continue to develop and support strategic partnerships with utilities, and state and local governments to provide support to builders and developers of BAP communities consistent with the financial and societal value of those communities.

BIRA did not have an active builder in the California Marine zone. The housing market slump produced a huge reduction in new production development, and resulted in even greater concern by the builders regarding first costs. Nonetheless, BIRA still actively looked for prototype and community opportunities in the California Marine zone.

“Must Meet” Gate Criteria -- Neutral Cost Target

Using the prescribed strategy developed by the BIRA team, 50% marine homes fulfilled the neutral cost target. BIRA worked with builders New Tradition Homes and Tom Walsh Construction to determine accurate costing data for the energy efficient features. The building was modeled as a 3,218 sq. ft., two-story, single family detached home.

	50% Features	Cost
Wall insulation	R21 Batts, 2x6 24" o.c. + 1" Foam	\$800
Ceiling Insulation	R50	\$220
Garage insulation	R30	
Windows	.325/.51	\$400
Improved Duct Sealing, Envelope Sealing, and Testing	0.00015 SLA	\$570
Ducting	In conditioned Space	\$675
Slab	2ft R10 Perimeter, R5 Gap	\$400 ¹¹
Appliances	Energy Star	\$240
Lighting	80% CFL	\$120
Furnace	92.5% AFUE	\$450
Water Heater	77% EF Tankless	\$550

Table 37: 50% Marine Strategy Costs

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	California Code Home	50% Marine Strategy	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	80.5	75.2	15.7	80.5%	79.1%	34.9%	38.3%
Space Cooling	8.4	1.9	0.0	100.0%	100.0%	4.6%	1.2%
DHW	20.1	18.0	10.6	47.2%	41.3%	5.1%	4.8%
Lighting	27.6	11.6	11.6	58.1%	0.0%	8.6%	0.0%
Appliances and MELs	49.0	48.6	45.5	7.1%	6.4%	1.9%	2.0%

¹¹ Oregon and Washington have \$0 incremental cost for these features. Slab insulation is already part of their code, and the advanced energy efficient windows have reached a mature market, and their price is comparable to code windows.

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	California Code Home	50% Marine Strategy	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%
Total Usage/ Savings	185.6	155.3	83.4	55.1%	46.3%	55.1%	46.3%

Table 38: 50% Marine Strategy Savings Summary - California

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Oregon Code Home	50% Marine Strategy	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	127.7	77.0	37.2	70.9%	51.7%	36.2%	21.6%
Space Cooling	17.9	4.9	0.0	100.0%	100.0%	7.1%	2.7%
DHW	20.8	18.7	11.2	45.9%	39.9%	3.8%	4.1%
Lighting	27.6	27.6	11.6	58.1%	58.1%	6.4%	8.7%
Appliances and MELs	56.1	55.8	52.7	6.1%	5.6%	1.4%	1.7%
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%
Total Usage/ Savings	250.1	184.1	112.7	54.9%	38.8%	54.9%	38.8%

Table 39: 50% Marine Strategy Savings Summary - Oregon

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Washington Code Home	50% Marine Strategy	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	138.4	75.7	41.7	69.9%	44.9%	38.0%	18.8%

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Washington Code Home	50% Marine Strategy	Percent of End Use		Percent of Total	
	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Cooling	11.0	2.3	0.0	100.0%	100.0%	4.3%	1.3%
DHW	21.2	19.1	11.7	45.0%	39.0%	3.8%	4.1%
Lighting	27.6	27.6	11.6	58.1%	58.1%	6.3%	8.9%
Appliances and MELs	56.1	55.7	52.6	6.1%	5.5%	1.4%	1.7%
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%
Total Usage/ Savings	254.3	180.4	117.6	53.8%	34.8%	53.8%	34.8%

Table 40: 50% Marine Strategy Savings Summary - Washington

This strategy worked fairly well across each of the targeted cities, with savings netting 55.1%, 54.9% and 53.8% in California, Oregon and Washington, respectively. Figure 8 summarizes estimated annual energy costs for each of the locations.

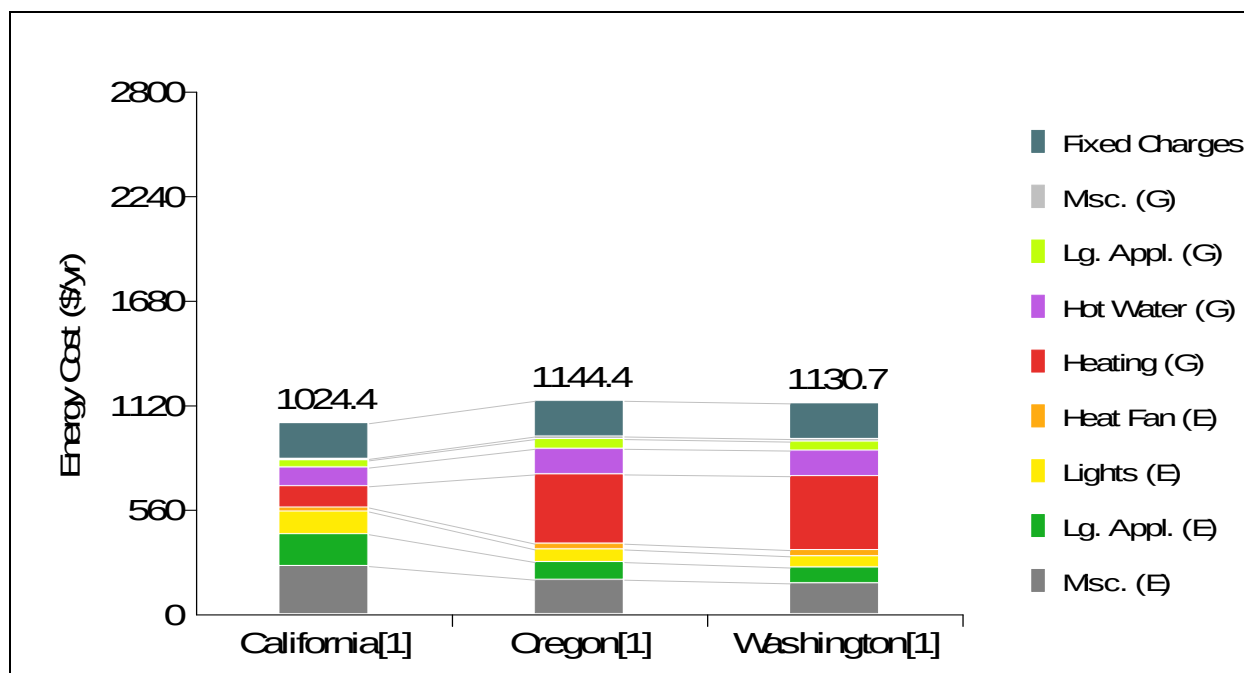


Figure 8. Estimated Annual Energy Costs for 50% Marine Strategy

When the cost of the features is mortgaged at 7% over 30 years, the incremental cost is amortized into the mortgage payments. Accounting for utility savings, each of the homes achieves a positive cash flow and provides significant annual savings to the consumer. Energy costs were calculated using the average state energy rate.

	Total cost of features	Amortized Cost	Net Annual Utilities Savings	Net annual cash flow to consumer
California	\$4,425.00	\$353.28	\$1,008.11	\$654.83
Oregon	\$3,625.00	\$289.41	\$1,388.83	\$1,099.43
Washington	\$3,625.00	\$289.41	\$1,337.09	\$1,047.69

Table 41: Net Annual Cash Flow Summary

“Should Meet” Gate Criteria - Marketability

BIRA worked with builder partners to determine the most cost effective and acceptable strategy to address the marine climate zone. All the features in the strategy are readily available, off-the-shelf components that do not require dramatic changes in current building practices. The practical benefit to buying an energy efficient house can be a key factor in the sales process.

“Should Meet” Gate Criteria - Builder Commitment

Builder commitment in this region is strong towards advancing energy efficient housing, despite the current market downturn. California was the hardest hit market area, while builders in Oregon and Washington continued to build, albeit at a significantly reduced pace. What was more important was that commitment in continued energy efficient development was equally strong despite a down-turned market.

“Should Meet” Gate Criteria - Gaps Analysis

Significant hurdles still remained to transforming the market into widely adopting advance housing concepts. For instance, moving ducts inside conditioned space involves the use of drop-downs and soffits. For New Tradition Homes, this method is three times more expensive than using bio-spray foam, including labor and materials, and is largely driven by scheduling with subcontractors. For example, using drop-downs requires the framer to return a second time. In one case, the framer actually framed the drop-downs when he first framed the house. This caused a problem when the HVAC installers arrived and had to work around the drop-down framing in order to install the ducts. This led to a very high cost for labor as well as a lower quality installation.

Bio-spray foam is much cheaper and involves placing the ducts in the attic and covering them with spray foam while keeping the furnace in conditioned space. Interestingly, even when New Traditions didn’t put the ducts inside for their Kent floor plan, they still use drop-downs and

soffits because they are architecturally pleasing and define the spaces and transitions between rooms.

In the future, New Tradition hoped to implement open-web trusses between the first and second floors to facilitate moving ducts inside. This design allows subcontractors the flexibility to run plumbing, electrical, and ductwork easily between floors, with little to no “trade damage” or “trade fighting.” Additional costs for this new truss design can be offset by cost savings in the HVAC system equipment and installation. These cost savings can be made possible through shorter, smaller duct runs and the purchase of smaller, less expensive furnaces due to reduced heating loads.

Another aspect Marine homes needed to improve further was tightening of the house envelope; caulking and/or foaming ceiling penetrations before installing attic insulation will prevent air leakage. This includes such ceiling penetrations as can lights. Figure 9 is an infrared image showing a can light in the kitchen. Note how leakage is evidenced by the darker colors near the light.

New Tradition was also strongly considering moving to 100% CFL lighting using screw-in CFLs for the remaining fixtures. Although not a long-term solution, this would certainly increase the energy savings at a small cost. New Traditions at the time estimated a cost of only \$24 per home, including a \$2 per bulb rebate from Clark Public Utilities.

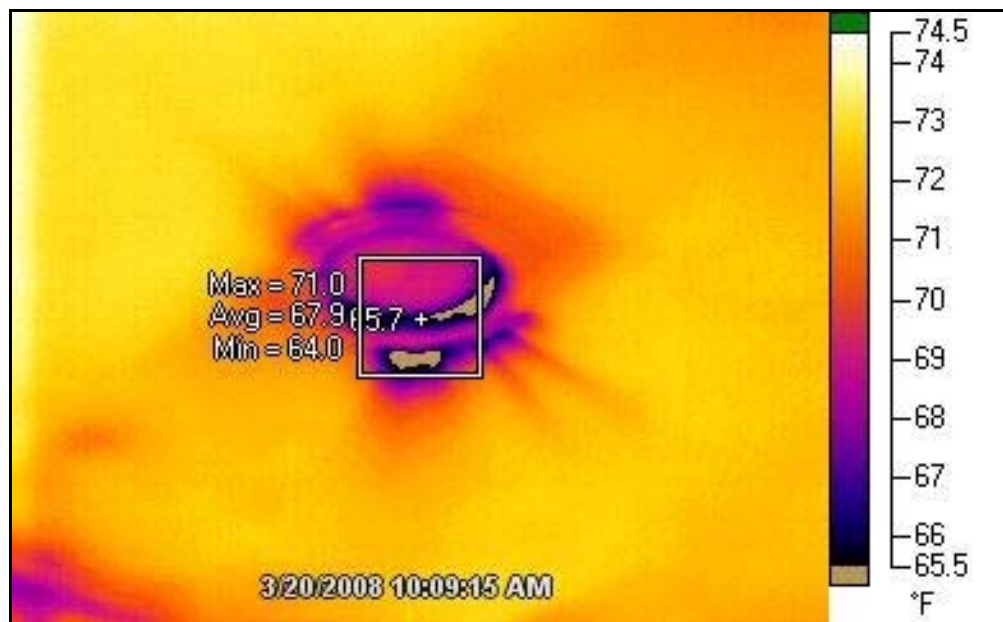


Figure 9. Infrared Picture of a Kitchen Can Light in a New Tradition Home

Slab insulation was an important solution in maintaining temperatures in the foundation, however it is not allowed in some jurisdictions that require the foundation to be visible for termite inspection. This possibly presents a problem in California.

Although many builders were uncomfortable with adding exterior foam sheathing, especially in the Northern Marine climate, several took the plunge. Two builders that BIRA worked with on 50% communities, Tom Walsh and Ruhoff Home Builders, added foam despite initial concerns. BIRA demonstrated proper installations of foam from past projects as well as introducing the builders to DOW and Hardie representatives. This, along with several on-site visits, convinced these builders to add foam. BIRA anticipated working with American Concrete Institute (ACI) and the Oregon DOE to educate builders about advanced wall systems using examples from Building America projects in the region.

50% Hot/Dry – Budget Period 1

“Must Meet” Gate Criteria -- Source Energy Savings

Using BEopt 0.8.7, an energy analysis was performed using standard building features for California. The features simulated were based on California’s Title-24 energy code. Results from these simulations indicated that current practices in California produce houses that perform at a 33% savings level over the BA benchmark (reference house). These simulation results are presented in Figure 10 below.

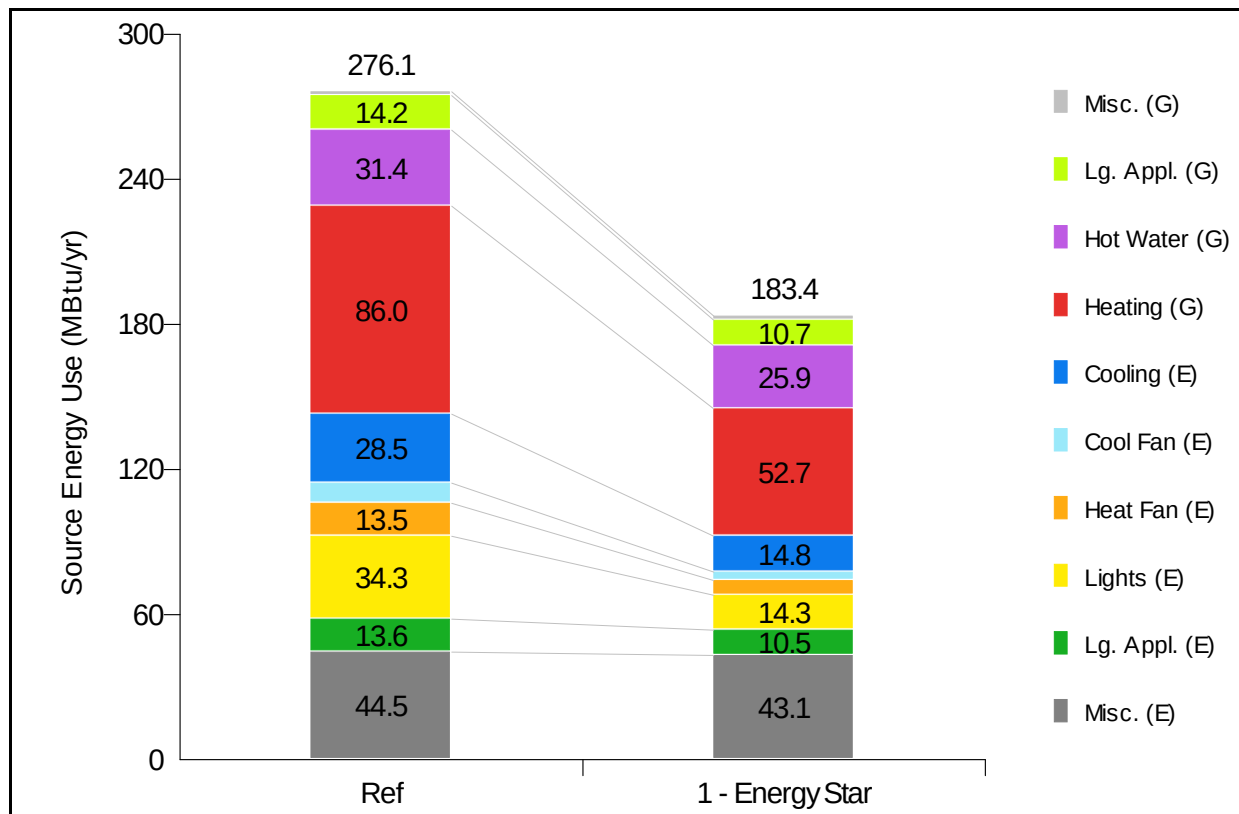


Figure 10. BA Benchmark vs. CA Title-24 (Hot/Dry Climate Zone)

Features	2005 Title-24	Example 50% Strategy
Insulation	R-13 Walls R-40 Ceiling R-20 Garage	R-21 Walls R-49 Ceiling R-30 Garage
Windows	U-Factor 0.38 SHGC 0.40	U-Factor 0.21 SHGC 0.27
Cooling	SEER 13	15 SEER
Heating	80% AFUE	94% AFUE
Ducts	R-4.2	Ducts in Conditioned Space
DHW	NG, 0.59 EF	Tankless, 0.82 EF
Infiltration	0.00048 SLA	0.00021 SLA
Lighting	80% Hardwire Fluorescent	100% Fluorescent

Table 42: Energy Efficiency Features Summaries – Hot/Dry

Leading candidates for reducing energy loads included improved wall systems: R-19 or R-21 in 2x6, 24" o.c. framing. By providing a better thermal seal, these advanced framing systems greatly reduced conductive heat loss/gain and helped decrease both heating and cooling loads. The advanced wall systems improves WHES by 5-6%. These improvements also included an increase in insulation over the garage (in two-stories) R-30.

Structurally insulated panels (SIPs) are another advanced wall solution, but many builders are hesitant to use them. Their main concern is not only the higher unit cost (though that can significantly impact their cost effectiveness), but rather the lack of familiarity subcontractors have with this wall system. As such, while all of the builders contacted during this analysis were interested in its potential as a quicker and cheaper framing option, none of them were yet willing to take the risk.

Cooling loads can be greatly reduced through improvements to the compressor efficiency and ducting. Improving the HVAC efficiency will naturally reduce cooling loads through a more energy efficient compressor unit. An HVAC with a 16 SEER rating would improve WHES by 3-4% while not suffering too much from diminishing returns. Moving all air ducts into conditioned space reduces efficiency losses due to duct leakage and improves WHES by 6-7%.

In order to target the domestic water heating (DWH) load, tankless water heating systems should be installed, typically provided efficiencies around 80-90%. Utilizing this technology increases WHES by 2-4%. Another option for this load is solar water heating, but for the purposes of this report only tankless water heaters were considered (due to the high cost and

low market penetration of solar water heating systems and the current limitations in BEopt modeling capabilities).

Combined, these features improved WHES by 16-21% above California's 2005 Title-24 code, achieving 50-60% savings above the BA benchmark.

"Must Meet" Gate Criteria -- Market Coverage

BIRA chose to focus its work in the Hot/Dry Climate in California's central valley and inland greater LA, Las Vegas, and parts of Arizona. The primary markets of interest were Redding, Sacramento, San Joaquin Valley and greater inland LA California, Las Vegas, Nevada, and Phoenix, Arizona. Partnerships were developed in each of the following cities, including Seastar in Redding, Treasure and Premier Homes in Sacramento, K Street LLC in Lancaster (NE of LA) and Newland Communities in Phoenix Arizona. These builders worked with BIRA to develop communities at the 40% WHES level (some already achieving the 50% WHES level) and were committed to finding cost effective methods to further improve their building techniques and achieving greater levels of energy efficiency.

"Must Meet" Gate Criteria -- Neutral Cost Target

Using the prescribed strategy developed by the BIRA team, along with estimated incremental feature costs, 50% Hot/Dry would homes fulfilled the neutral cost target. BIRA worked with builder K Street LLC on their O Bel! Sol community in Lancaster, CA (40 miles NE of Los Angeles), with the projected savings 56% above the benchmark. The building was modeled as a 3218 sq. ft. two-story, single family detached home.

Features	2005 Title-24	O Bel Sole Estates	Incremental Cost
Insulation	R-13 Walls R-40 Ceiling R-20 Garage	R-21 Wall R-49 Attic R-30 Garage	\$588
Windows	U-Factor 0.38 SHGC 0.40	U-Factor 0.20 SHGC 0.21	\$400
Cooling	SEER 13	SEER 16 EER 12.5	\$800
Heating	80% AFUE	95% AFUE	\$500
Ducts	R-4.2	R-8 with Improved Duct Sealing	\$450
DHW	NG, 0.59 EF	Tankless, 0.82 EF	\$1,500
Infiltration	0.0005 SLA	0.00021 SLA	\$570
Lighting	80% Hardwire Fluorescent	80% Hardwire Fluorescent	0\$

Features	2005 Title-24	O Bel Sole Estates	Incremental Cost
Radiant Barrier	n/a	Yes	\$536
Total			\$4,894

Table 43: 50% Hot/Dry Strategy Costs

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	California Code Home	Plan B 3218	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	95.0	74.3	31.4	66.9%	57.7%	17.8%	16.3%
Space Cooling	139.5	92.2	41.8	70.0%	54.7%	27.3%	19.2%
Domestic Hot Water	23.3	21.2	11.4	51.1%	46.2%	3.3%	3.7%
Lighting	38.8	16.5	16.5	57.5%	0.0%	6.2%	0.0%
Appliances and MELs	61.3	58.8	54.0	11.9%	8.2%	2.0%	1.8%
Total Usage/ Savings	358.0	263.0	155.2	56.6%	41.0%	56.6%	41.0%

Table 44: 50% Hot/Dry Strategy Savings Summary

This strategy worked reasonably well across each of the targeted cities, with energy savings equaling 53%, 52%, 54%, 54% in Bakersfield, Redding, Sacramento and Tucson, respectively. The strategy did not focus on one specific component, so despite the varying heating and cooling loads between the cities, they all achieved consistent savings. Figure 11 summarizes estimated annual energy costs for each of the locations.

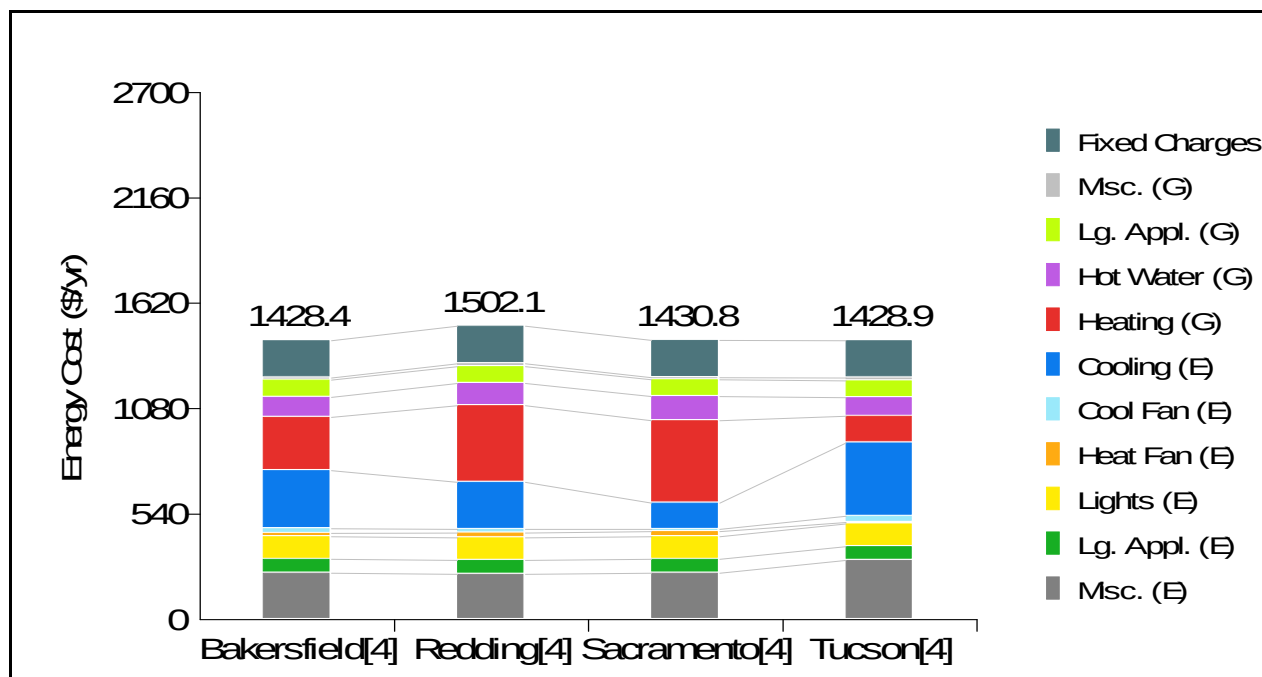


Figure 11. Estimated Annual Energy Costs for 50% Strategy

When the cost of the features is mortgaged at 7% over 30 years, the \$4,894 incremental cost translates to a \$402.69 increase in the annual mortgage payment. Annual utility savings are projected to be \$1,836 per year, netting a total of \$1,433.60 per year in savings to the consumer. This analysis was based in Bakersfield, California is summarized in Table 33.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	California Code Home	50% Hot/Dry Strategy	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	95.0	74.3	31.4	66.9%	57.7%	17.8%	16.3%	\$562.23
Space Cooling	139.5	92.2	41.8	70.0%	54.7%	27.3%	19.2%	\$692.55
DHW	23.3	21.2	11.4	51.1%	46.2%	3.3%	3.7%	\$109.30
Lighting	38.8	16.5	16.5	57.5%	0.0%	6.2%	0.0%	\$158.24
Appliances and MELs	61.3	58.8	54.0	11.9%	8.2%	2.0%	1.8%	\$58.24
Total Usage/Savings	358.0	263.0	155.2	56.6%	41.0%	56.6%	41.0%	\$1,836.30
					Energy Efficiency Feature		Annual Mortgage Cost	
							vs. Code	
					80% CFL Lighting		(\$9.58)	
					82% EF Tankless Water Heater (x2)		(\$119.75)	
					Improved Duct Sealing, Envelope Sealing and Testing		(\$35.93)	
					Radiant Barrier		(\$42.79)	
					R-30 Above Garage Insulation		(\$8.22)	
					R-21 Wall Insulation		(\$11.98)	
					R-49 Attic Insulation		(\$26.75)	
					95% AFUE Furnace		(\$39.92)	
					16 SEER (12.5 EER) A/C unit		(\$63.87)	
					Highly Efficient Windows		(\$31.93)	
					Pipe Insulation Water Distribution		(\$11.98)	
					Total Annual Mortgage Cost		(\$402.69)	
					Net Annual Cash Flow to Consumer		\$1,433.60	

Table 45: 50% Strategy Cost Savings

“Should Meet” Gate Criteria -- Marketability

BIRA worked with builder partners to determine the most cost effective and acceptable strategy to address the Hot/Dry Climate Zone. All the features in the strategy are readily available, off-the-shelf components that do not require dramatic changes in current building practices. The practical benefit to buying an energy efficient house can be a key factor in the sales process.

“Should Meet” Gate Criteria -- Builder Commitment

Builder commitment in this region is strong towards advancing energy efficient housing. However, the current markets in California, Nevada and Arizona have been particularly hard hit. Housing inventory in both states is still too high, and housing prices have dropped 25-30% over 2008¹². What’s more important is that commitment in continued development is equally strong despite a down-turned market.

“Should Meet” Gate Criteria -- Gaps Analysis

The only significant gap in moving forward to prototype homes is the current housing market. When builders were surveyed, practically all new community development has halted for the near future. Addressing builders’ concerns for advanced framing options, like 2x4 24” o.c. and SIPs, will be important for reaching future milestones. Nonetheless, this will have to wait for a new community for evaluation.

A less significant gap involves the possible learning curve associated with builders who are unfamiliar with advanced framing techniques. This may slow down the adoption of advanced wall construction. However, once the technique becomes more familiar it should prove to be more cost effective as it reduces material cost and construction time. Improved envelope systems also improve the HVAC performance.

40% Cold – Budget Period 1

The 40% Cold study focused on the high desert regions, notably Salt Lake City, Utah, and Reno, Nevada, as these sites offer on-going research opportunities for the BIRA team.

Stage Gate 1A work for the Cold Climate is in progress. Strategies for obtaining the 40% energy savings target have been identified and are currently in the process of being evaluated by BIRA builder and industry partners.

¹² http://money.cnn.com/2008/10/28/real_estate/August_Case_Shiller/?postversion=2008102813

“Must Meet” Gate Criteria -- Source Energy Savings

Using BEopt 0.8.6, an energy analysis was performed using standard building features for Salt Lake City, as representative of the Cold climate high desert regions. These features were decided upon by information given to BIRA by its builder partners and represent a typical new construction. Results from these simulations indicate that Kennecott Land’s current practices, which follow ENERGY STAR® guidelines, produce homes that perform at a 34% savings level. These results are shown below in Figure 12.

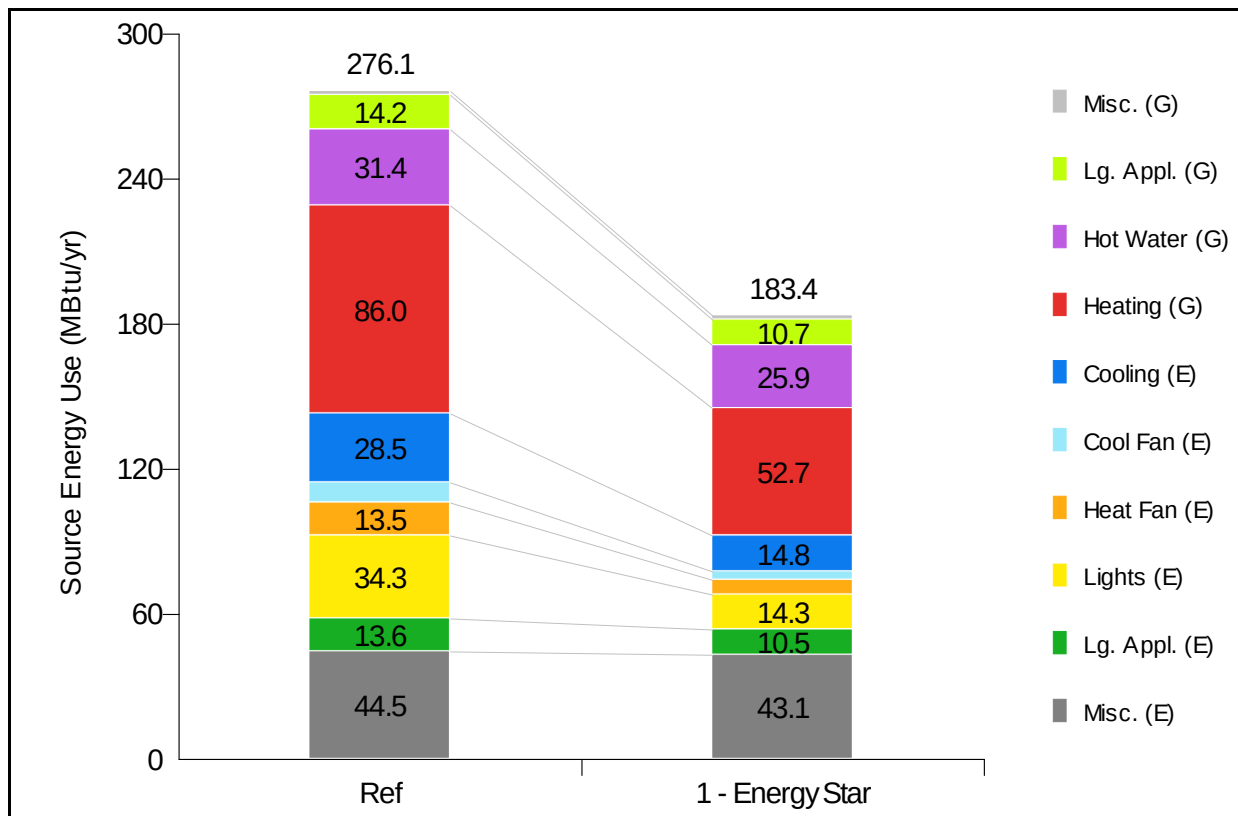


Figure 12. BEopt Analysis for Kennecott Land Current Construction Practice

Features	2006 IECC	Kennecott	Energy Star	As Built (41.6%)
Insulation	R-19 Wall R-30 Ceiling R-13 Basement	R-19 Wall R-38 Ceiling R-13 Basement	R-19 Wall R-38 Ceiling R-13 Basement	R-25 Wall R-49 Ceiling R-13 Basement
Windows	0.35 U-Factor SHGC NR	0.35 U-Factor 0.38 SHGC	0.35 U-Factor SHGC NR	0.31 U-Factor 0.25 SHGC
Cooling	SEER 13	SEER 13	SEER 13	SEER 15

Features	2006 IECC	Kennecott	Energy Star	As Built (41.6%)
Heating	0.78 AFUE	0.90 AFUE	0.90 AFUE	0.925 AFUE
Ducts	R-6	R-8 Supply R-4 Return In Uncond. Space	R-6 in Unconditioned Space	Ducts inside
DHW	NG 0.67 EF	NG 0.60 EF	NG 0.60 EF	0.80 EF Tankless

Table 46: Comparison of Major Features

Simulation results comparing the IECC 2006, Kennecott Sustainability, ENERGY STAR, and As-Built features are shown in Figure 13 below.

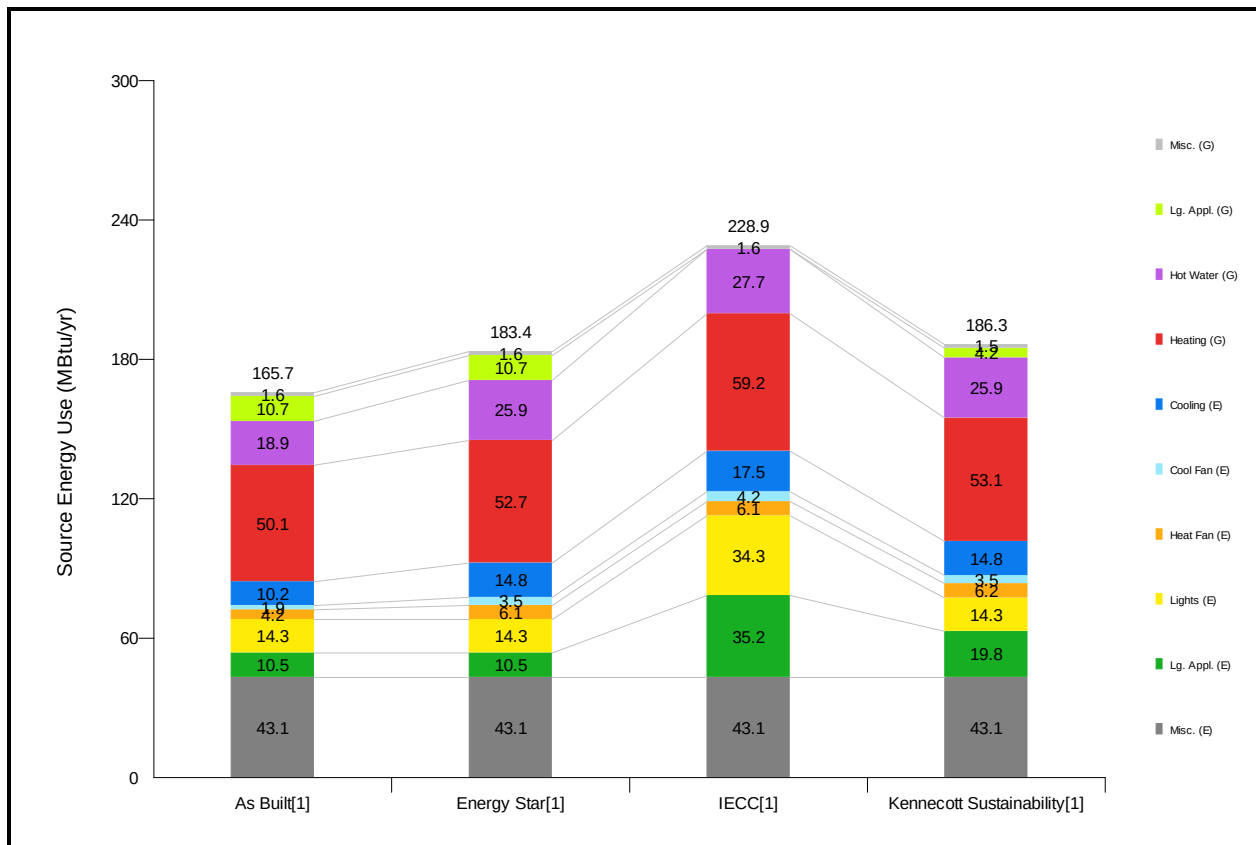


Figure 13. Comparison of IECC 2006, Kennecott Sustainability, Energy Star and As-Built

Leading candidates for reducing the heating load include higher efficiency furnaces (95% AFUE) and improved wall systems, specifically SIPS walls or walls that utilize a 2x6 at 24" o.c. advanced framing technique. By providing better thermal properties and improved air sealing, these advanced framing systems greatly reduce conductive heat loss/gain and will serve to decrease both heating and cooling loads. The impact of advanced framing on WHES depends on the choice of wall insulation.

Tankless water heaters have typically provided efficiencies around 80-90%. However, Tankless water heating systems are not common in this region and therefore not as cost effective. Utilizing this technology can increase WHES by 4-5%. Solar water heating may be an opportunity in this region which has good solar resources.

The current standard for hardwired lighting is already at 100% fluorescent. This leaves only two possible paths for improvement. The first path is to push CFL use for plug-in lights, however this is a behavioral modification and is therefore unenforceable. The alternative path is to move towards using LED lights. Despite having a claimed lifetime 6 times longer than that of a CFL while consuming considerably less electricity, there are still many arguments against LED lights; most commonly that they produce dim and unnatural light, are very expensive, and, due to poor heat-management, do not last nearly as long as claimed. Whether these arguments are justified or not is beyond the scope of this report, however it is clear that the building industry is not yet ready to adopt LED lighting.

BIRA is currently testing a dual stage (indirect/direct) evaporative cooler that is ideally suited for use in the dry, high desert regions. Initial performance data shows about an 80% reduction in energy needed to achieve the same cooling capacity compared to a SEER 13 condensing unit. Utilizing this technology could increase WHES by 4-5%

When combined, any two of these three technologies would increase energy efficiency enough to achieve the 40% savings goal assuming the remaining load is built to ENERGY STAR standards.

"Must Meet" Gate Criteria -- Neutral Cost Target

Initial feedback from BIRA builder partners indicates that the increased costs of improvements meet the cost neutrality target when compared to regional standard practice which is IECC 2006, Kennecott current building guidelines for all builders within the Daybreak community build to an Energy Star. Liberty Homes (Daybreak Builder) provided the following cost information with the cost differential to their typical building practices.

Features	Regional Standard Practice	Builder Standard Practice	Energy Star	As Built (41.6%)	Incremental Cost to build at 40% BA
Insulation	R-19 Wall R-38 Ceiling R-13 Basement	-	-	R-25 Wall R-49 Ceiling R-13 Basement	\$2,500 (Wall) \$300 (Ceiling)
Windows	0.35 U-Factor SHGC NR	0.35 U-Factor 0.38 SHGC	0.35 U-Factor SHGC NR	0.31 U-Factor 0.25 SHGC	No appreciable price increase
Appliances	Standard Appliances	Energy Star Dishwasher		All Energy Star Certified	\$750

Features	Regional Standard Practice	Builder Standard Practice	Energy Star	As Built (41.6%)	Incremental Cost to build at 40% BA
Lighting	Not Specified	100% Fluorescent		100% Fluorescent	\$200
Cooling	SEER 13	-	-	SEER 15	\$2,050
Heating	0.78 AFUE	0.90 AFUE	-	0.925 AFUE	
Ducts	R-6	R-8 Supply R-4 Return In Uncond. Space	R-6 in Unconditioned Space	Ducts inside	No appreciable price increase
DHW	NG 0.60 EF	NG 0.60 EF	-	0.80 EF Tankless	\$1,600
Total:					\$7,400

Table 47: Feature Cost Comparison

A price comparison of the total annual utility costs for all four design options is given in the Figure 14 below. Note that in all subsequent cost analysis, the total annual cost is divided over twelve months to obtain an average monthly cost for comparison.

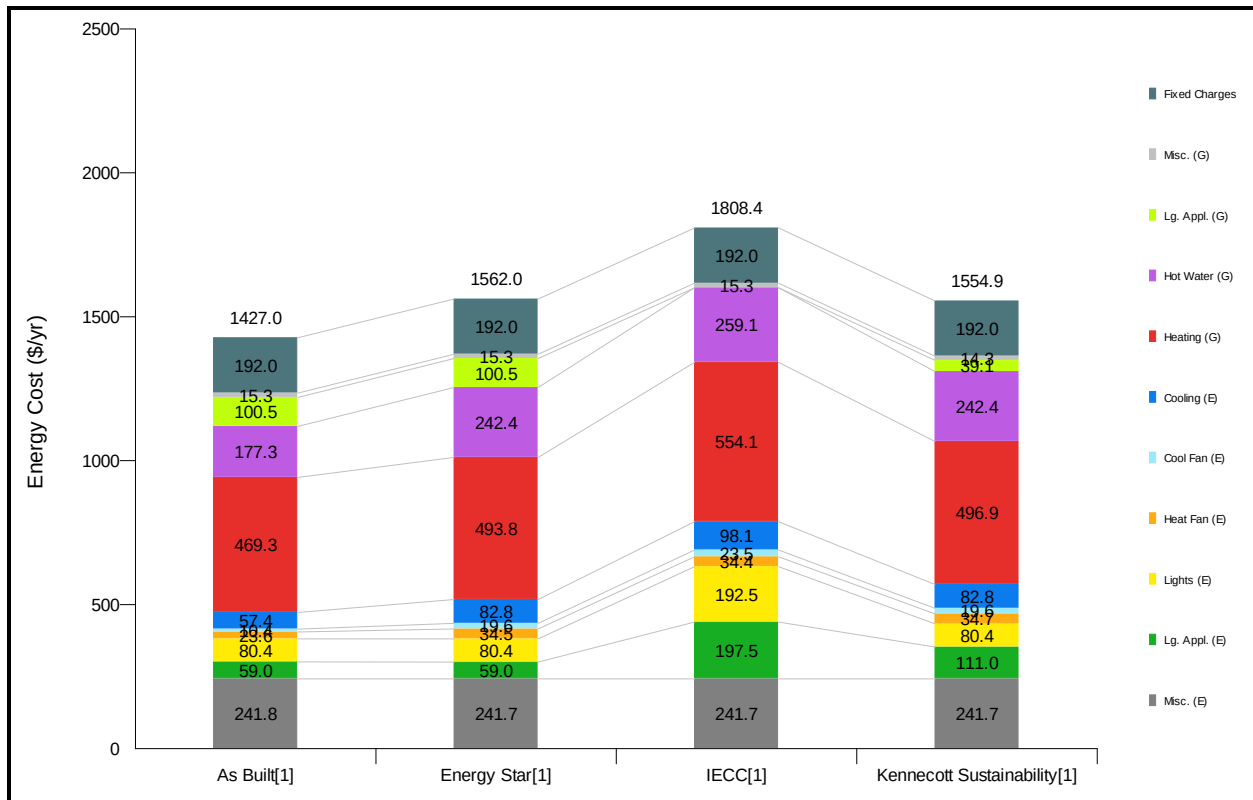


Figure 14. Cost Comparison for Four Design Options

When mortgaged over 30 years, the \$7,400 cost increase translates to a \$49.23 increase in the monthly mortgage payment (assuming 7% APR over 30 years). BEopt analysis estimates the annual utility costs for a code house in Salt Lake City to be \$1,808. Similarly, the 40% BA design described above has an estimated annual utility cost of \$1,427. This constitutes a yearly savings of \$381, or a monthly savings of \$31.75, which offsets about three-fifths of the increase in monthly mortgage payments. To put that in terms of initial incremental cost, these monthly savings justify \$4,700 of the \$7,400 spent on improvements. It is important to realize that the \$7,400 does not represent mature market costs, rather they are significantly higher. To estimate the impacts of mature incremental costs, it is instructive to apply utility incentives that are intended to move the market toward sustainable costs.

For this particular design, the following incentives were available through both the electric utility, Rocky Mountain Power, and the natural gas utility, Questar.

Appliances	Description	Incentive Amount
Rocky Mountain Power		
Base Package 2	Meet 2007 ENERGY STAR specifications including product requirement and performance base duct sealing. 14 SEER HVAC equipment with correct sizing and best practices installation. Low e windows.	\$350
Plus Measures	Duct placement inside conditioned space	\$200
	Installation of a ducted, high-efficiency evaporative cooling system	\$750
	Installation of an Energy Star Dishwasher	\$10
	Lighting upgrade to 15 Energy Star Fixtures or CLFs	\$50
Total:		\$1,360
Questar		
Energy Star New Home	HERS Index of 85 or less	\$500
Federal Tax Credit Home		\$800
H. Efficiency Gas Furnace	90% AFUE rating or higher	\$300
Tankless Gas Water Heater	0.80 or higher energy factor	\$300
Total:		\$1,900
Total Available Incentives:		\$3,260

Table 48: Available Incentives

Deducting these incentives from the initial incremental cost leaves only \$4,140 to be mortgaged, lowering the monthly mortgage payments increase to \$27.54. This amount is now offset by the \$31.75/month utility bill savings, assuming current incentives more accurately represent mature market costs in the future. This would make this 40% design cost neutral.

Within Kennecott Land, construction practices are equivalent to Energy Star. When the 40% BA design is compared to Kennecott builder standard practice, the opportunities for savings are narrowed. The narrowed utility savings margin is \$11.25/month while the increase in monthly mortgage cost due to improvements remains higher at \$18.23/month even after incentives are applied. The major difference between Energy Star and IECC 2006 is in going from a .78 AFUE furnace to a .90 AFUE. When going from IECC 2006 to the As Built (40%) case, both the furnace and the wall/ceiling insulation were improved. It is clear from this result that to achieve appreciable, cost effective savings in a heating dominated climate, improvements to the envelope are required alongside increasing the heating system efficiency.

“Should Meet” Gate Criteria -- Marketability

BIRA sees no barriers to the marketability of these improvements other than being able to sell the value to the consumer. No drastic measures are needed to achieve 40% savings, making it such that these houses would be indistinguishable from a typical code house on the surface. This would assuage any reticence a buyer may have to buying a “green” home and similarly, reluctance builders might have to producing them. Conversely, energy efficiency and maintenance cost reduction are factors playing more and more strongly on the decisions of buyers. Assuming cost effectiveness can be achieved, the practical benefits of buying an energy efficient house can be key factors in the sales process.

“Should Meet” Gate Criteria -- Builder Commitment

Builder commitment in this region is strong due to the sustainability goals of Kennecott Land and a few of their lead builders. More importantly, the commitment in continued development is equally strong despite a down-turned market. The Kennecott Land project has a goal of building 200,000 homes over the next 100 years with a strong emphasis placed on sustainable development. BIRA has worked with four Kennecott Land’s builders and developed key partnerships that are already providing opportunities to achieve higher energy efficiency levels. BIRA is working with the Sustainability Director at Kennecott Land to increase the minimum energy efficiency requirements for building at Daybreak, which should include incorporating as much as possible of the 40% BA design in near-future, new phases of development.

“Should Meet” Gate Criteria -- Gaps Analysis

The most significant gap in moving forward to prototyping is that the energy-efficiency market is relatively undeveloped in Utah, resulting in costs for improvements being too high to obtain cost effective strategies. BIRA has partnered with local utilities as well as state and local policy officials to work together to provide incentives for energy efficiency measures and other market support to help the market in this region reach a more mature level in energy efficiency.

Other market gaps include very high efficiency space heating and market acceptance of improved envelopes. This includes the learning curve associated with builders and

subcontractors who are unfamiliar with SIPS and advanced framing techniques. This may slow down the adoption of advanced wall construction. However, once the technique becomes more familiar it should be more cost effective as it reduces material cost and construction time.

50% Marine Budget Period 2

This report targets three cities in the Marine climate zone, biased towards regions where eligible communities will more likely occur, to develop a more representative understanding of the zone: San Barbara, and San Jose, CA, and Seattle, WA. While all three of these cities are within the same Building America climate zone (Marine), each experiences a dramatically different winter season.

“Must Meet” Gate Criteria -- Source Energy Savings

Using Energy Gauge v.2.8.01, an energy analysis was performed using 2008 Title-24 compliant features from Micropas and 2009 IECC prescriptive features. Using the baseline home, 50% WHES features were determined by upgrading code features and adhering to the standard practice and design in region. BIRA’s builder partners provided information about the building features’ availability, ease of use, and cost which was used to further refine the 50% WHES technology pathway.

This analysis showed that the 50% WHES can be achieved with a smart building design, improved construction practices and planning, and high efficiency, “off-the-shelf” building components. Relative to the BA Benchmark, the 2008 Title-24 standard achieves approximately 18% WHES and the 2009 IECC standard achieves approximately 23% WHES. A baseline home built at the 50% WHES will achieve approximately 37% greater WHES than a baseline home built at the 2008 Title-24 standard and approximately 39% greater WHES than a baseline home built at the 2009 IECC standard. These comparisons can be seen in Figure 15 and Figure 16

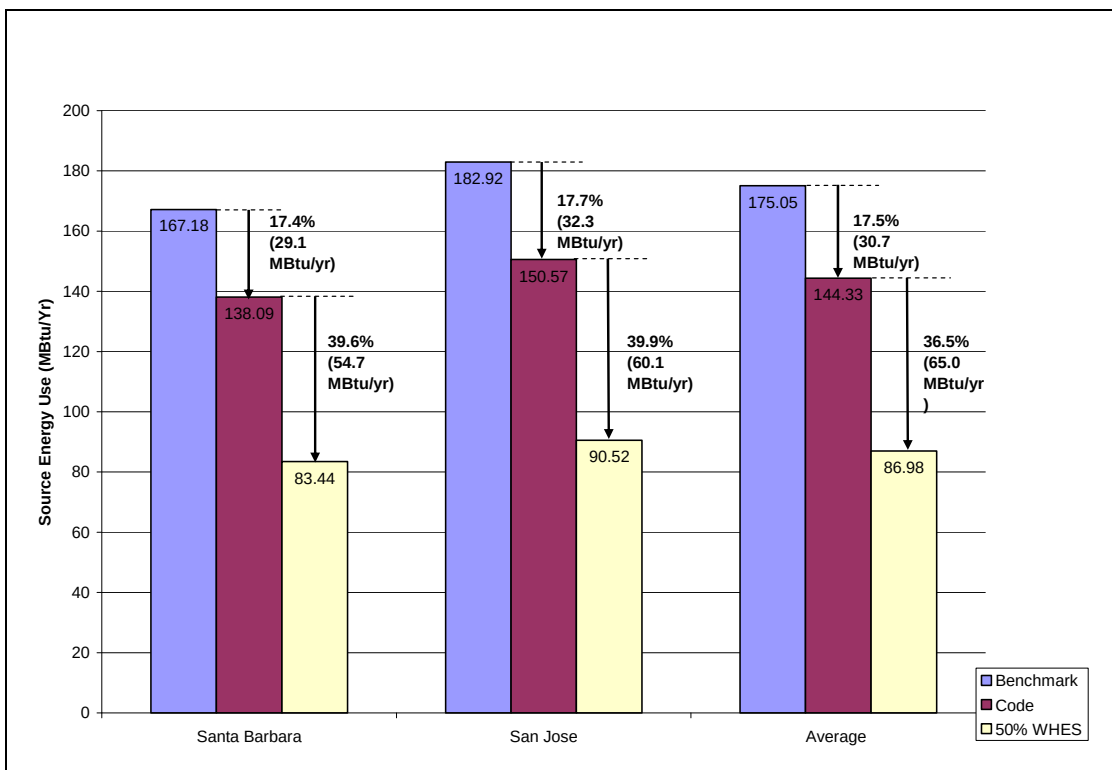


Figure 15. Whole-House Energy Savings in Title-24 Region

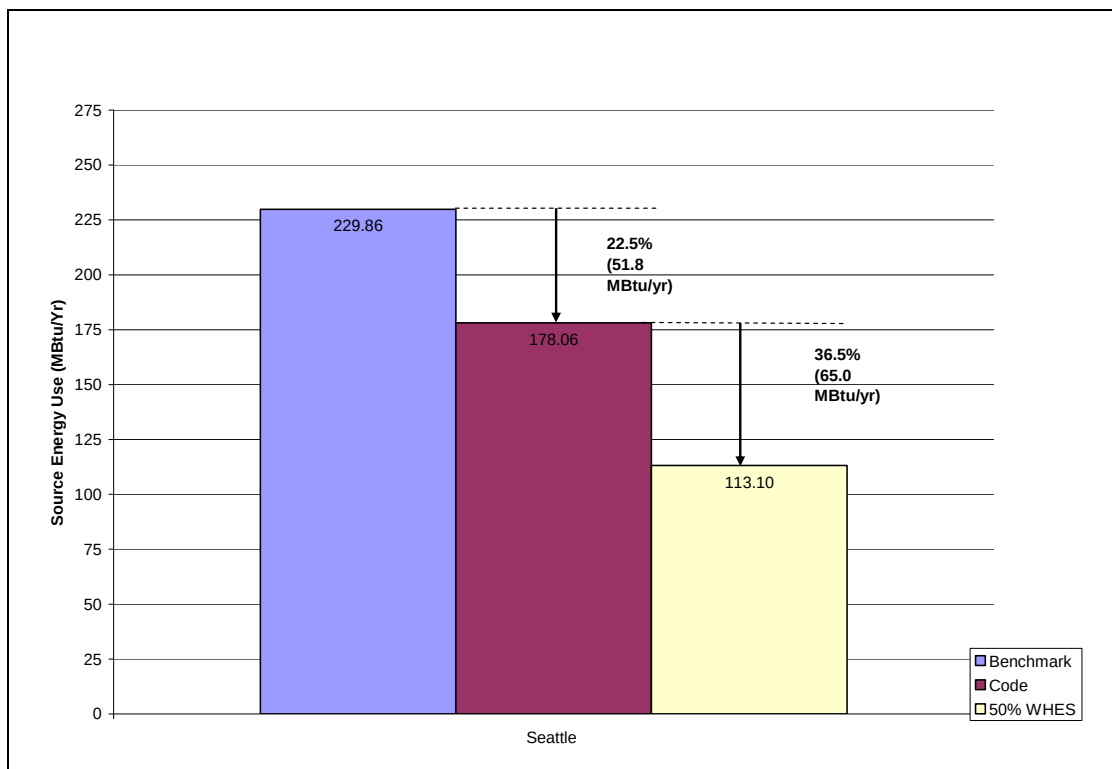


Figure 16. Whole-House Energy Savings in IECC Region

Although MELs is the largest load group for both the Title-24 and IECC regions and accounts for approximately 54% of the whole house energy loads, they have been excluded from this list because solutions to MELs cannot be applied to all climate zones equivalently and are being addressed in separate research projects. Analysis shows space heating, space cooling, and lighting are the next major loads. Figure 17 and Figure 18 show the variation in end-use loads for Title-24 and IECC climates zones, respectively.

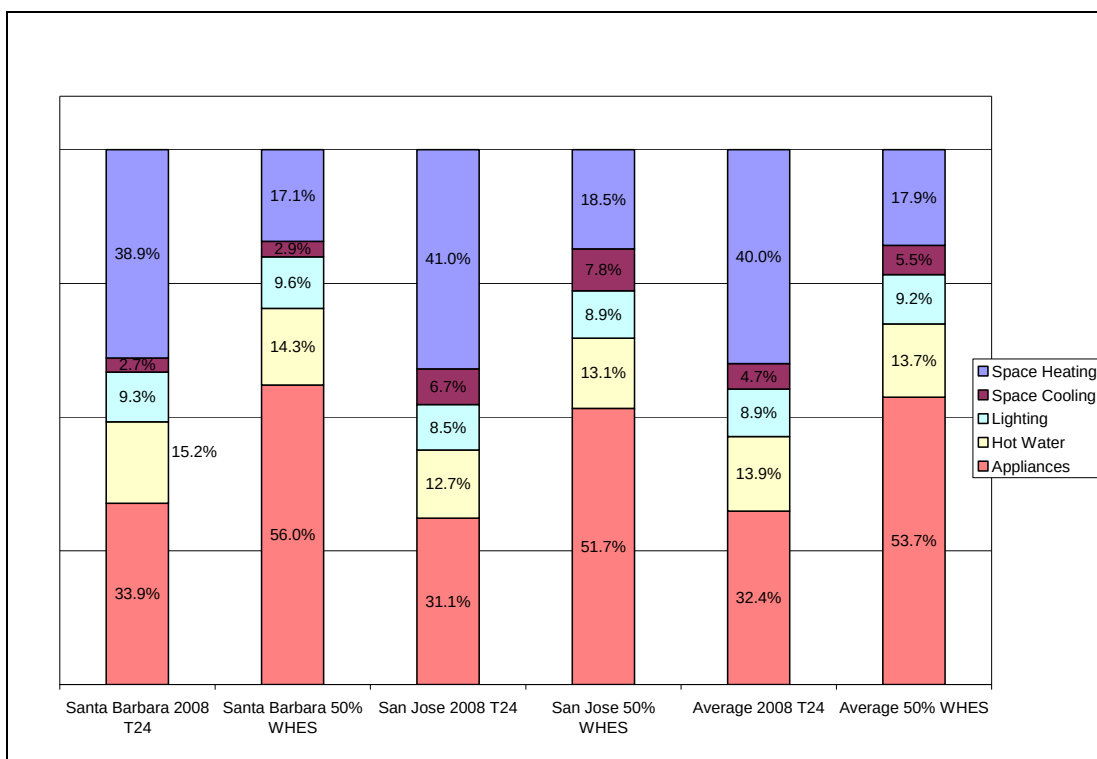


Figure 17. End-Use Energy Loads for 2008 Title-24 and 50% WHES

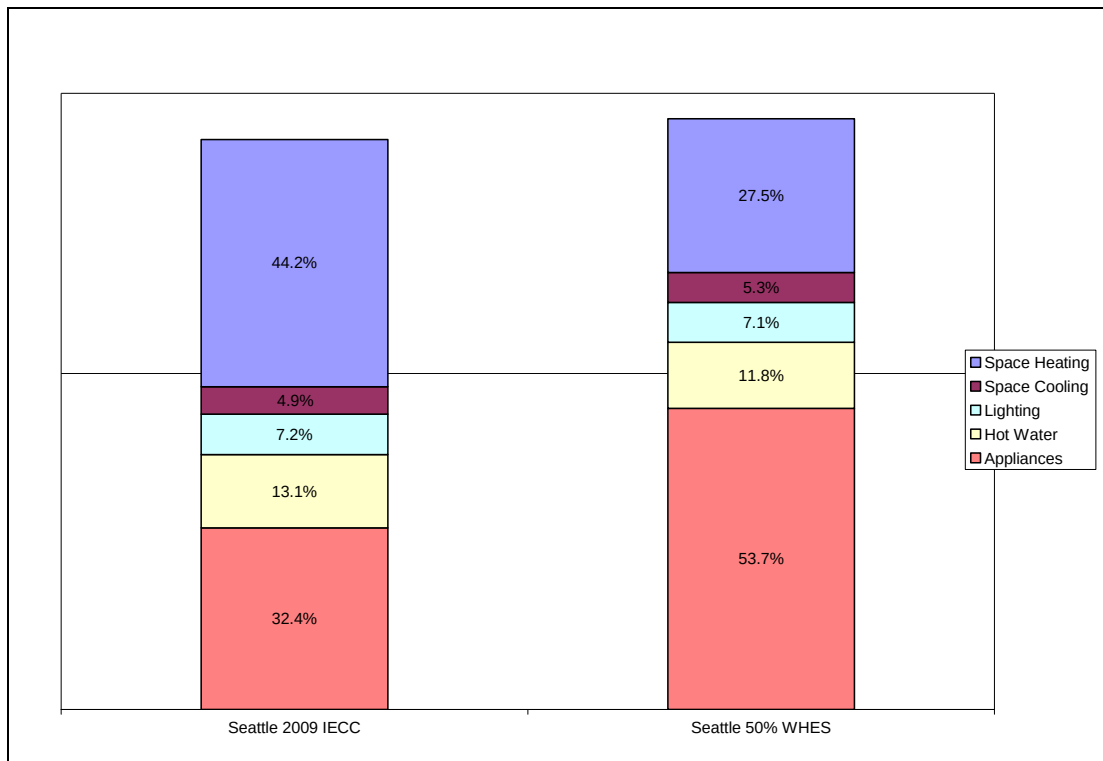


Figure 18. End-Use Energy Load for 2009 IECC and 50% WHES

Analyses were run in all four cardinal orientations to produce an average WHES for solar orientation. Achieving the 50% WHES level does not require orienting homes in any particular direction. However, making the best use of the sun brings many advantages. Builders should, if possible, consider orientation during the site development stage of the homebuilding process; a virtually no-cost option for improving energy performance is to account for optimum orientation for passive solar benefit. Site planning should take advantage of southern windows and roof exposure, as well.

Average features for code compliant and 50% WHES homes for the Marine climate zone used in this simulation are given in Table 49 and Table 50.

Features	2008 Title-24	50% WHES
Insulation	R-13+1" foam Walls (2x4) R-19+1" foam Walls(2x6) R-30 to 38 Ceiling R-13 Garage	R-15+1" (R4) foam Walls (2x4) R-23+1" (R4) foam Walls (2x6) R-60 Ceiling R-15 Garage
Windows	U-Factor 0.35 SHGC 0.31	U-Factor 0.22 SHGC 0.22
Cooling	SEER 13	SEER 16
Heating	80% AFUE	95% AFUE

Features	2008 Title-24	50% WHES
Ducts	R-4.2/attic	R-8/interior
DHW	50 gal, 0.62 EF	Tankless, 0.98 EF
Infiltration	0.00038 SLA	0.00025 SLA
Lighting	80% Hardwire Fluorescent	100% Fluorescent

Table 49: Average 2008 Title-24 and 50% WHES Features Summaries

Features	2009 IECC	50% WHES
Insulation	R-13+1" foam Walls (2x4) R-19+1" foam Walls (2x6) R-38 Ceiling R-13 Garage	R-15+1" (R4) foam Walls (2x4) R-23+1" (R4) foam Walls (2x6) R-49 Ceiling R-15 Garage
Windows	U-Factor 0.35 SHGC 0.65	U-Factor 0.22 SHGC 0.85
Cooling	SEER 13	SEER 16
Heating	78% AFUE	95% AFUE
Ducts	R-8/attic	R-8/interior
DHW	50 gal, 0.58	Tankless, 0.98 EF
Infiltration	0.00036 SLA	0.00025 SLA
Lighting	80% Hardwire Fluorescent	100% Fluorescent

Table 50: Average 2009 IECC and 50% WHES Features Summaries

Leading candidates for reducing both the space heating and space cooling end-use loads include improvements to the wall framing and HVAC system. The impact of advanced framing on WHES depends on the choice of wall insulation. Walls with high R-values are critical for cooling load reduction during the summer months and heat retention during the winter months. Different building materials and practices can be used to create a house with high R-value walls such as structural insulated panels (SIPs), optimum value engineered (OVE) walls, and exterior foam sheathing. The 50% WHES technology pathway include walls that utilize a 2x6 @ 24" o.c. advanced framing technique incorporating R-15 insulation with 1" sheathing (R4), as well as R-23 insulation with 1" sheathing (R4) in a portion of the house. By providing a better thermal seal, these advanced framing systems greatly reduce conductive heat loss or gain, thereby decreasing both heating and cooling loads.

Furthermore, the 50% WHES technology pathway increased HVAC system efficiency by moving all air ducts into conditioned space which reduces efficiency losses due to duct leakage. Improving the HVAC efficiency as a system will naturally reduce energy loads through a more

efficient unit. The 50% WHES technology pathway for both the Title-24 and the IECC regions incorporated a 95% AFUE natural gas furnace and a 16 SEER central air conditioning unit.

Analysis shows that there is a potential for 20 to 24% WHES improvement in space heating over 2008 Title-24 and 2009 IECC, respectively, with the use of the high-efficiency natural gas furnaces. The high-SEER central A/C unit result in 1% WHES for both 2008 Title-24 and 2009 IECC. Note: While percentage of end-use energy load savings is minor, the cooling load reduction was needed to achieve 50% WHES while maintaining cost effectiveness.

In order to target the domestic water heating (DWH) load, tankless water heating systems should be installed, typically provided efficiencies around 95 to 98%. Utilizing this technology can increase WHES by 4 to 5%.

Combined, these features can improve WHES by 28-33% above the 2009 IECC and 2008 Title-24 code respectively, thereby achieving 50% savings above the BA Benchmark. The defined features can be utilized as a technology pathway which will ease progression into the next Joule milestone. The next Joule milestone for Marine will be 70% WHES in 2017. "Must Meet" Gate Criteria -- Neutral Cost Target

BIRA builder partners provided accurate incremental costs and industry review of proposed features for 50% WHES technology pathway. Builder partners who provided incremental costs and reviews in the Marine climate zone include the McNaughton Group, LLC. Incomplete incremental costs were supplemented with costs from the database of Energy Gauge. In cases of summed incremental costs (provided by builder partners), costs were divided between components for average costs.

Feedback from builder partners indicates that the increased costs of improvements meets the cost neutrality target when compared to regional standard practice (2008 Title-24 for California or 2009 IECC for non-California locations). For a baseline home built to 50% WHES, analysis shows that the annual utility bills plus the annual incremental mortgage (upgraded from code building features) is less than the annual utility bills of the BA Benchmark. The annual savings for 50% WHES can be seen on Figure 19 and Figure 20, for 2008 Title-24 and 2009 IECC, respectively.

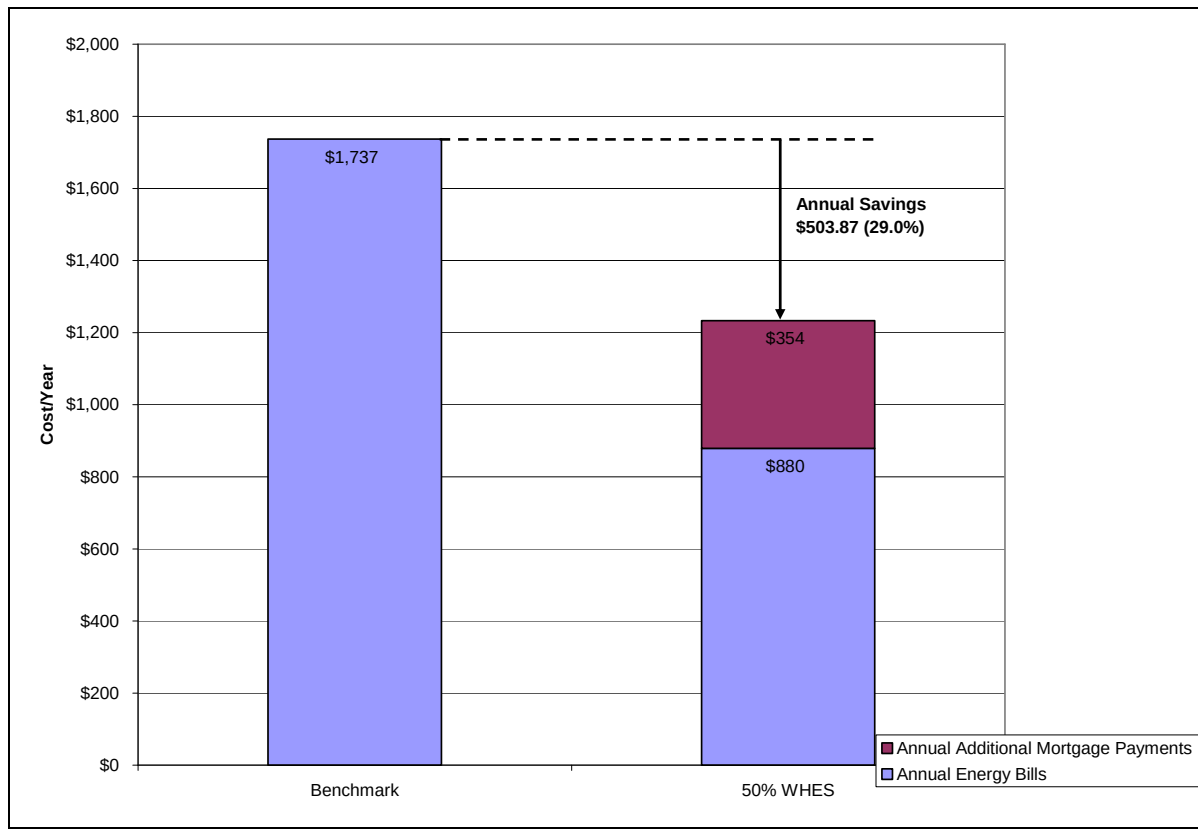


Figure 19: Annual Net Savings for 50%WHES (upgraded from 2008 Title-24)

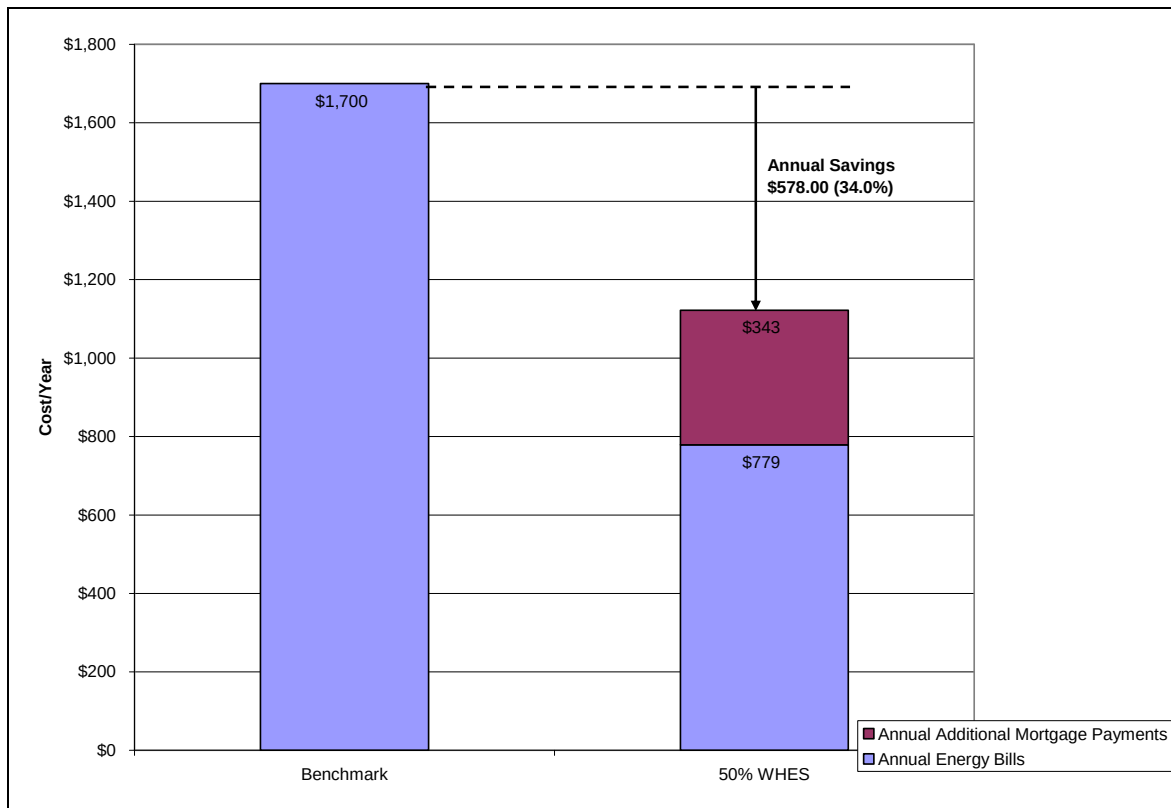


Figure 20: Annual Net Savings for 50%WHES (upgraded from 2009 IECC)

BIRA's 2008 Marine Dry Stage Gate 1A report showed that 50% WHES fulfills the neutral cost target from 2005 Title-24 and 2006 IECC. Cost neutrality was demonstrated by using the prescribed strategy developed by the BIRA team, along with estimated incremental feature costs. Current Stage Gate 1A analysis uses similar methods with verified incremental feature costs to show the positive cash flow for a 50% WHES baseline home upgraded from 2008 Title-24 and 2009 IECC.

Although there are currently thousands of incentive dollars available for new production homebuilders and homebuyers for energy efficient homes, there will eventually be insufficient funds to support the increase in new energy efficient homes construction and purchasing. Therefore rebates or tax credits were not included in the calculation of cost flow to provide a more accurate analysis.

When the 50% WHES baseline home in a Title-24 region is mortgaged at 7% APR over 30 years, the \$4,429 incremental features cost translates to a \$354 increase in the annual mortgage payment. Annual utility savings are projected to be \$858 per year, thereby netting a total of \$504 per year in savings to the homeowner. This analysis is summarized in Table 51.

The 50% WHES baseline home in an IECC region was also studied using similar methods and found to have a positive cash flow of \$578 per year to the homeowner. This analysis is

summarized in Table 52.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	California Code Home	Prototype	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	63.6	57.7	15.5	75.6%	73.1%	27.4%	29.2%	\$433
Space Cooling	11.8	6.8	4.8	59.8%	30.5%	4.0%	1.4%	\$78
DHW	21.6	20.1	11.9	44.7%	40.7%	5.5%	5.7%	\$84
Lighting	28.8	12.9	8.0	72.1%	37.6%	11.9%	3.3%	\$235
Appliances and MELs	49.3	46.8	46.8	5.2%	0.1%	1.5%	0.0%	\$28
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%	\$0
Total Usage/ Savings	175.1	144.3	87.0	50.3%	39.7%	50.3%	39.7%	\$858

	Energy Efficiency Feature				Builder Cost	10% Markup	Total	Annual Mortgage Cost vs. Code	
	100% CFL Lighting				\$0	\$0	\$0	\$0	
	98% EF Tankless Water Heater				\$720	\$72	\$792	(\$63)	
	Improved Duct Sealing, Envelope Sealing, and Testing				\$620	\$62	\$681	(\$54)	
	Radiant Barrier				\$512	\$51	\$56	(\$45)	
	R30 Above Garage insulation				\$132	\$13	\$145	(\$12)	
	R15 Wall Insulation+1" foam				\$140	\$14	\$154	(\$12)	
	R23 Wall Insulation+1" foam				\$449	\$45	\$494	(\$39)	
	R15 Garage Walls				\$35	\$3	\$38	(\$3)	
	R60 Attic Insulation				\$166	\$17	\$18	(\$15)	
	5/8" Drywall				\$60	\$6	\$66	(\$5)	
	95% AFUE Furnace				\$310	\$31	\$341	(\$27)	
	16 SEER A/C unit				\$310	\$31	\$341	(\$27)	
	Highly Efficient Windows				\$424	\$42	\$467	(\$37)	
	Pipe Insulation Water Distribution				\$150	\$15	\$165	(\$13)	
	Totals				\$4,027	\$403	\$4,429	(\$354)	
	Net Annual Cash Flow to Consumer					\$504			

Table 51: Average Cost Savings for 50% WHES in Title- 24 Region

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	California Code Home	Prototype	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	113.6	78.6	31.1	72.6%	60.5%	35.9%	26.7%	\$707
Space Cooling	6.9	8.7	6.0	12.0%	30.4%	0.4%	1.5%	\$5
DHW	23.4	23.3	13.4	43.0%	42.6%	4.4%	5.6%	\$89
Lighting	28.8	12.9	8.0	72.1%	37.6%	9.0%	2.7%	\$108
Appliances and MELs	57.2	54.6	54.6	4.5%	0.0%	1.1%	0.0%	\$13
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%	\$0
Total Usage/ Savings	229.9	178.1	113.1	50.8%	36.5%	50.8%	36.5%	\$921

	Energy Efficiency Feature				Builder Cost	10% Markup	Total	Annual Mortgage Cost vs. Code	
	100% CFL Lighting				\$0	\$0	\$0	\$0	
	98% EF Tankless Water Heater				\$720	\$72	\$792	(\$63)	
	Improved Duct Sealing, Envelope Sealing, and Testing				\$619	\$62	\$680	(\$54)	
	Radiant Barrier				\$512	\$51	\$563	(\$45)	
	R30 Above Garage insulation				\$0	\$0	\$0	\$0	
	R15 Wall Insulation+2" foam				\$140	\$14	\$154	(\$12)	
	R23 Wall Insulation+2" foam				\$449	\$45	\$494	(\$39)	
	R15 Garage Walls				\$35	\$3	\$38	(\$3)	
	R49 Attic Insulation				\$166	\$17	\$183	(\$15)	
	5/8" Drywall				\$70	\$7	\$77	(\$6)	
	95% AFUE Furnace				\$309	\$31	\$340	(\$27)	
	16 SEER A/C unit				\$309	\$31	\$340	(\$27)	
	Highly Efficient Windows				\$424	\$42	\$467	(\$37)	
	Pipe Insulation Water Distribution				\$150	\$15	\$165	(\$13)	
	Totals				\$3,903	\$390	\$4,293	(\$343)	
	Net Annual Cash Flow to Consumer					\$578			

Table 52: Average Cost Savings for 50% WHES in IECC Region

“Should Meet” Gate Criteria -- Least Cost

Building America's team-based systems-research approach, including use of systems-engineering and operations research techniques, provides opportunities for cost and performance trade-offs that improve whole-building performance and value, while minimizing increases in overall building cost. Systems research includes analysis of system performance and cost tradeoffs as they relate to whole-building energy performance and cost optimization, including interactions between advanced envelope designs, mechanical and electrical systems, lighting systems, space-conditioning systems, hot water systems, major appliances, miscellaneous electric loads, energy control systems, renewable energy systems, and onsite power generation systems. Accordingly, the recommended technology pathways for 50% WHES in this report have been demonstrated to cost effectively increase overall product value and quality compared to conventional approaches, while significantly reducing energy use and use of raw materials when used on a production basis. The incremental cost of the technology package is less than the currently available “least cost” alternatives based on sum of utility bills and energy-related increases in mortgage costs.

“Should Meet” Gate Criteria -- Marketability

The BIRA team sees no barriers to the marketability of these improvements. No drastic measures are needed to achieve 50% WHES, making it such that these houses would be indistinguishable from a typical code-built home on the surface. This would lessen any reluctance a buyer may have to buying a “green” home and similarly, reluctance builders might have to producing them. Moreover, energy efficiency is a factor that is becoming increasingly more significant to homebuyers. Analysis has shown cost neutrality can be achieved; the practical benefit of buying a money-saving house will be critical in the marketing process when presenting an above-code built home. Potential homeowner satisfaction should be marketed by presenting both comfort and cost efficiency through advanced building features that result in energy savings.

“Should Meet” Gate Criteria -- Gaps Analysis

A possible gap involves the learning curve associated with builders who are unfamiliar with advanced wall framing or optimal value engineering (OVE). Addressing builders' concerns for OVE options like 2x6 @ 24" o.c. and CSIPs will be important for reaching future Joule milestones. Once the technique becomes more familiar it should prove to be more cost effective as it reduces material cost and construction time. Additionally, if a CSIP product is chosen as part of a 50% technology pathway, research regarding local training and warranty restrictions should be completed.

Another potential barrier to successfully implement the advanced wall framing technique is inspection and permitting issues from local building departments. Due to the relatively unknown nature of OVE, some building departments have resorted to denying permits.

Advanced wall framing can add complication to the inspection process if the building department is not familiar with the building practice. The BIRA team recommends working with the local building department during the beginning stages of planning and devolvment in an effort to avoid such situations.

50% Hot/Dry Budget Period 2

The Hot/Mixed-Dry Climate Zone spans a large range of actual climate conditions, so this study targeted four cities, biased towards regions where eligible communities will more likely occur, to develop a more representative understanding of the zone: Sacramento, CA, Lancaster, CA, Albuquerque, NM, and Tucson, AZ. While all four of these cities are within the same Building America climate zone (Hot/Mixed-Dry), each experiences a dramatically different winter season.

“Must Meet” Gate Criteria -- Source Energy Savings

Using Energy Gauge v.2.8.01, energy analyses were performed using 2008 Title-24 compliant features from Micropas and 2009 IECC prescriptive features. Using the baseline home, 50% WHES features were determined by upgrading code features and adhering to the region’s standard practice and design. BIRA’s builder partners provided information about the building features’ availability, ease of use, and cost which was used to further refine the 50% WHES technology pathway.

This analysis showed that the 50% WHES can be achieved with a smart building design, improved construction practices and planning, and high efficiency, “off-the-shelf” building components. Relative to the BA Benchmark, the 2008 Title-24 standard achieves approximately 24% WHES and the 2009 IECC standard achieves approximately 18% WHES. A baseline home built at the 50% WHES will achieve approximately 36% more WHES than a baseline home built at the 2008 Title-24 standard and approximately 39% more WHES than a baseline home built at the 2009 IECC standard. These comparisons can be seen in Figure 21 and Figure 22.

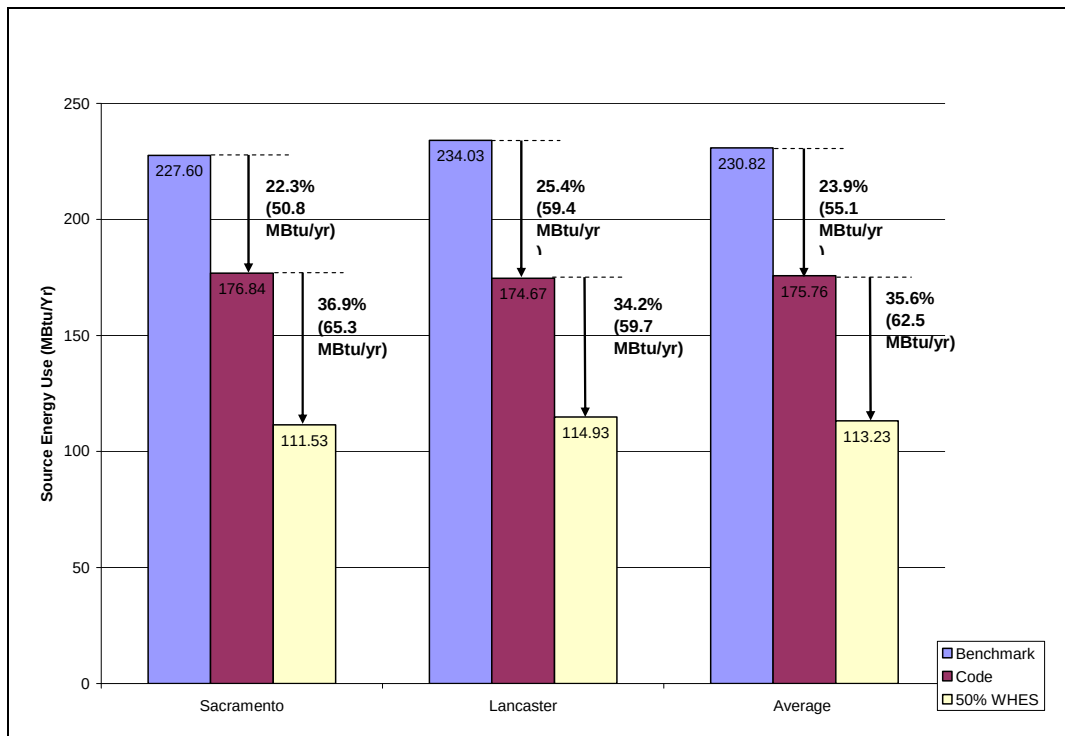


Figure 21: Whole-House Energy Savings in Title-24 Region

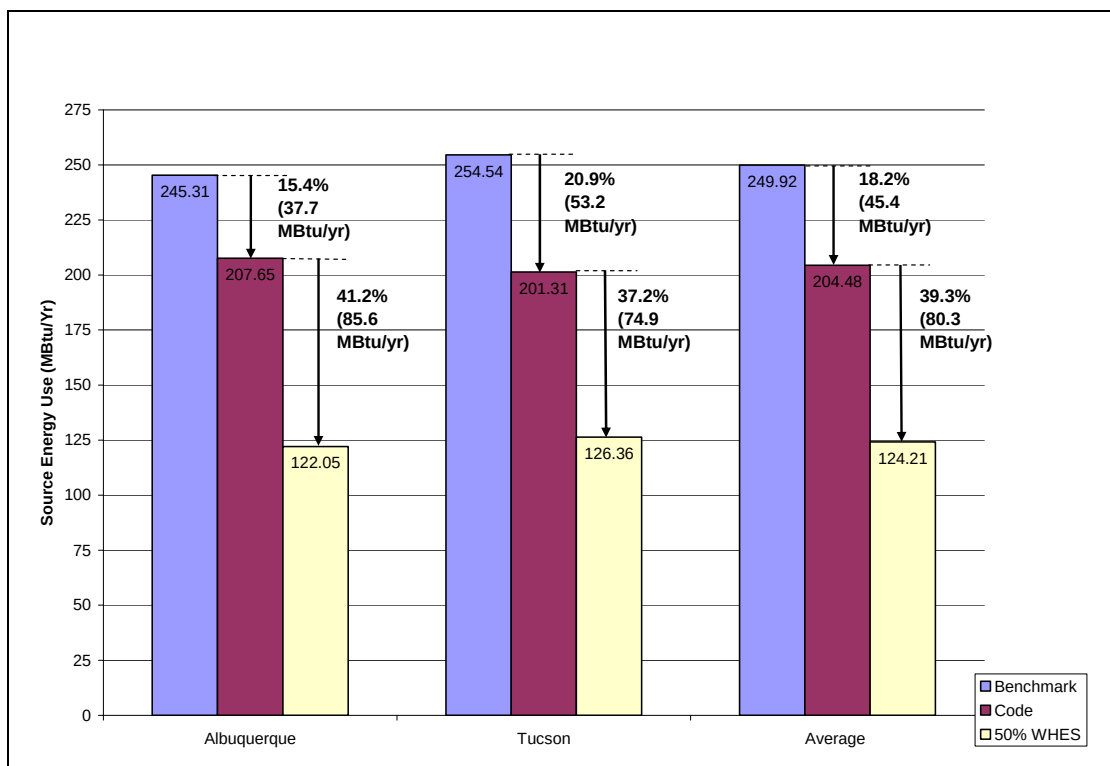


Figure 22: Whole-House Energy Savings in IECC Region

Although MELs is the largest load group for both the Title-24 and IECC regions and accounts for approximately 41% of the whole house loads, they have been excluded from this list because solutions to MELs cannot be applied to all climate zones equivalently and are being addressed in separate research projects. Analysis shows space heating, space cooling, and lighting are the next highest major loads, as well as the loads with the greatest variation within the Hot/Mixed-Dry Climate. Figure 23 and Figure 24 show the variation in end-use loads for Title-24 and IECC climates zones, respectively.

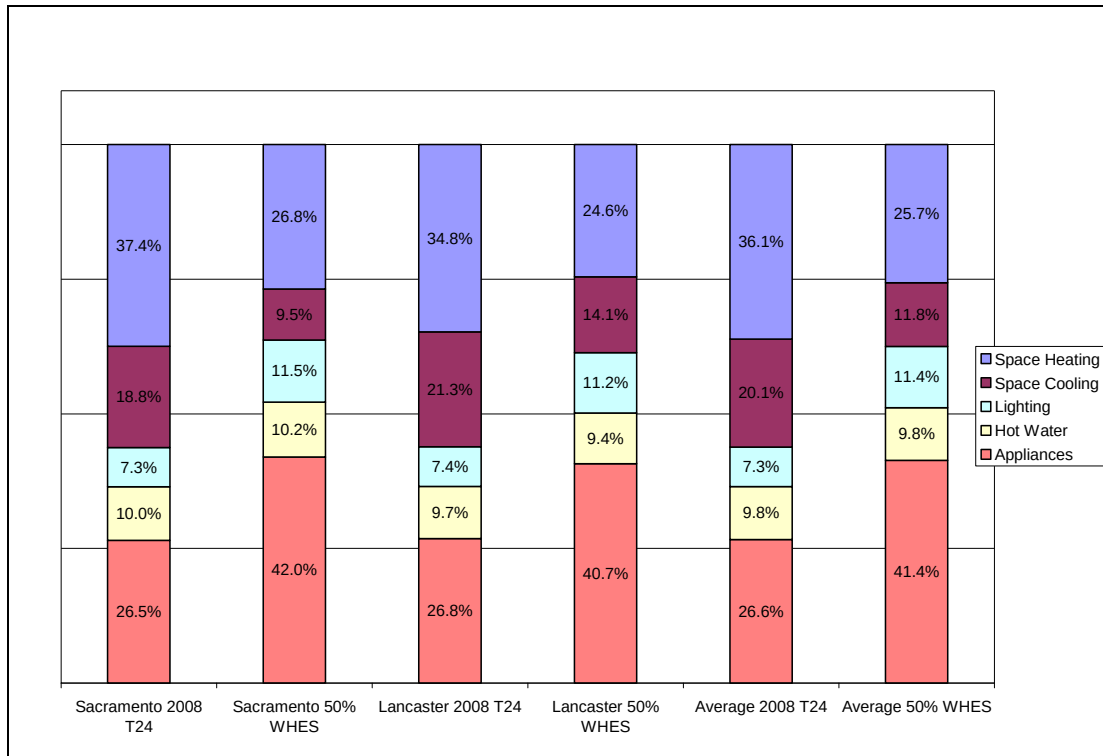


Figure 23: End-Use Energy Loads for 2008 Title-24 and 50% WHES

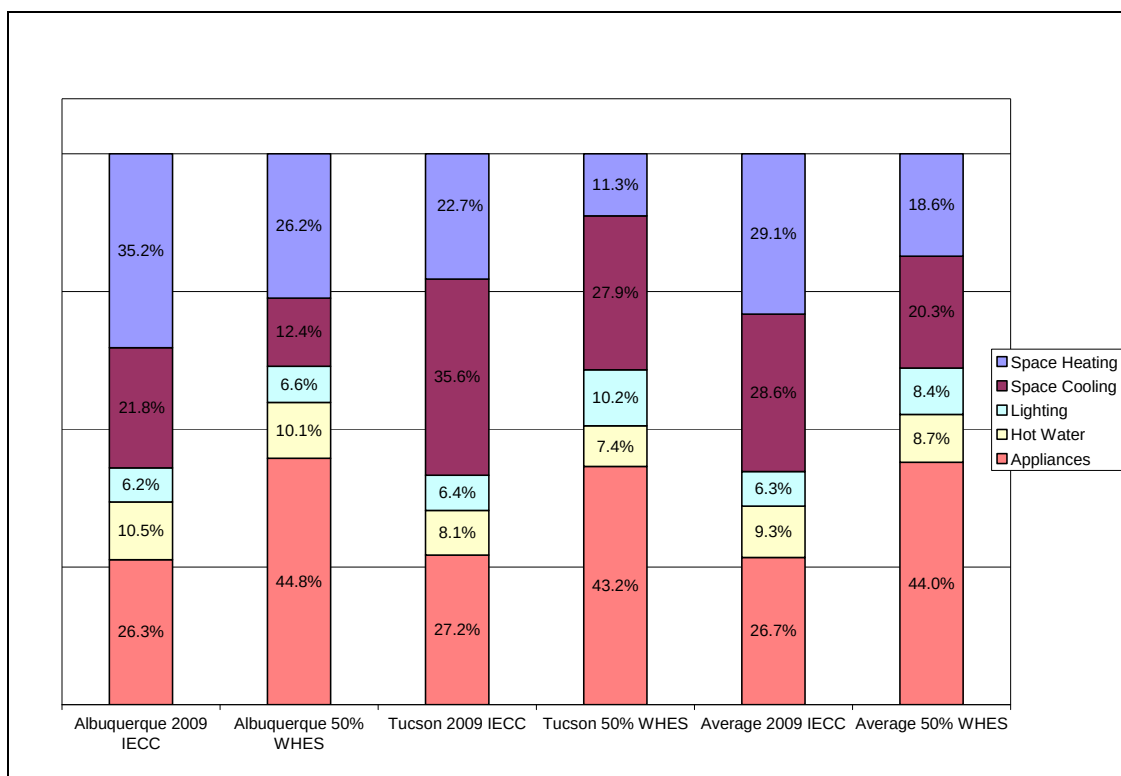


Figure 24: End-Use Energy Load for 2009 IECC and 50% WHES

Analyzes were run in all four cardinal orientations to produce an average WHES for solar orientation. Achieving the 50% WHES level does not require orienting homes in any particular direction. However, making the best use of the sun brings many advantages. Builders should, if possible, consider orientation during site development stage of the homebuilding process; a virtually no-cost option for improving energy performance is to account for optimum orientation for passive solar benefit. Site planning should take advantage of southern windows and roof exposure, as well.

Average features for code compliant and 50% WHES homes for the Hot/Mixed-Dry climate zone used in this simulation are given in Table 53 and Table 54.

Features	2008 Title-24	50% WHES
Insulation	R-13+1" foam Walls (2x4) R-19+1" foam Walls(2x6) R-30 to 38 Ceiling R-13 Garage	R-15+1" foam (R4) Walls (2x4) R-23+1" foam (R4) Walls (2x6) R-49 Ceiling R-15 Garage
Windows	U-Factor 0.35 SHGC 0.31	U-Factor 0.22 SHGC 0.22
Cooling	SEER 13 to SEER 14	SEER 15 to SEER 16
Heating	80% AFUE	90% AFUE

Features	2008 Title-24	50% WHES
Ducts	R-6/attic	R-8/interior
DHW	50 gal, 0.62 EF	Tankless, 0.98 EF
Infiltration	0.00038 SLA	0.00025 SLA
Lighting	80% Fluorescent	80% Fluorescent

Table 53: Average 2008 Title-24 and 50% WHES Features Summaries

Features	2009 IECC	50% WHES
Insulation	R-13 Walls (2x4) R-19 Walls (2x6) R-30 to 38 Ceiling R-13 Garage	R-15+1" foam (R4 to R5) Walls (2x4) R-23+1" foam (R4 to R5) Walls (2x6) R-49 to 60 Ceiling R-15 Garage
Windows	U-Factor 0.35 to 0.65 SHGC 0.35 to 0.65	U-Factor 0.22 SHGC 0.22 to 0.40
Cooling	SEER 13	SEER 13 to SEER 15
Heating	78% AFUE	80% to 95% AFUE
Ducts	R-8/attic	R-8/interior
DHW	50 gal, 0.58 to 0.62 EF	Tankless, 0.98 EF
Infiltration	0.00036 SLA	0.00025 SLA
Lighting	80% Fluorescent	80% to 100% Fluorescent

Table 54: Average 2009 IECC and 50% WHES Features Summaries

Leading candidates for reducing both the space heating and space cooling end-use energy loads include improvements to the wall framing and HVAC system. The impact of advanced framing on WHES depends on the choice of wall insulation. Walls with high R-values are critical for cooling load reduction during the summer months and heat retention during the winter months. Different building materials and practices can be used to create a house with high R-value walls such as structural insulated panels (SIPs), optimum value engineered (OVE) walls, and exterior foam sheathing. The 50% WHES technology pathway include walls that utilize a 2x6 @ 24" o.c. advanced framing technique incorporating R-15 insulation with 1" sheathing (R4), as well as R-23 insulation with 1" sheathing (R4) in a portion of the house. By providing a better thermal seal, these advanced framing systems greatly reduce conductive heat loss or gain, thereby decreasing both heating and cooling loads.

Furthermore, the 50% WHES technology pathway increased HVAC system efficiency by moving all air ducts into conditioned space reducing efficiency losses due to duct leakage. Improving

the HVAC efficiency as a system will naturally reduce energy loads through a more efficient unit. The 50% WHES technology pathway for the Title-24 region incorporated a 90% AFUE natural gas furnace and a 15 to 16 SEER (based on exact location) central air conditioning unit and the 50% technology pathway for the IECC region incorporated an 80% to 94% AFUE natural gas furnace and a 13 to 15 SEER central air conditioning unit

Analysis shows that there is a potential for 15% WHES improvement in space heating over 2008 Title-24 and 2009 IECC with the use of the high-efficiency natural gas furnaces. The high-SEER central A/C unit result in 10% to 13 % WHES for 2008 Title-24 and 2009 IECC respectively.

In order to target the domestic water heating (DWH) load, tankless water heating systems should be installed, provided efficiencies around 95% to 98%. Utilizing this technology can increase WHES by 3%.

Combined, these features can improve WHES by 27-32% above the 2008 Title-24 and 2009 IECC standard, thereby achieving 50% WHES. The defined features can be utilized as a technology pathway which will ease progression into the next Joule milestone. The next Joule milestone for Hot/Mixed-Dry will be 70% WHES in 2015.

“Must Meet” Gate Criteria -- Neutral Cost Target

BIRA builder partners provided accurate incremental costs and industry review of proposed features for 50% WHES technology pathway. Builder partners who provided incremental costs and reviews in the Hot/Mixed-Dry climate zone include K Street LLC and Artistic Homes. Incomplete incremental costs were supplemented with costs from the database of Energy Gauge. In cases of summed incremental costs (provided by builder partners), costs were divided between components for average costs.

Feedback from builder partners indicates that the increased costs of improvements meet the cost neutrality target when compared to regional standard practice (2008 Title-24 for California or 2009 IECC for non-California locations). For a baseline home built to 50% WHES, analysis shows that the annual utility bills plus the annual incremental mortgage (upgraded from code building features) is less than the annual utility bills of the BA Benchmark. The annual savings for 50% WHES can be seen on Figure 25 and Figure 26, for 2008 Title-24 and 2009 IECC, respectively.

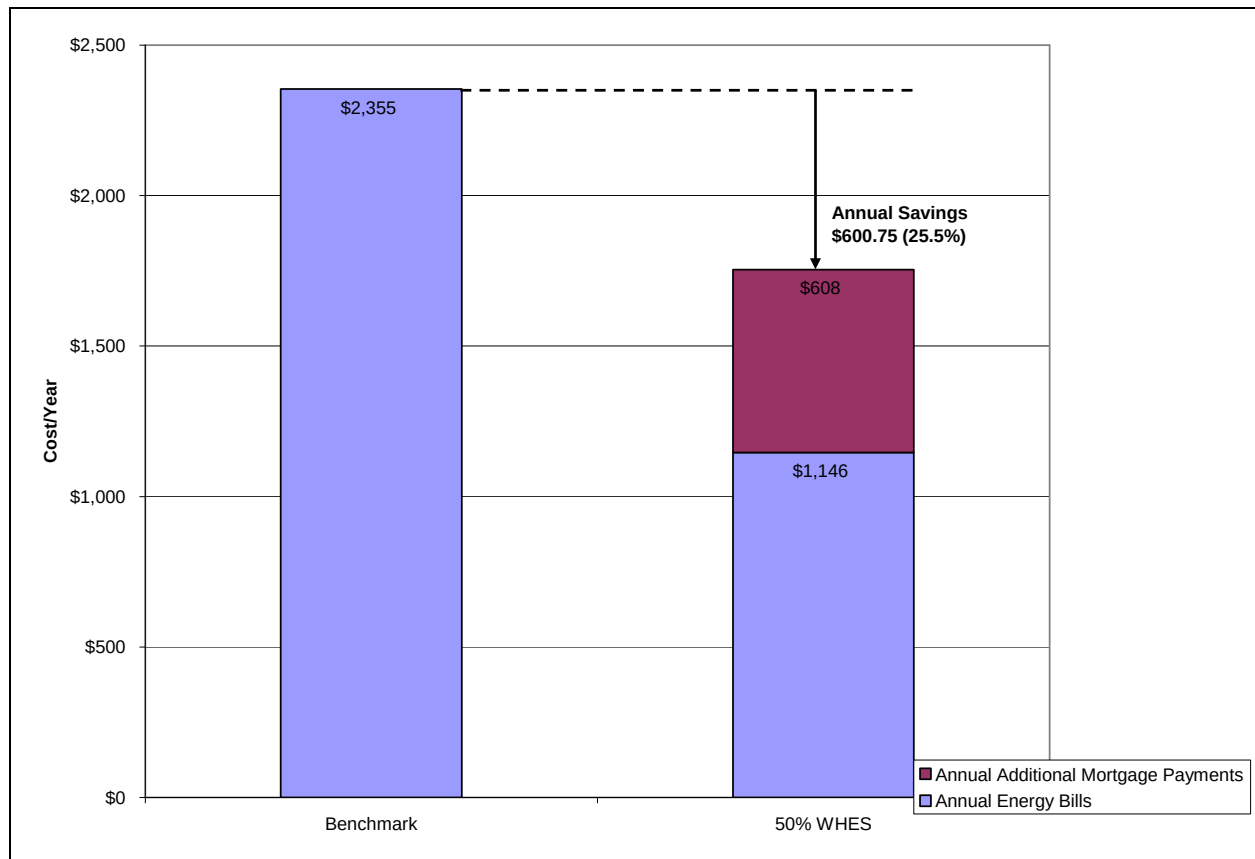


Figure 25: Annual Net Savings for 50% WHES (upgraded from 2008 Title-24)

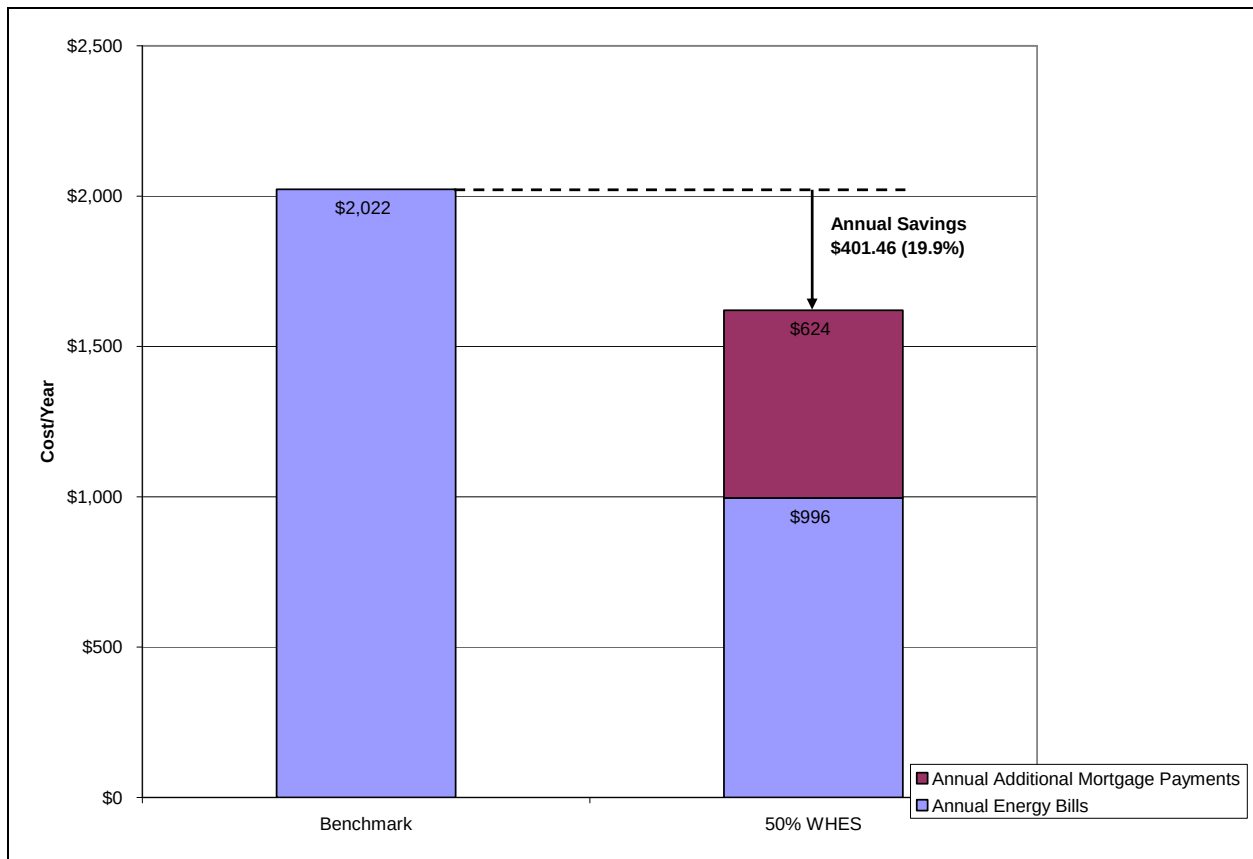


Figure 26: Annual Net Savings for 50% WHES (upgraded from 2009 IECC)

The 2008 Hot/Mixed-Dry Stage Gate 1A analysis showed that 50% WHES fulfills the neutral cost target from 2005 Title-24 and 2006 IECC. Cost neutrality was demonstrated by using the prescribed strategy developed by the BIRA team, along with estimated incremental feature costs. Current Stage Gate 1A analysis uses similar methods with verified incremental feature costs to show a positive cash flow for a 50% WHES baseline home upgraded from 2008 Title-24 and 2009 IECC.

Although there are currently thousands of incentive dollars available for new production homebuilders and homebuyers for energy efficient homes, there will eventually be insufficient funds to support the increase in new energy efficient homes construction and purchasing. Therefore rebates or tax credits were not included in the calculation of cost flow to provide a more accurate analysis.

When the 50% WHES baseline home in a Title-24 region is mortgaged at 7% APR over 30 years, the \$7,612 incremental features cost translates to a \$608 increase in the annual mortgage payment. Annual utility savings are projected to be \$1,209 per year, thereby netting a total of \$601 per year in savings to the homeowner. This analysis is summarized in Table 55.

The 50% baseline home in an IECC region was also studied using similar methods and found to

have a positive cash flow of \$401 per year to the homeowner. This analysis is summarized in Table 56.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	California Code Home	Prototype	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	71.3	63.5	29.1	59.2%	54.2%	18.3%	19.6%	\$378
Space Cooling	60.9	35.3	13.4	78.0%	62.1%	20.6%	12.5%	\$539
DHW	20.5	17.3	11.1	45.8%	35.8%	4.1%	3.5%	\$83
Lighting	28.8	12.9	12.9	55.3%	0.0%	6.9%	0.0%	\$180
Appliances and MELs	49.3	46.8	46.8	5.1%	0.0%	1.1%	0.0%	\$29
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%	\$0
Total Usage/ Savings	230.8	175.8	113.2	50.9%	35.6%	50.9%	35.6%	\$1,209

	Energy Efficiency Feature			Builder Cost	10% Markup	Total	Annual Mortgage Cost vs. Code
	80% CFL Lighting			\$0	\$0	\$0	\$0
	98% EF Tankless Water Heater			\$657	\$66	\$722	(\$58)
	Improved Duct Sealing, Envelope Sealing, and Testing			\$1,242	\$124	\$1,366	(\$109)
	Radiant Barrier			\$506	\$51	\$557	(\$44)
	R30 Above Garage insulation			\$79	\$8	\$87	(\$7)
	R15 Wall Insulation+1" foam			\$742	\$74	\$817	(\$65)
	R23 Wall Insulation+1" foam			\$795	\$80	\$875	(\$70)
	R15 Garage Walls			\$110	\$11	\$121	(\$10)
	R49 Attic Insulation			\$578	\$58	\$635	(\$51)
	5/8" Drywall			\$240	\$24	\$264	(\$21)
	90% AFUE Furnace			\$328	\$33	\$361	(\$29)
	15 to 16 SEER A/C unit			\$369	\$37	\$406	(\$32)
	Highly Efficient Windows			\$1,126	\$113	\$1,238	(\$99)
	Pipe Insulation Water Distribution			\$150	\$15	\$165	(\$13)
	Totals			\$6,920	\$692	\$7,612	(\$608)
	Net Annual Cash Flow to Consumer			\$601			

Table 55: Average Cost Savings for 50% WHES in Title- 24 Region

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	California Code Home	Prototype	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	70.9	59.5	23.1	67.4%	61.2%	19.1%	17.8%	\$436
Space Cooling	73.0	58.5	25.2	65.5%	56.9%	19.1%	16.3%	\$344
DHW	20.1	19.0	10.8	46.2%	43.1%	3.7%	4.0%	\$90
Lighting	28.8	12.9	10.4	63.7%	18.8%	7.3%	1.2%	\$137
Appliances and MELs	57.2	54.6	54.6	4.4%	0.0%	1.0%	0.0%	\$19
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%	\$0
Total Usage/ Savings	249.9	204.5	124.2	50.3%	39.3%	50.3%	39.3%	\$1,026

	Energy Efficiency Feature	Builder Cost	10% Markup	Total	Annual Mortgage Cost vs. Code
	80% to 100% CFL Lighting	\$0	\$0	\$0	\$0
	98% EF Tankless Water Heater	\$657	\$66	\$722	(\$58)
	Improved Duct Sealing, Envelope Sealing, and Testing	\$1,242	\$124	\$1,366	(\$109)
	Radiant Barrier	\$506	\$51	\$557	(\$44)
	R30 Above Garage insulation	\$211	\$21	\$232	(\$19)
	R15 Wall Insulation+R4 to R5 sheathing	\$970	\$97	\$1,067	(\$85)
	R23 Wall Insulation+R4 to R5 sheathing	\$795	\$80	\$875	(\$70)
	R15 Garage Walls	\$110	\$11	\$121	(\$10)
	R49 to R60 Attic Insulation	\$578	\$58	\$635	(\$51)
	5/8" Drywall	\$245	\$25	\$270	(\$22)
	80% to 95% AFUE Furnace	\$250	\$25	\$275	(\$22)
	13 to 15 SEER A/C unit	\$271	\$27	\$298	(\$24)
	Highly Efficient Windows	\$1,126	\$113	\$1,238	(\$99)
	Pipe Insulation Water Distribution	\$150	\$15	\$165	(\$13)
	Totals	\$7,109	\$711	\$7,820	(\$624)
	Net Annual Cash Flow to Consumer				\$401

Table 56: Average Cost Savings for 50% WHES in IECC Region

“Should Meet” Gate Criteria -- Least Cost

Building America's team-based systems-research approach, including use of systems-engineering and operations research techniques, provides opportunities for cost and performance trade-offs that improve whole-building performance and value, while minimizing increases in overall building cost. Systems research includes analysis of system performance and cost tradeoffs as they relate to whole-building energy performance and cost optimization, including interactions between advanced envelope designs, mechanical and electrical systems, lighting systems, space-conditioning systems, hot water systems, major appliances, miscellaneous electric loads, energy control systems, renewable energy systems, and onsite power generation systems. Accordingly, the recommended technology pathways for 50% WHES in this report have been demonstrated to cost effectively increase overall product value and quality compared to conventional approaches, while significantly reducing energy use and use of raw materials consumption when utilized on a production basis. The incremental cost of the 50% WHES technology package is less than the currently available “least cost” alternatives based on sum of utility bills and energy-related increases in mortgage costs.

“Should Meet” Gate Criteria -- Marketability

The BIRA team sees no barriers to the marketability of these improvements. No drastic measures are needed to achieve 50% WHES, making it such that these houses would be indistinguishable from a typical code-built home on the surface. This would lessen any reluctance a buyer may have to buying a “green” home and similarly, reluctance builders might have to producing them. Moreover, energy efficiency is a factor that is becoming increasingly more significant to homebuyers. Analysis has shown cost neutrality can be achieved; the practical benefit of buying a money-saving house will be critical in the marketing process when presenting an above-code built home. Potential homeowner satisfaction should be marketed by presenting both comfort and cost efficiency through advanced building features that result in energy savings.

“Should Meet” Gate Criteria -- Gaps Analysis

A possible gap involves the learning curve associated with builders who are unfamiliar with advanced wall framing or optimal value engineering (OVE). Addressing builders' concerns for OVE options such as 2x6 @ 24" o.c. and CSIPs will be important for reaching future Joule milestones. Once the technique becomes more familiar, it should prove to be more cost effective as it reduces material cost and construction time. Additionally, if a CSIP product is chosen as part of a 50% technology pathway, research regarding local training and warranty restrictions should be completed.

Another potential barrier to successfully implement the advanced wall framing technique is inspection and permitting issues from local building departments. Due to the relatively unknown nature of OVE, some building departments have resorted to denying permits.

Advanced wall framing can add complication to the inspection process if the building department is not familiar with the building practice. BIRA recommends working with the local building department during the beginning stages of planning and devolvment in an effort to avoid such situations.

50% Cold Budget Period 2

The 50% Cold study focused on the high desert regions, notably Salt Lake City, Utah as this area offers on-going research opportunities for BIRA in both Cold and Hot/Mixed Dry climates.

Stage Gate 1A work is in progress. Technology pathways for reaching the 50% WHES goal have been identified. These strategies have been evaluated by builder and industry partners and are the most feasible solution to achieving 50% WHES. NREL will be asked to review the pathways after builder and industry feedback is completed.

"Must Meet" Gate Criteria -- Source Energy Savings

Simulations run in Energy Gauge v.2.8.01 indicate that Kennecott Land's current building practices, which closely resemble ENERGY STAR guidelines, produce homes that perform at a 34% WHES level relative to the BA Benchmark. The 50% WHES technology pathway was decided based on information about the building features' availability, ease of use, and cost, provided by the BIRA team's builder partners. The technology pathways used in simulations are shown in Table 57.

Features	2006 IECC	Kennecott	Energy Star	50%WHES
Insulation	R-14.33 Wall R-28.73 Ceiling	R-19 Wall R-38 Ceiling	R-19 Wall R-38 Ceiling	R-23+1"foam (R5) Wall R-60 Ceiling
Windows	0.35 U-Factor 0.40 SHGC	0.35 U-Factor 0.38 SHGC	0.35 U-Factor SHGC NR	0.22 U-Factor 0.55 SHGC
Cooling	SEER 13	SEER 13	SEER 13	SEER 19
Heating	0.78 AFUE	0.90 AFUE	0.90 AFUE	0.95 AFUE
Ducts	Interior Ducts	R-8 Supply R-4 Return In Uncond. Space	R-6 in Unconditioned Space	Interior Ducts
DHW	NG 0.56 EF	NG 0.60 EF	NG 0.60 EF	0.98 EF Tankless

Table 57: Comparison of Major Features

Simulation of the baseline home built at the 2006 IECC standard shows that it is approximately 19% WHES above the BA Benchmark. The baseline home built at the 50% WHES level will perform approximately 39% better than the 2006 IECC standard. A source energy use comparison of the benchmark, 2006 IECC and 50% WHES are shown in Figure 27.

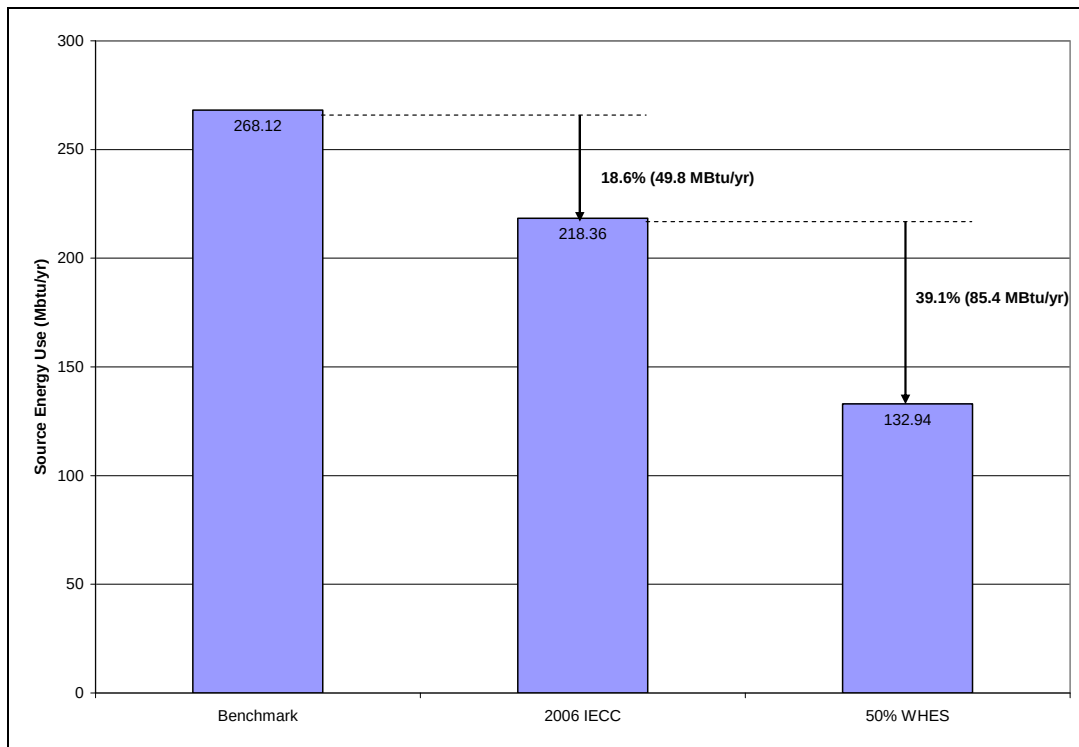


Figure 27: Whole-House Energy Savings

The major loads for 50% WHES in the Cold Climate are heating (~30%), water heating (~10%) and lighting (~10%). Although MELs is the largest load group and accounts for approximately 41% of the whole house loads, they have been excluded from this list because solutions to MELs cannot be applied to all climate zones equivalently and are being addressed in separate research projects. While not a significant load in most regions of the Cold Climate, cooling still shows significant impact on whole house energy consumption in the high desert region (~9%). With the exception of lighting, currently available and well established solutions to these major loads exist and can be implemented to achieve the 50% WHES level. Solutions to the lighting load exist, but lack the market penetration of the other load solutions. End-use energy loads are shown in Figure 28 and Figure 29.

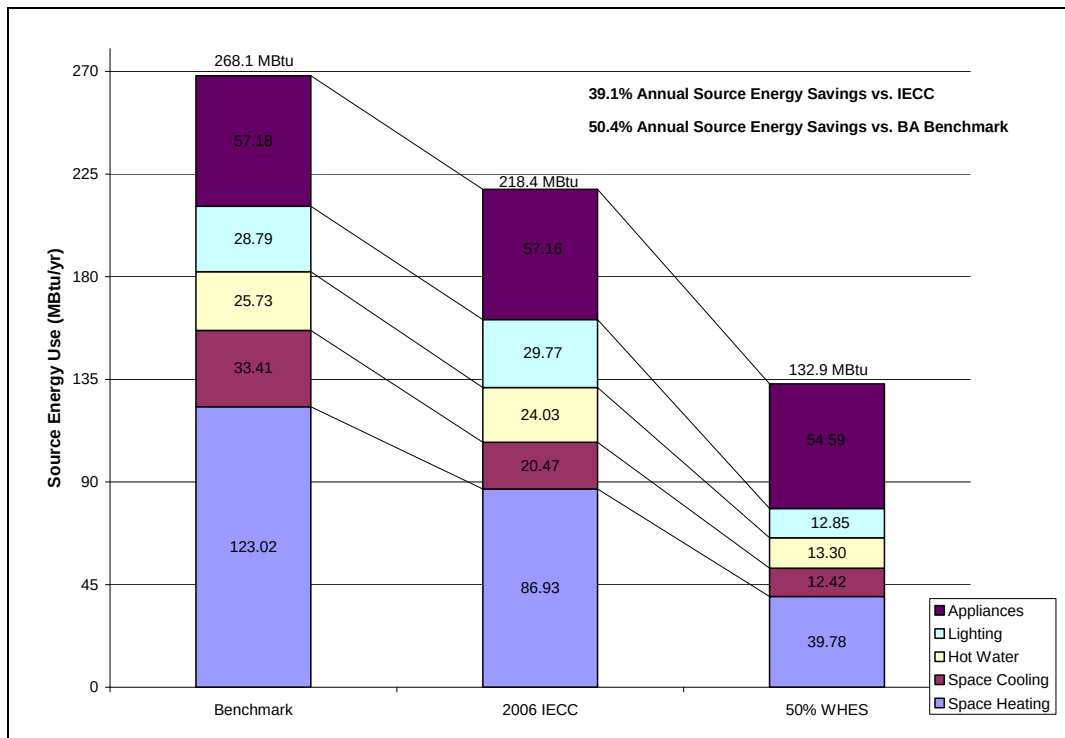


Figure 28: End-Use Energy Loads

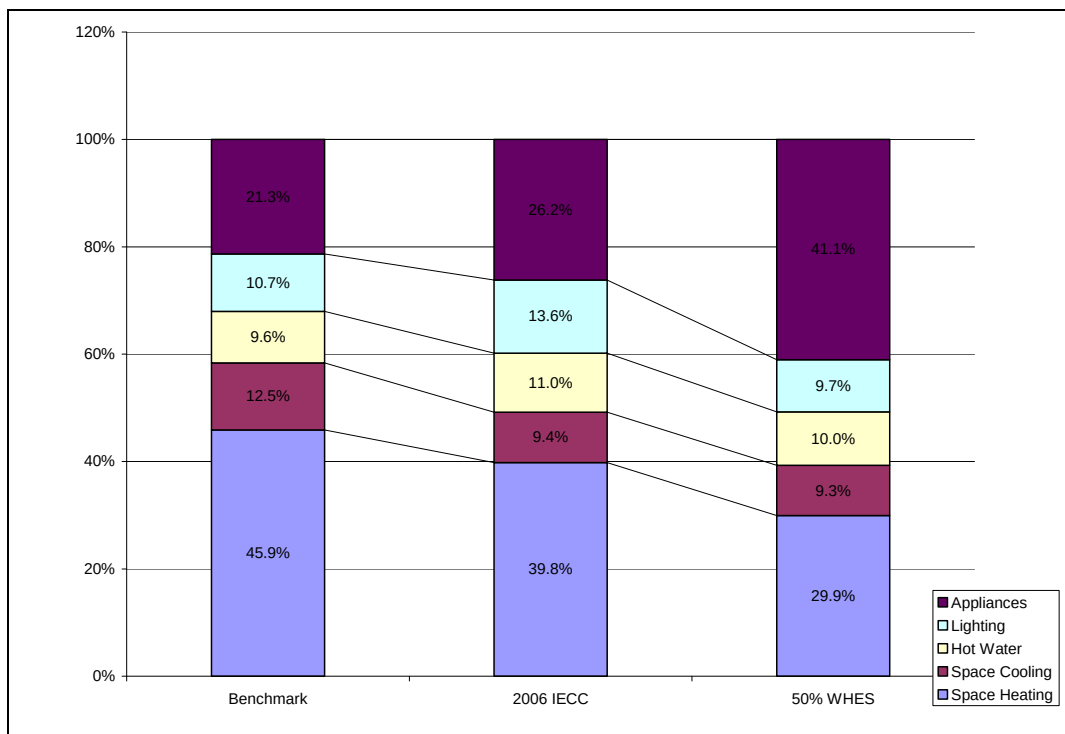


Figure 29: End-Use Energy Load as Percentage of Total

Analyses were run in all four cardinal orientations to produce an average savings based on solar orientation. Achieving the 50% WHES level does not require orienting homes in any particular direction. However, making the best use of the sun brings many advantages. Builders should, if possible, consider orientation during site development phase of the homebuilding process; a virtually no-cost option for improving energy performance is to account for optimum orientation for passive solar benefit. Site planning should take advantage of southern windows and roof exposure, as well.

Leading candidates for reducing both the space heating and space cooling end-use energy loads include improvements to the wall framing and HVAC system. The impact of advanced framing on WHES depends on the choice of wall insulation. Walls with high R-values are critical for cooling load reduction during the summer months and heat retention during the winter months. Different building materials and practices can be used to create a house with high R-value walls such as structural insulated panels (SIPs), optimum value engineered (OVE) walls, and exterior foam sheathing. The 50% WHES technology pathway includes walls that utilize a 2x6, 24" o.c. advanced framing techniques incorporating R-15 insulation with 1" sheathing (R5), as well as R-23 insulation with 1" sheathing (R5) in a portion of the house. By providing a better thermal seal, these advanced framing systems greatly reduce conductive heat loss or gain, thereby decreasing both heating and cooling loads.

Furthermore, the 50% WHES technology pathway increased HVAC system efficiency by moving all air ducts into conditioned space which reduces efficiency losses due to duct leakage. Improving the HVAC efficiency as a system will naturally reduce energy loads through a more efficient unit. The 50% WHES technology pathway incorporated a 95% AFUE natural gas furnace and a 19 SEER central air conditioning unit.

Analysis shows that there is a potential for 31% WHES improvement in space heating over 2006 IECC with the use of the 95% AFUE natural gas furnace and an additional 8% WHES is available in space cooling when the 19 SEER central A/C unit is utilized. Future work in Gate 1B will incorporate research in high efficiency HVAC systems, including both high-SEER, central compressor A/C units and high-SEER, compressor-less evaporative coolers.

In order to target the domestic water heating (DWH) load, tankless water heating systems should be installed, with provided efficiencies around 95% to 98%. Utilizing this technology can increase WHES by 5%.

The 2006 IECC standard for hardwired lighting is 10% fluorescent. By upgrading the baseline home with 80% CFL, the lighting end-use energy load will add 6% WHES.

When combined, these technologies would increase energy efficiency enough to achieve the 50% WHES goal assuming the remaining load is built to 2006 IECC standards. The defined features can be utilized as a technology pathway which will ease progression into the next Joule milestone. (The next Joule milestone for the Cold Climate will be 70% WHES in 2018.)

“Must Meet” Gate Criteria -- Neutral Cost Target

BIRA’s builder partners provided accurate incremental costs and industry review of proposed features for the 50% WHES technology pathway. Builder partners who provided incremental costs and reviews in the Cold Climate included Gold Medallion Homes. Incomplete incremental costs were supplemented with costs from the database of Energy Gauge. In cases of summed incremental costs (provided by builder partners), costs were divided between components for average costs.

Feedback from the builder partner indicates that the increased costs of improvements meet the cost neutrality target when compared to the 2006 IECC standard. For a baseline home built to 50% WHES, analysis shows that the annual utility bills plus the annual incremental mortgage (upgraded from the 2006 IECC building features) is less than the annual utility bills of the BA Benchmark. The annual savings for 50% WHES can be seen on Figure 30.

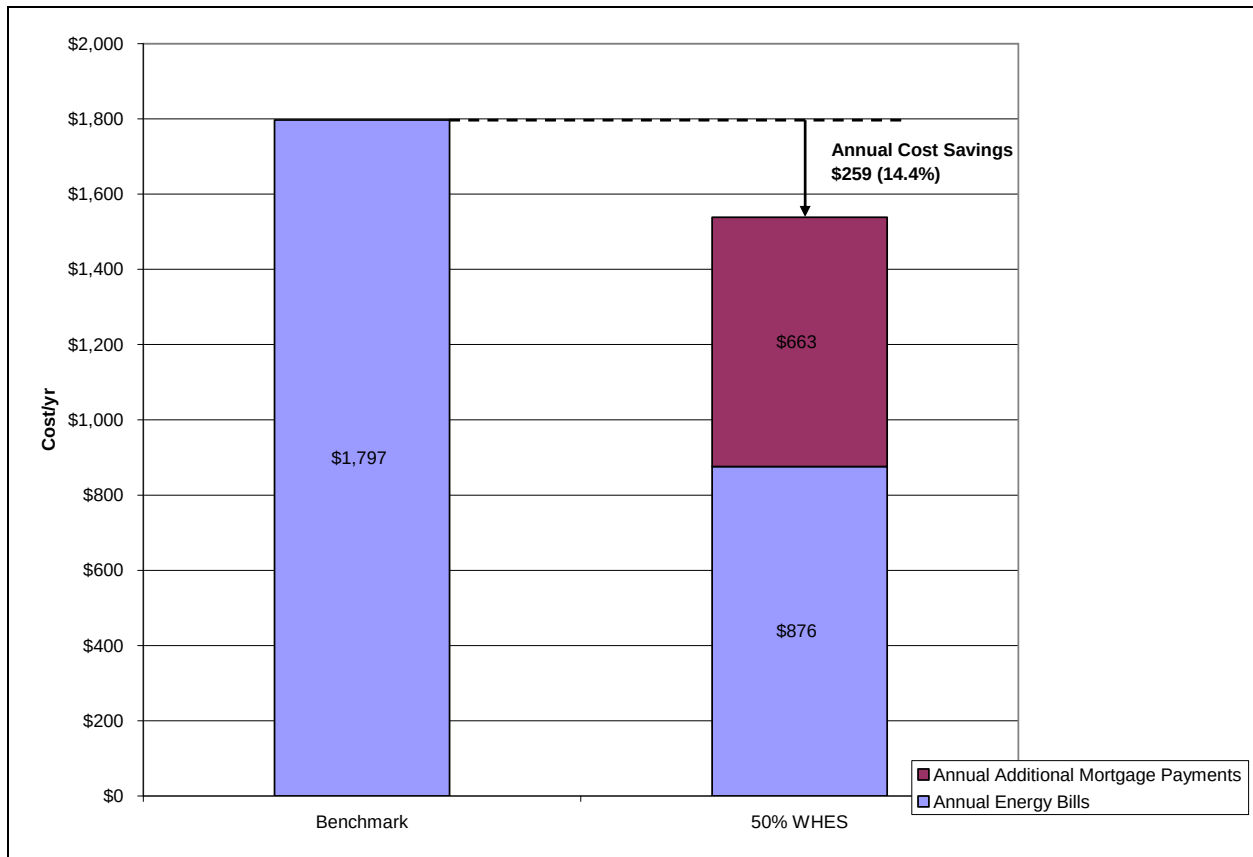


Figure 30: Annual Net Savings for 50% WHES

Although there are currently thousands of incentive dollars available for new production homebuilders and homebuyers for energy efficient homes, there will eventually be insufficient funds to support the increase in new energy efficient home construction and purchasing. Therefore rebates or tax credits were not taken into account for calculation of cost flow to be

as accurate as possible.

When the 50% WHES baseline home is mortgaged at 7% APR over 30 years, the \$8,304 incremental features cost translates to a \$663 increase in the annual mortgage payment. Annual utility bill savings are projected to be \$922 per year, thereby netting a total of \$259 per year in savings to the homeowner. This analysis is summarized in Table 58.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	California Code Home	Prototype	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	123.0	86.9	39.8	67.7%	54.2%	31.0%	21.6%	\$597
Space Cooling	33.4	20.5	12.4	62.8%	39.3%	7.8%	3.7%	\$128
DHW	25.7	24.0	13.3	48.3%	44.6%	4.6%	4.9%	\$84
Lighting	28.8	29.8	12.9	55.3%	56.8%	5.9%	7.7%	\$98
Appliances and MELs	57.2	57.2	54.6	4.5%	4.5%	1.0%	1.2%	\$15
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%	\$0
Total Usage/ Savings	268.1	218.4	132.9	50.4%	39.1%	50.4%	39.1%	\$922

	Energy Efficiency Feature			Builder Cost	10% Markup	Total	Annual Mortgage Cost vs. Code
	80% CFL Lighting			\$0	\$0	\$0	\$0
	98% EF Tankless Water Heater			\$700	\$70	\$770	(\$61)
	Improved Duct Sealing, Envelope Sealing, and Testing			\$1,155	\$116	\$1,271	(\$101)
	Radiant Barrier			\$512	\$51	\$563	(\$45)
	R30 Above Garage insulation			\$132	\$13	\$145	(\$12)
	R15 Wall Insulation+1" foam (R5)			\$224	\$22	\$246	(\$20)
	R23 Wall Insulation+1" foam (R5)			\$538	\$54	\$592	(\$47)
	R15 Garage Walls			\$0	\$0	\$0	\$0
	R60 Attic Insulation			\$1,806	\$181	\$1,987	(\$159)
	5/8" Drywall			\$70	\$7	\$77	(\$6)
	95% AFUE Furnace			\$314	\$31	\$345	(\$28)
	19 SEER A/C unit			\$1,184	\$118	\$1,302	(\$104)
	Highly Efficient Windows			\$764	\$76	\$840	(\$67)
	Pipe Insulation Water Distribution			\$150	\$15	\$165	(\$13)
	Totals			\$7,549	\$755	\$8,304	(\$663)
	Net Annual Cash Flow to Consumer						\$259

Table 58: Cash Flow for 50% WHES

“Should Meet” Gate Criteria – Least Cost

Building America's team-based systems-research approach, including use of systems-engineering and operations research techniques, provides opportunities for cost and performance trade-offs that improve whole-building performance and value, while minimizing increases in overall building cost. Systems research includes analysis of system performance and cost tradeoffs as they relate to whole-building energy performance and cost optimization, including interactions between advanced envelope designs, mechanical and electrical systems, lighting systems, space-conditioning systems, hot water systems, major appliances, miscellaneous electric loads, energy control systems, renewable energy systems, and onsite power generation systems. Accordingly, the recommended technology pathways for 50% WHES described in this report have been demonstrated to cost effectively increase overall product value and quality compared to conventional approaches, while significantly reducing energy use and raw materials consumption when utilized on a production basis. The incremental cost of the 50% WHES technology package is less than the currently available “least cost” alternatives based on sum of utility bills and energy-related increases in mortgage costs.

“Should Meet” Gate Criteria -- Marketability

BIRA sees no barriers to the marketability of the 50% WHES technology pathway. No drastic measures are needed to achieve 50% WHES, making it such that these houses would be indistinguishable from a typical 2006 IECC house on the surface. This would lessen any reservation a buyer may have to buying a “green” home and similarly, reluctance builders might have to producing them. Moreover, energy efficiency is a factor that is becoming more significant to homebuyers. Analysis has shown cost neutrality can be achieved; the practical benefit of buying a money-saving house will be critical in the marketing process when presenting a home that is built above-code. Potential homeowner satisfaction should be marketed by presenting both comfort and cost effectiveness achieved through advanced building features that result in energy savings.

“Should Meet” Gate Criteria -- Gaps Analysis

A possible gap involves the extended learning curve associated with builders who are unfamiliar with advanced wall framing or optimal value engineering (OVE). Addressing builders' concerns for OVE options like 2x6 @ 24" o.c. and CSIPs will be important for reaching future Joule milestones. Once the technique becomes more familiar it should prove to be more cost effective as it reduces material cost and construction time. Additionally, if a CSIP product is chosen as part of a 50% technology pathway, research regarding local training and warranty restrictions should be completed.

Another potential barrier to successfully implement the advanced wall framing technique is inspection and permitting issues from local building departments. Due to the relatively unknown nature of OVE, some building departments have resorted to denying permits.

Advanced wall framing can add complication to the inspection process if the building department is not familiar with the building practice. The BIRA team recommends working with the local building department during the beginning stages of planning and development in an effort to avoid such situations.

Gate 1A 60% Marine Budget Period 3

This report targets three cities in the Marine climate zone, biased towards regions where eligible communities will more likely occur, to develop a more representative understanding of the zone: Santa Barbara, San Jose, CA, and Seattle, WA. While all three of these cities are within the same Building America climate zone (Marine), each experiences a dramatically different winter season.

“Must Meet” Gate Criteria - Source Energy Savings

A baseline home was first established for a uniform analysis across all regions in the Marine climate zone. The design was based on typical industry practices in the region. Standard design for a medium size home includes 2123 square feet, 18% glazing, two floors, three bedrooms, and two bathrooms. The baseline home was used in all software analysis.

In EnergyGauge®, an energy analysis was performed using 2008 Title 24 and 2009 IECC prescriptive features. Using the baseline home, 60% WHES features were determined by upgrading code features and adhering to the region’s standard practice and design in region.

Analyses were run in all four cardinal orientations for an average solar orientation. Achieving the 60% level of energy savings does not require orienting homes in any particular direction. However, making the best use of the sun brings many advantages. Builders should, if possible consider orienting at the site development level of the homebuilding process; a virtually no-cost option for improving energy performance is to account for optimum orientation for passive solar benefit. Site planning should take advantage of southern windows and roof exposure, as well.

Results from simulations indicate homes built to 2008 Title 24 code provide on average 19% energy savings over the BA benchmark, while those built to 2009 IECC standards provide 22% energy savings over the BA benchmark. On average, homes built with the 60% WHES technological pathway provide 51% energy savings when compared to 2008 Title 24. Homes built to 60% WHES level in the IECC region will save 49% more energy than a home built to code. Comparisons can be seen in [Figure 31](#) and [Figure 32](#)

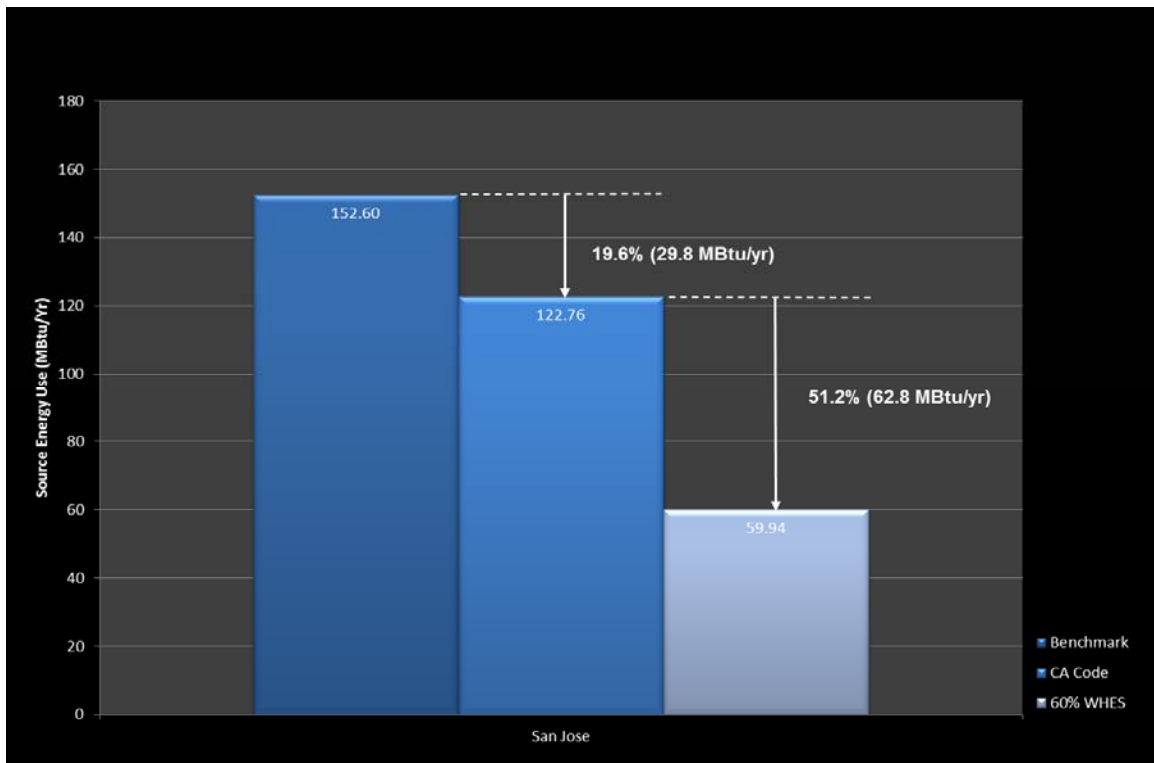


Figure 31: WHES in Title-24 region

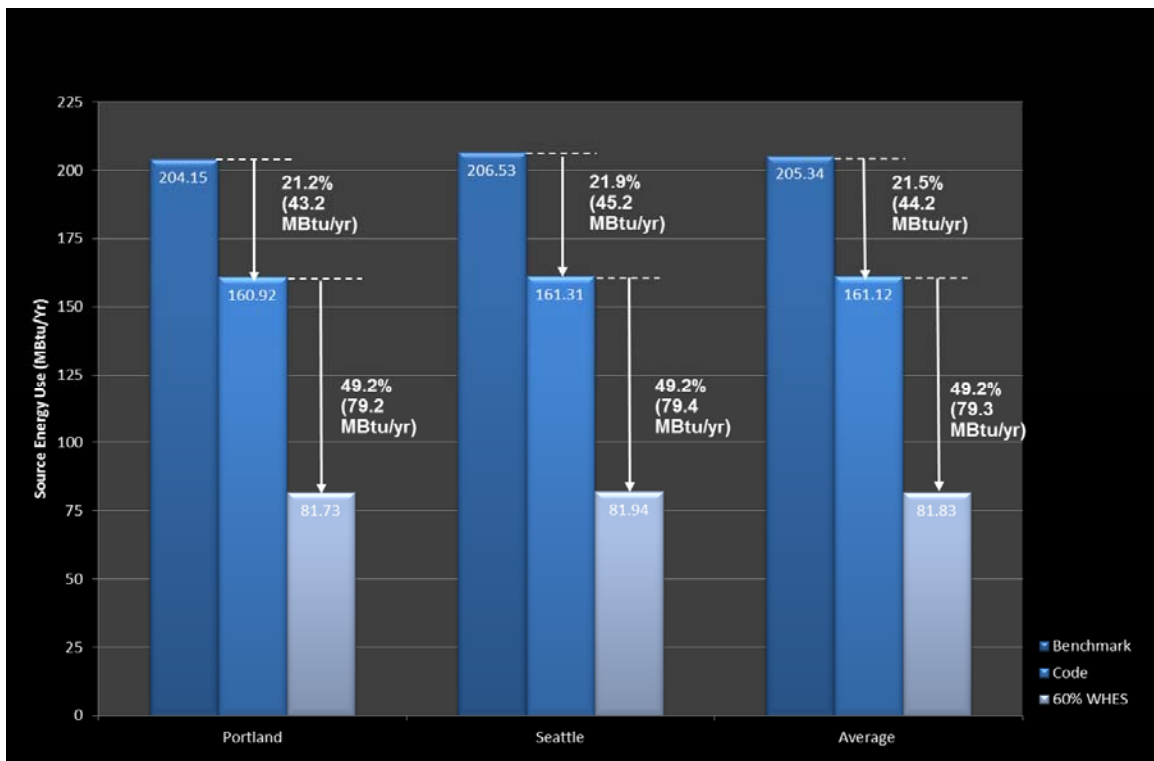


Figure 32: Whole-House energy savings in 2009 IECC region

For both the 2008 Title 24 and 2009 IECC regions, appliances (including MELs) represent the largest energy end-use load. In prior Gate 1A analysis, appliance efficiencies were not modified due the non-climate specific nature of the energy load. However, to reach the 60% WHES level, energy efficient appliances were required to be simulated. Analysis shows space heating, space cooling, and lighting are the next major loads, as well as the loads with the greatest variation within the Marine Climate. Figure 33 and Figure 34 show the variation in end-use loads for Title 24 and IECC regions, respectively.

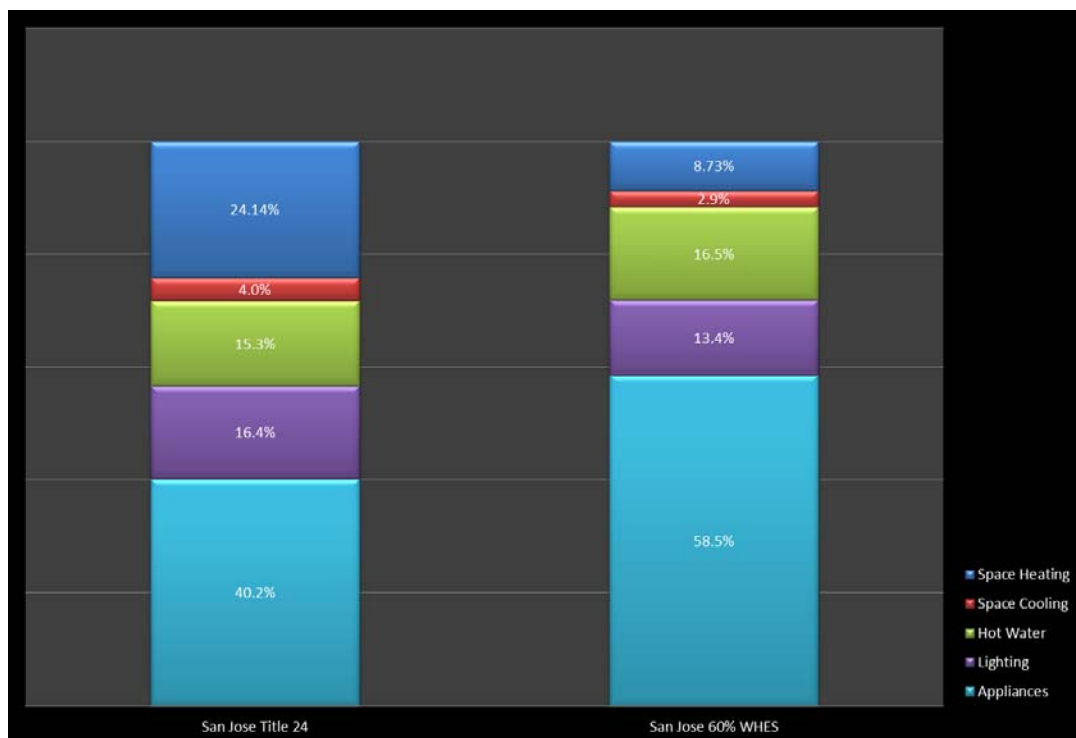


Figure 33: End-use energy loads for 2008 Title-24 and 60% WHES

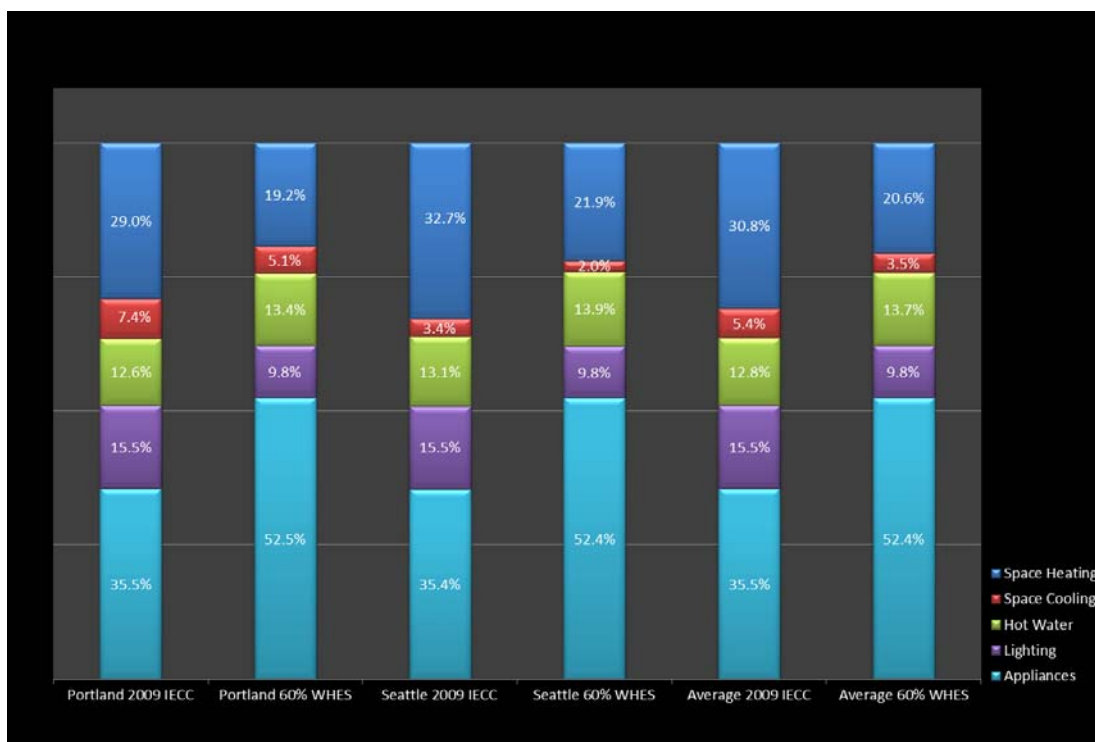


Figure 34: End-use energy load for 2009 IECC and 60% WHES

Analyses were run in all four cardinal orientations to produce an average WHES for solar orientation. Achieving the 50% WHES level does not require orienting homes in any particular direction. However, making the best use of the sun brings many advantages. Builders should, if possible, consider orientation during the site development stage of the homebuilding process; a virtually no-cost option for improving energy performance is to account for optimum orientation for passive solar benefit. Site planning should take advantage of southern windows and roof exposure, as well.

Average features for code compliant and 60% WHES homes for the Marine climate zone used in this simulation are given in [Table 49](#) and [Table 60](#).

Features	2008 Title-24	60% WHES
Insulation	R-13 Walls	R-42 Walls
	R-30 Ceiling	R-60 Ceiling
	R-19 Garage	R-30 Garage
Windows	U-Factor 0.40 SHGC 0.40	U-Factor 0.19 SHGC 0.40
Cooling	SEER 13	SEER 20
Heating	7.7 HSPF	10 HSPF
Ducts	N/A	Ductless

Features	2008 Title-24	60% WHES
DHW	50 gal, 0.62 EF	Tankless, 0.98 EF
Infiltration	3.6 ACH (50)	2.0 ACH(50)
Appliances	Standard	ENERGY STAR® rated
Lighting	50% Fluorescent	100% Fluorescent

Table 59: Average 2008 Title-24 and 60% WHES features summaries

Features	2009 IECC	60% WHES
Insulation	R-13+1" foam Walls R-38 Ceiling R-30 Garage	R-15+1" (R4) foam Walls (2x4) R-23+1" (R4) foam Walls (2x6) R-49 Ceiling R-15 Garage
Windows	U-Factor 0.35 SHGC 0.65	U-Factor 0.19 SHGC 0.65
Cooling	SEER 13	SEER 20
Heating	7.7 HSPF	10 HSPF
Ducts	N/A	Ductless
DHW	50 gal, 0.62 EF	Tankless, 0.98 EF
Infiltration	3.6 ACH (50)	2.0 ACH(50)
Appliances	Standard	ENERGY STAR® rated
Lighting	30% Fluorescent	100% Fluorescent

Table 60: Average 2009 IECC and 60% WHES features summaries

The technological pathway was developed based on a systems approach. All building features play a role in providing energy savings yet they are interdependent of each other. For that reason, building envelope air sealing was targeted for improvement. A low air infiltration rate will allow conditioned air to remain within the thermal envelope and will reduce exterior air infiltration. By improving envelope tightness, the advanced framing systems greatly reduce conductive heat loss or gain, thereby decreasing both heating and cooling loads. To prevent air leakage, it is important to properly seal the thermal envelope during the construction process, prior to the installation of drywall. Builder partner feedback shows this a mutual area of focus for improving whole house energy efficiency. Builder partners such as Martha Rose Construction, is continuously improving their standard building practice to ensure the envelope is constructed and sealed for maximum energy efficiency (refer to the final report Appendix D).

Leading candidates for reducing both the space heating and space cooling end-use energy loads include improvements to the wall assembly. The impact of advanced framing on WHES depends on the choice of wall insulation. Walls with high R-values are critical for cooling load reduction

during the summer months and heat retention during the winter months. Different building materials and practices can be used to create a house with high R-value walls such as structural insulated panels (SIPs), optimum value engineered (OVE) walls, and exterior foam sheathing. The 60% WHES technology pathway include walls that utilize a 2x6 @ 24" o.c. advanced framing technique and incorporate R-42 insulation. The advanced framing and high R-value insulation was continued throughout the building envelope, including the attic floor and above-garage floor. R60 ceiling insulation is a common building practice for Marine builder partners and subsequently was included in the 60% WHES technological pathway. Raised heel truss framing is required to ensure full insulation coverage and thickness all the way to the attic walls.

In the Marine climate zone, HVAC systems are region specific. In the Northern regions, space cooling is not addressed, however in Southern regions such as in San Jose the space cooling load is greater and homes typically include some form of air conditioning. The 60% WHES technology pathway utilizes increased HVAC system efficiency by incorporating a ductless mini split heat pump package system. Ductless HVAC systems eliminate efficiency losses due to duct leakage into unconditioned space. Improving the HVAC efficiency as a system will naturally reduce energy loads through a more efficient unit. Analysis shows the mini-split heat pump must have at least 10 HSPF and 20 SEER in both the Title 24 and IECC regions to reach the 60% WHES level. Analysis shows that there is a potential for 18 to 19% WHES improvement in space heating and cooling over 2008 Title 24 and 2009 IECC with the use of the high-efficiency ductless mini-split heat pump.

In order to target the domestic water heating (DWH) load, high efficiency water heating systems should be installed. Tankless hot water heaters can provide efficiencies around 98% and were used to achieve the 60% WHES. Utilizing this technology can increase WHES by 5 to 6%, depending on location. Water heating systems are continuously evolving and improving. Currently, there are several tank hot water heaters with high efficiency (maximum 96% EF) available in industry, including heat pump and direct vent systems; however tankless hot water systems provide a superior cost benefit. Appliance efficiencies were also analyzed and incorporated into the 60% WHES technological pathway. Prior Gate 1A studies did not utilize savings from energy efficient appliances because appliance energy loads are not relative to location (heating degree days). Appliances are also subject to potential removal and replacement with less energy efficient appliances by the homeowner. To ensure homes maintain the 60% WHES level, the energy efficient appliance industry will need to develop a specific plug and outlet combination available only to energy efficient appliances, similar to pin-based CFLS and LEDS bulbs. Combined, energy efficient appliances can improve WHES by 7 to 9%, thereby providing the remaining energy required to achieve the 60% WHES level.

The defined features can be utilized as a technology pathway which will ease progression into the next PMMs. The next PMM for Marine will be 70% WHES in 2015.

Neutral Cost Target

BA builder partners were utilized for accurate incremental costs and industry review of proposed features for the 60% WHES level. Feedback from builder partners, along with simulated energy costs, indicates that the additional cost of improvements meet the cost neutrality target when compared to regional standard practice (2008 Title 24 for California or 2009 IECC for non-California locations). For a baseline home built to 60% WHES, analysis shows that the annual utility bills plus the annual incremental mortgage (upgraded from code building features) is less than the annual utility bills of the BA Benchmark. The annual savings for 60% WHES can be seen on [Figure 35](#) and [Figure 36](#), for 2008 Title 24 and 2009 IECC, respectively.

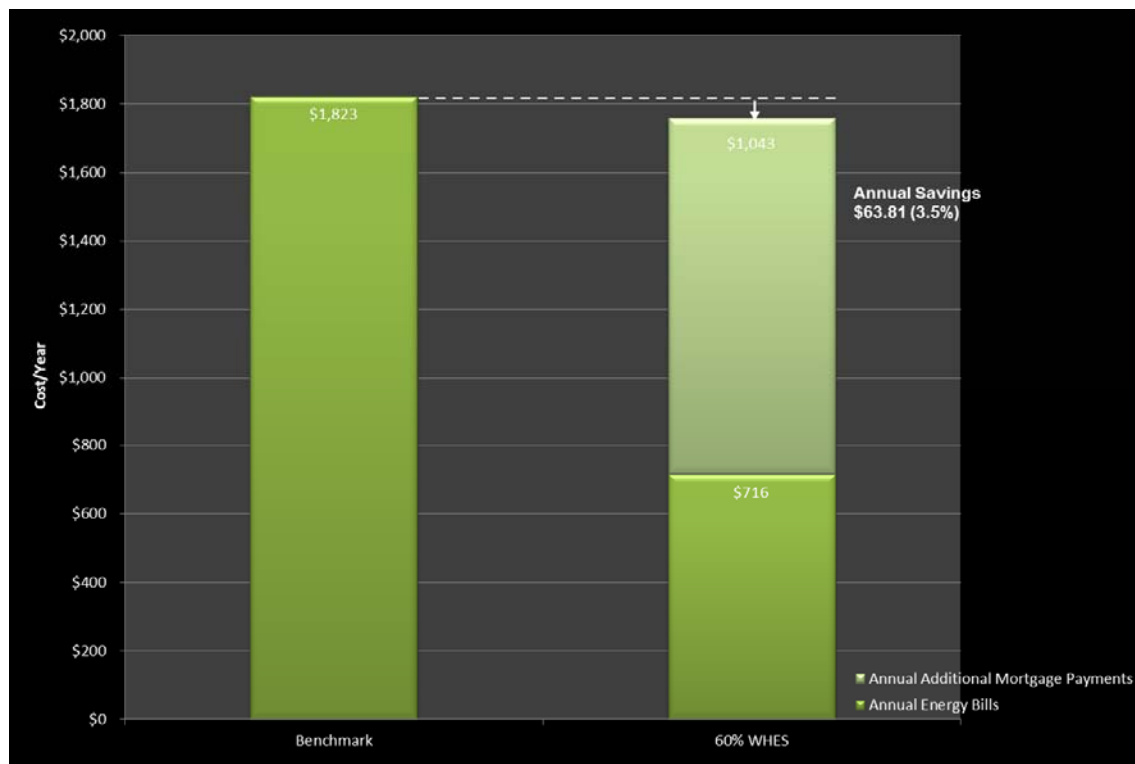


Figure 35: Annual net cost savings for 60%WHES (upgraded from 2008 Title-24)

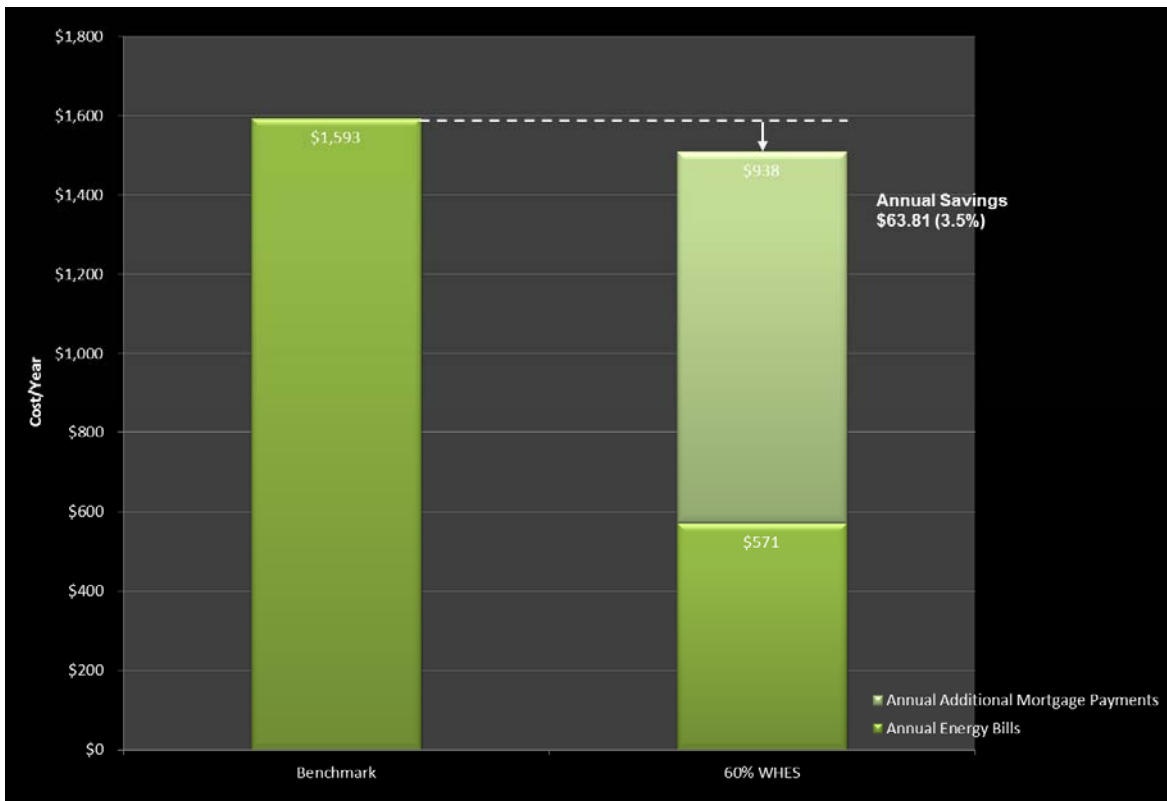


Figure 36: Annual net cost savings for 60%WHES (upgraded from 2009 IECC)

Although there are currently thousands of incentive dollars available for new production homebuilders and homebuyers for energy efficient homes, there will eventually be insufficient funds to support the increase in new energy efficient homes construction and purchasing. Therefore rebates or tax credits were not included in the calculation of cost flow to provide a more accurate analysis.

When the 60% WHES baseline home in a Title 24 region is mortgaged at 7% APR over 30 years, the \$13,070 incremental features cost translates to a \$1,043 increase in the annual mortgage payment. Annual utility savings are projected to be \$1,107 per year, thereby netting a total of \$64 per year in savings to the homeowner. This analysis is summarized in [Table 51](#).

The 60% baseline home in an IECC region was also studied using similar methods and found to have a positive cash flow of \$84 per year to the homeowner. This analysis is summarized in [Table 62](#).

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	California Code Home	Prototype	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	41.7	29.6	5.2	87.4%	82.3%	23.9%	19.9%	\$439.25
Space Cooling	8.4	5.0	1.8	79.0%	64.6%	4.3%	2.6%	\$79.00
DHW	21.5	18.8	9.9	54.2%	47.4%	7.6%	7.2%	\$136.00
Lighting	28.8	20.1	8.0	72.1%	60.1%	13.6%	9.8%	\$250.00
Appliances and MELs	52.2	49.3	35.1	32.9%	28.9%	11.2%	11.6%	\$203.00
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%	\$0
Total Usage/ Savings	152.6	122.8	59.9	60.7%	51.2%	60.7%	51.2%	\$1,107.25
	Energy Efficiency Feature				Builder Cost	10% Markup	Total	Annual Mortgage Cost vs. Code
	R-60 Attic Insulation				\$1,806	\$181	\$1,987	(\$159)
	R-42 Wall Insulation (2x6 @ 24" o.c.)				\$4,145	\$414	\$4,559	(\$364)
	R-30 Floor (Above Garage) Insulation				\$158	\$16	\$174	(\$14)
	R-10 Slab Insulation				\$1,457	\$146	\$1,603	(\$128)
	Radiant Barrier				\$0	\$0	\$0	\$0
	Improved Envelope Sealing and Testing				\$746	\$75	\$821	(\$66)
	5/8" Drywall				\$83	\$8	\$91	(\$7)
	Highly Efficient Windows				\$766	\$77	\$843	(\$67)
	10 HSPF/ 20 SEER Mini-split Heat Pump				\$1,250	\$125	\$1,375	(\$110)
	98% EF Tankless Water Heater				\$700	\$70	\$770	(\$61)
	ENERGY STAR® Appliances				\$750	\$75	\$825	(\$66)
	100% CFL Lighting				\$20	\$2	\$22	(\$2)
	Totals				\$11,882	\$1,188	\$13,070	(\$1,043.33)
	Net Annual Cash Flow to Consumer				\$63.81			

Table 61: Average cost savings for 60% WHES in Title-24 region

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	California Code Home	Prototype	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	86.8	49.7	16.8	80.6%	66.1%	34.1%	20.4%	\$498.74
Space Cooling	6.2	8.7	2.9	53.0%	66.6%	1.6%	3.6%	\$27.19
DHW	23.5	20.7	11.2	52.4%	45.9%	6.0%	5.9%	\$168.00
Lighting	28.8	24.9	8.0	72.1%	67.8%	10.1%	10.5%	\$151.37
Appliances and MELs	60.1	57.1	42.9	28.6%	24.9%	8.4%	8.8%	\$176.89
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%	\$0
Total Usage/ Savings	205.3	161.1	81.8	60.1%	49.2%	60.1%	49.2%	\$1,022.19
	Energy Efficiency Feature				Builder Cost	10% Markup	Total	Annual Mortgage Cost vs. Code
	R-60 Attic Insulation				\$1,806	\$181	\$1,987	(\$159)
	R-42 Wall Insulation (2x6 24" o,c,)				\$4,145	414	\$4,559	(\$364)
	R-30 Floor (Above Garage) Insulation				\$0	\$0	\$0	\$0
	R-10 Slab Insulation				\$0	\$0	\$0	\$0
	Radiant Barrier				\$512	\$51	\$563	(\$45)
	Improved Envelope Sealing and Testing				\$746	\$75	\$821	(\$66)
	5/8" Drywall				\$83	\$8	\$91	(\$7)
	Highly Efficient Windows				\$670	\$67	\$738	(\$59)
	10 HSPF / 20 SEER Mini-Split Heat Pump				\$1,250	\$125	\$1,375	(\$110)
	98% EF Tankless Water Heater				\$700	\$70	\$770	(\$61)
	ENERGY STAR® Appliances				\$750	\$75	\$825	(\$66)
	100% CFL Lighting				\$20	\$2	\$22	(\$2)
	Totals				\$10,682	\$1,068	\$11,750	(\$938.10)
	Net Annual Cash Flow to Consumer				\$84.09			

Table 62: Average cost savings for 60% WHES in IECC region

“Should Meet” Gate Criteria - Least Cost

Building America's team-based systems-research approach, including use of systems-engineering and operations research techniques, provides opportunities for cost and performance trade-offs that improve whole-building performance and value, while minimizing increases in overall building cost. Systems research includes analysis of system performance and cost trade-offs as they relate to whole-building energy performance and cost optimization, including interactions between advanced envelope designs, mechanical and electrical systems, lighting systems, space-conditioning systems, hot water systems, major appliances, miscellaneous electric loads, energy control systems, renewable energy systems, and onsite power generation systems.

Several alternative building features were studied for possible use in the 60% WHES technological pathway, including ducted HVAC systems and tank hot water heaters, but were found not to provide the necessary energy savings to achieve a cost benefit. The incremental cost of the 60% WHES technology package is less than those alternatives, based on the sum of utility bills and energy-related increases in mortgage costs. Builder partner feedback concurs, given the currently available, market-ready products, the 60% WHES provides the least cost technological pathway for production builders.

“Should Meet” Gate Criteria - Marketability

Based on builder partner feedback, there are no barriers to the marketability of these improvements. Although the 60% WHES technological pathway includes many non-conventional building features, these houses will be almost indistinguishable from a typical code-built home on the surface. This would lessen any reluctance a buyer may have to buying a “green” home and similarly, reluctance builders might have to producing them. Most energy saving building features will not be seen on a daily basis, such as high R-value insulation, high efficiency, low-E windows, and tankless water heating. That being said, one of the most obvious energy efficient building features includes the ductless mini split system. The indoor air handler will be noticeable; however by highlighting the energy savings capabilities of the system, homeowners can use it to “show-off” the home’s energy efficiency, similar to a PV array. Moreover, energy efficiency is a factor that is becoming increasingly more significant to homebuyers. Analysis has shown cost neutrality can be achieved; the practical benefit of buying a money-saving house will be critical in the marketing process when presenting an above-code built home. Potential homeowner satisfaction should be marketed by presenting both comfort and cost efficiency through advanced building features that result in energy savings.

“Should Meet” Gate Criteria - Gaps Analysis

A significant gap in achieving the 60% WHES level is planning and developing the required building features during the design process (pre-construction). The advanced envelope requires modification to traditional architectural plans to account for the additional material. Such

features as windows frames and door jams will need to be adjusted to accommodate wall thickness.

A possible gap involves the learning curve associated with builders who are unfamiliar with advanced wall framing or optimal value engineering (OVE). Addressing builders' concerns for OVE options such as 2x6 @ 24" o.c. and SIPs will be important for reaching future PMMs. Once the technique becomes more familiar, it should prove to be more cost-effective as it reduces material cost and construction time. Additionally, if a SIP product is chosen as part of a 60% technology pathway, research regarding local training and warranty restrictions should be completed.

Another potential barrier to successfully implementing the advanced wall framing technique is inspection and permitting issues from local building departments. Due to the relatively unknown nature of OVE, some building departments have resorted to denying permits. Advanced wall framing can add complication to the inspection process if the building department is not familiar with the building practice. BIRA recommends working with the local building department during the beginning stages of planning and devolvement in an effort to avoid such situations.

Gate 1A 60% Hot/Mixed-Dry Budget Period 3

The Hot/Mixed-Dry Climate Zone spans a large range of actual climate conditions, so this study targeted four cities, biased towards regions where eligible communities will more likely occur, to develop a more representative understanding of the zone: Sacramento, CA; Lancaster, CA; Albuquerque, NM; and Tucson, AZ. While all four of these cities are within the same Building America climate zone (Hot/Mixed-Dry), each experiences a dramatically different winter season.

"Must Meet" Gate Criteria - Source Energy Savings

A baseline home was first established for a uniform analysis across all regions in the Hot/Mixed-Dry climate zone. The design was based on typical industry practices in the region. Standard design for a medium size home includes 2123 square feet, 18% glazing, two floors, three bedrooms, and two bathrooms. The baseline home was used in all software analyses.

In EnergyGauge®, an energy analysis was performed using 2008 Title 24 and 2009 IECC prescriptive features. Using the baseline home, 60% WHES features were determined by upgrading code features and adhering to the region's standard practice and design in region.

Analyses were run in all four cardinal orientations for an average solar orientation. Achieving the 60% level of energy savings does not require orienting homes in any particular direction. However, making the best use of the thermal properties of the sun brings many advantages. Builders should, if possible consider orienting at the site development level of the homebuilding

process; a virtually no-cost option for improving energy performance is to account for optimum orientation for passive solar benefit. Site planning should take advantage of southern windows and roof exposure, as well.

Results from simulations indicate homes built to 2008 Title 24 standards provide on average 24% energy savings over the BA benchmark, while those built to 2009 IECC standards provide 22% energy savings over the BA benchmark. On average, homes built to the 60% WHES level provide 48% energy savings in the 2008 Title 24 region. The savings increase further in the IECC region, with an average of 50% energy savings for a 60% WHES technological pathway. Comparisons can be seen in [Figure 37](#) and [Figure 38](#).

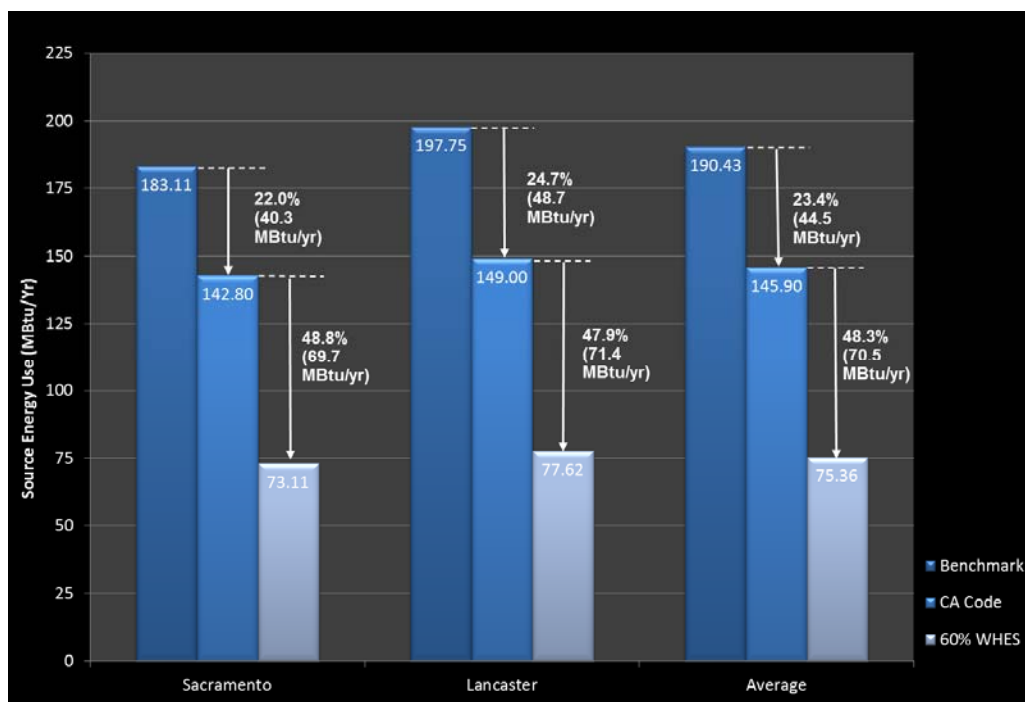


Figure 37: WHES in Title-24 region

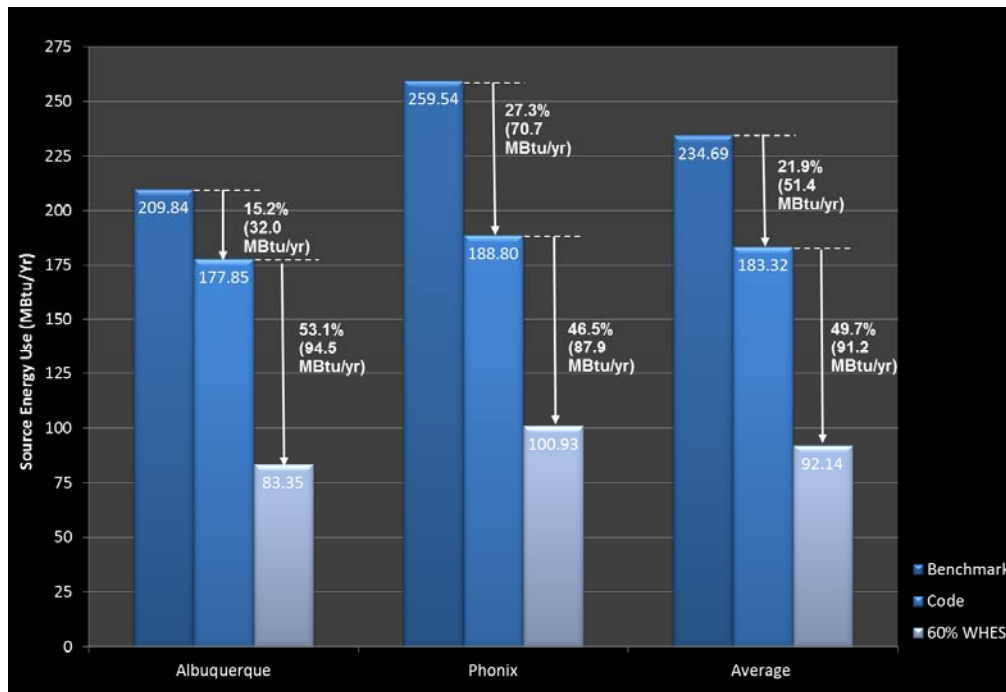


Figure 38: WHES in IECC region

For both the 2008 Title 24 and 2009 IECC regions, appliances (including MELs) represent the largest energy end-use load. In prior Gate 1A analysis, appliance efficiencies were not modified due to the non-climate specific nature of the energy load. However, to reach the 60% WHES level, energy efficient appliances were required to be simulated. Analysis shows space heating, space cooling, and lighting are the next major loads, as well as the loads with the greatest variation within the Hot/Mixed-Dry Climate. [Figure 39](#) and [Figure 40](#) show the variation in end-use loads for Title 24 and IECC regions, respectively.

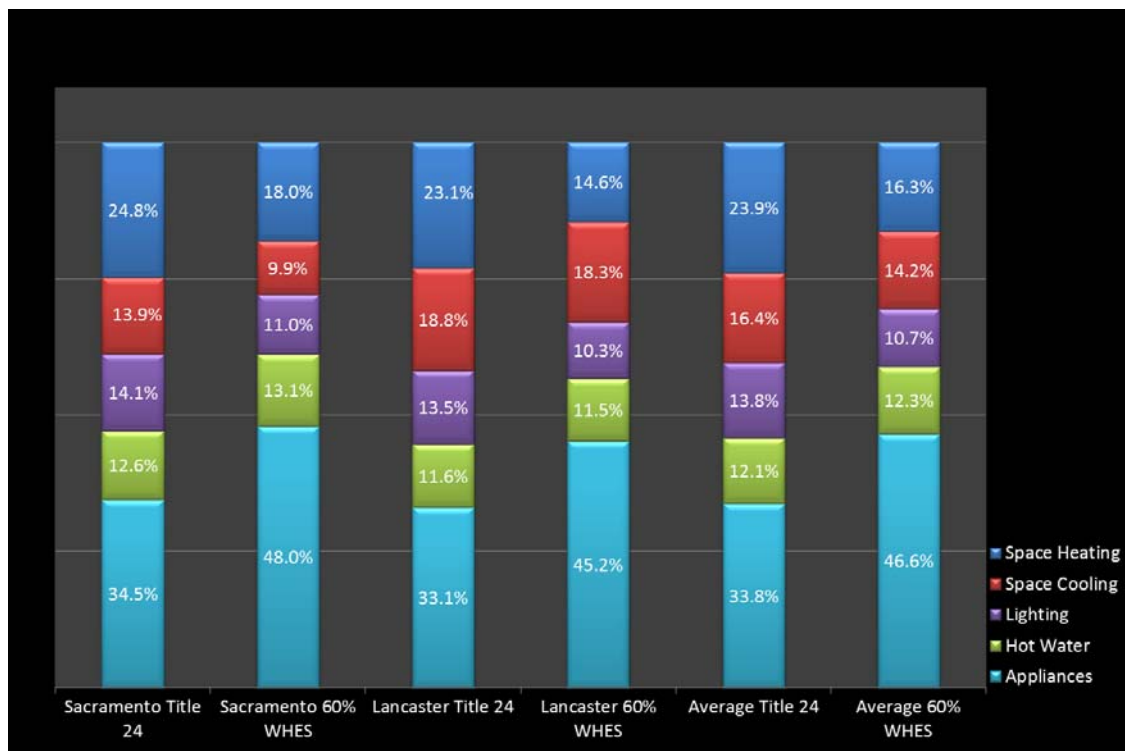


Figure 39: End-use energy loads for 2008 Title-24 and 60% WHES

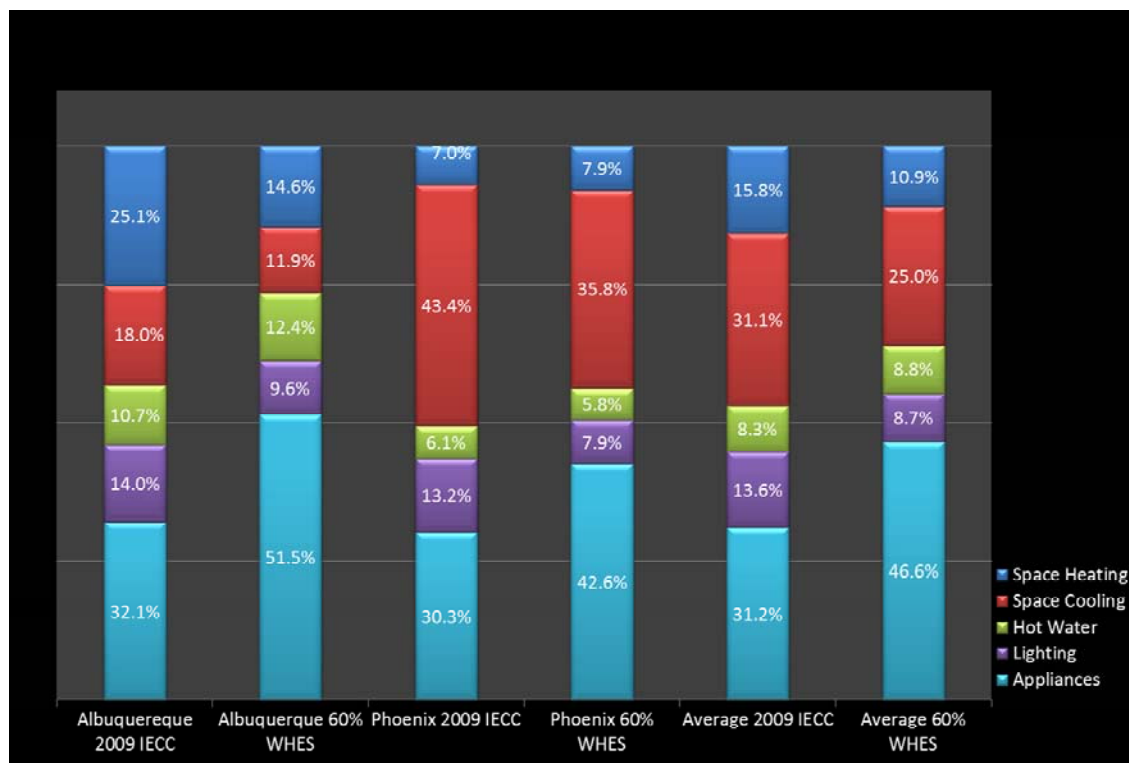


Figure 40: End-use energy load for 2009 IECC and 60% WHES

Analyses were run in all four cardinal orientations to produce an average WHES for solar orientation. Achieving the 50% WHES level does not require orienting homes in any particular direction. However, making the best use of the sun brings many advantages. Builders should, if possible, consider orientation during site development stage of the homebuilding process; a virtually no-cost option for improving energy performance is to account for optimum orientation for passive solar benefit. Site planning should take advantage of southern windows and roof exposure, as well.

Table 53 and Table 54 show the code complaint standards (prescriptive method) and the 60% WHES technological pathway for the Hot/Mixed-Dry Climate zone.

Features	2008 Title-24	60% WHES
Insulation	R-19 to R-21 Walls(2x6) R-38 Ceiling R-139Garage	R-42 Walls (2x6) R-42 Ceiling R-42 Garage
Windows	U-Factor 0.40 SHGC 0.40	U-Factor 0.19 SHGC 0.40
Cooling	SEER 13	SEER 17
Heating	7.7 HSPF	7.7 HSPF
Ducts	N/A	Ductless
DHW	50 gal, 0.62 EF	Tankless, 0.98 EF
Infiltration	3.6 ACH(50)	2.0 ACH(50)
Appliances	Standard	ENERGY STAR® rated
Lighting	50% Fluorescent	100% Fluorescent

Table 63: Average 2008 Title-24 and 60% WHES features summaries

Features	2009 IECC	60% WHES
Insulation	R-13 Walls R-30 to 38 Ceiling R-13 to R-19 Garage	R-42 Walls R-42 Ceiling R-42 Garage
Windows	U-Factor 0.35 SHGC 0.65	U-Factor 0.19 to .30 SHGC 0.30 to 0.40
Cooling	SEER 13	SEER 15 to SEER 20
Heating	7.7 HSPF	7.7 to 11 HSPF
Ducts	N/A	Ductless
DHW	50 gal, 0.62 EF	Tankless, 0.98 EF

Features	2009 IECC	60% WHES
Infiltration	3.6 ACH(50)	2.0 ACH(50)
Appliances	Standard	ENERGY STAR® rated
Lighting	30% Fluorescent	100% Fluorescent

Table 64: Average 2009 IECC and 60% WHES features summaries

To achieve 60% WHES, a high performance thermal envelope will be required. A thermal envelope is the exterior “shell” of a building and is the first line of defense against external elements. Building features such as the framing, insulation, air sealing and window, all contribute to the energy efficiency of the envelope.

The impact of advanced framing on WHES depends on the choice of wall assembly and insulation efficiency (R-value). The whole-house thermal envelope with high R-values and minimal thermal bridging are critical for cooling load reduction during the summer months and heat retention during the winter months. Different building materials and practices can be used to create an energy efficient thermal envelope such as structural insulated panels (SIPs), optimum value engineered (OVE) walls, and exterior insulating foam sheathing. The 60% WHES technology pathway include walls that utilize a 2x6 @ 24” o.c. advanced framing technique and incorporates R-42 insulation. The advanced framing and high R-value insulation was continued throughout the building envelope, including the attic floor and above-garage floor.

A critical component of the thermal envelope is proper air sealing which allows conditioned air to remain within the thermal envelope and will reduce exterior air infiltration. By improving envelope tightness, the advanced framing systems greatly reduce conductive heat loss or gain, thereby decreasing both heating and cooling loads. This concept demonstrates the interdependency of all building features’ potential for energy saving. Builder partners in the Hot/Mixed-Dry climate zone, such as Artistic Homes, concur that improvements to the building envelope are feasible, in terms of constructability and cost-effectiveness.

In the Hot/Mixed-Dry climate zone, traditional building practices adhere to minimal region building code standards and utilize “off-the-shelf” building features, such as split system central air conditioning and ducted gas furnace. The 60% WHES technology pathway utilizes increased HVAC system efficiency by incorporating a ductless mini-split heat pump package system. Ductless HVAC systems eliminate efficiency losses due to duct leakage into unconditioned space. Improving the HVAC efficiency as a system will naturally reduce energy loads through a more efficient unit. For the Hot/Mixed-Dry climate zone, analysis shows the mini-split heat pump must have at least 7.7 HSPF and 17 SEER in the Title 24 region and at least 7.7 to 11 HSPF and 15 to 20 SEER (based on target location) in the IECC region to reach the 60% WHES level. In conjunction with high performance envelope, there is a potential for 19% WHES improvement in space heating and cooling over 2008 Title 24 and 24% WHES improvement over 2009 IECC with the use of the high-efficiency ductless mini-split heat pump.

In order to target the domestic water heating (DWH) load, high efficiency water heating systems should be installed. Tankless hot water heaters can provide efficiencies around 98% and were used to achieve the 60% WHES. Utilizing this technology can increase WHES by 3 to 4%, depending on location. Water heating systems are continuously evolving and improving. Currently, there are several tank hot water heaters with high efficiency (maximum 96% EF) available in industry, including heat pump and direct vent systems; however tankless hot water systems provide a superior cost benefit. Builder partner feedback indicates that tankless hot water heating systems are currently being used in the Hot/Mixed-Dry climate zone with successful results.

Appliance efficiencies were also analyzed and incorporated into the 60% WHES technological pathway. Prior Gate 1A studies did not utilize savings from energy efficient appliances because appliance energy loads are not relative to location (heating degree days). The appliances are also subject to potential removal and replacement with less energy efficient appliances by the homeowner. To ensure homes maintain the 60% WHES level, the energy efficient appliance industry will need to develop a specific plug and outlet combination available only to energy efficient appliances, similar to pin-based CFLs and LED bulbs. Combined, energy efficient appliances can improve WHES by 6 to 7.5%, thereby providing the remaining energy savings required to achieve the 60% WHES level.

The defined features can be utilized as a technology pathway which will ease progression into future PMMs. The next PMM for Hot/Mixed-Dry will be 70% WHES in 2015.

“Must Meet” Gate Criteria - Neutral Cost Target

For a baseline home built to 60% WHES, analysis shows that the annual utility bills plus the annual incremental mortgage (upgraded from code building features) is less than the annual utility bills of the BA Benchmark. Builder partners’ feedback was utilized for accurate incremental costs and industry review of proposed features for the 60% WHES level. Given this information, the cost benefit analysis indicates that the increased costs of improvements meet the cost neutrality target when compared to regional standard practice (2008 Title 24 for California or 2009 IECC for non-California locations). The annual savings for 60% WHES can be seen on [Figure 41](#) and Figure 42, for 2008 Title 24 and 2009 IECC, respectively.

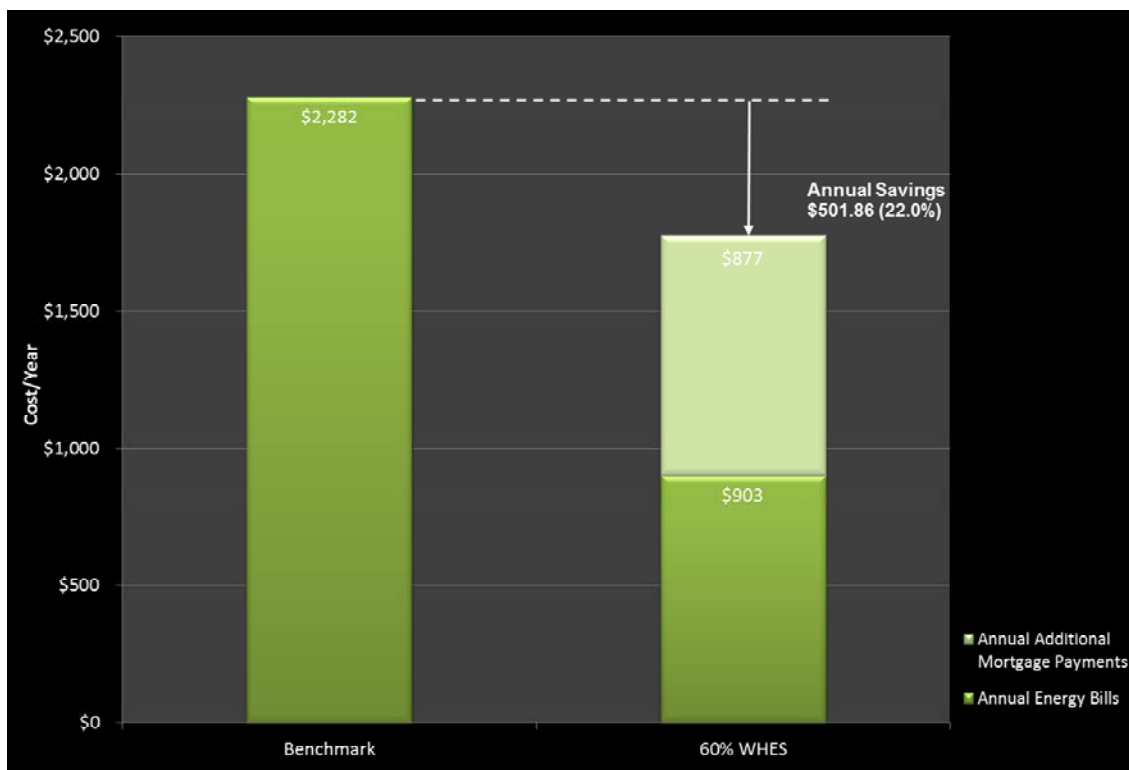


Figure 41: Annual net cost savings for 60% WHES (upgraded from 2008 Title-24)

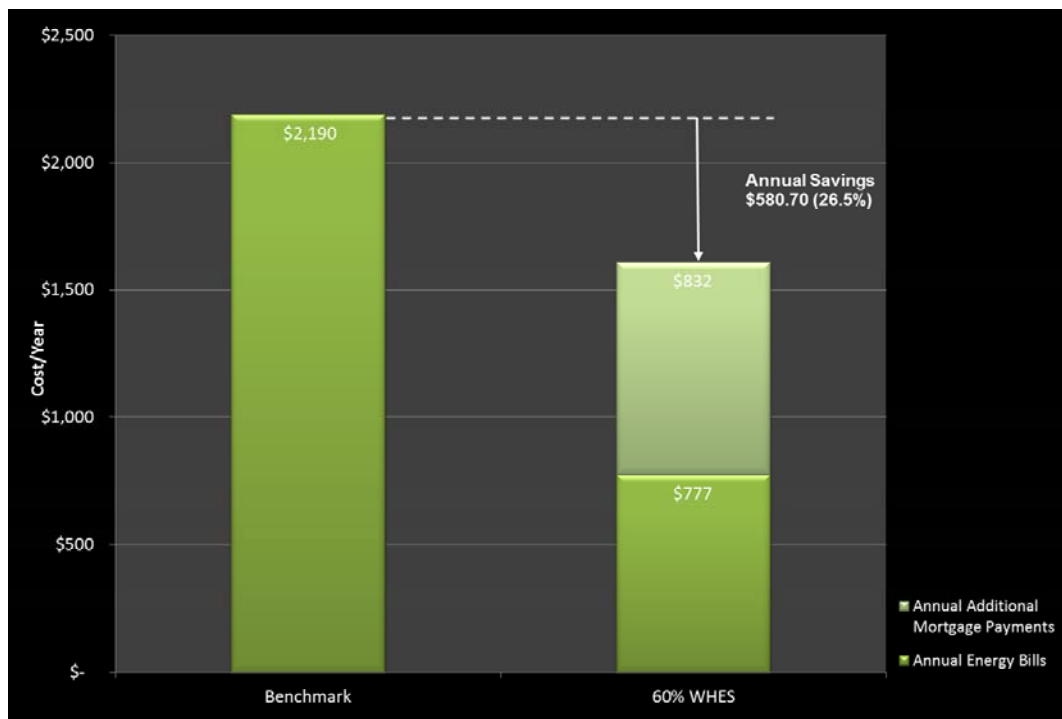


Figure 42: Annual net cost savings for 60% WHES (upgraded from 2009 IECC)

Rebates and tax credits represent a significant additional source of cost savings for both

homeowner and production builders. Energy efficient products and building practices are supported through programs such as ENERGY STAR® which assist in developing of energy efficiency in industry. There are currently thousands of incentive dollars available for new production homebuilders and homebuyers for energy efficient homes, there will eventually be insufficient funds to support the increase in new energy efficient homes construction and purchasing. Therefore rebates or tax credits were not included in the calculation of cost flow to provide a more accurate analysis.

When additional costs for the 60% WHES technological pathway in a Title 24 region is mortgaged at 7% APR over 30 years, the \$10,985 incremental features cost translates to an \$877 increase in the annual mortgage payment. Annual utility savings are projected to be \$1,379 per year, thereby netting a total of \$502 per year in savings to the homeowner. This analysis is summarized in [Table 55](#).

The 60% WHES technological pathway in the IECC region was also studied using similar methods and found to have a positive cash flow of \$581 per year to the homeowner. This analysis is summarized in [Table 56](#).

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	California Code Home	Prototype	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	51.4	34.9	12.3	76.2%	64.9%	20.6%	15.5%	\$471.75
Space Cooling	37.5	24.0	10.7	71.4%	55.3%	14.1%	9.1%	\$322.00
DHW	20.6	17.6	9.2	55.1%	47.4%	6.0%	5.7%	\$132.00
Lighting	28.8	20.1	8.0	72.1%	60.1%	10.9%	8.3%	\$250.00
Appliances and MELs	52.1	49.3	35.1	32.6%	28.8%	8.9%	9.7%	\$203.13
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%	\$0.00
Total Usage/ Savings	190.4	145.9	75.4	60.4%	48.3%	60.4%	48.3%	\$1,378.88

	Energy Efficiency Feature			Builder Cost	10% Markup	Total	Annual Mortgage Cost vs. Code
	R-42 Attic Insulation			\$597	\$60	\$657	(\$52)
	R-42 Wall Insulation (2x6 @ 24" o.c.)			\$4,145	\$414	\$4,559	(\$364)
	R-42 Floor (Above Garage) Insulation			\$158	\$16	\$174	(\$14)
	R-5 Slab Insulation			\$921	\$92	\$1,013	(\$81)
	Radiant Barrier			\$0	\$0	\$0	\$0
	Improved Envelope Sealing and Testing			\$746	\$75	\$821	(\$66)
	5/8" Drywall			\$83	\$8	\$91	(\$7)
	Highly Efficient Windows			\$766	\$77	\$843	(\$67)
	7.7 HSPF / 17 SEER Mini-Split Heat Pump			\$1,100	\$110	\$1,210	(\$97)
	98% EF Tankless Water Heater			\$700	\$70	\$770	(\$61)
	ENERGY STAR® Appliances			\$750	\$75	\$825	(\$66)
	100% CFL Lighting			\$20	\$2	\$22	(\$2)
	Totals			\$9,986	\$999	\$10,985	(\$877.01)
	Net Annual Cash Flow to Consumer			\$501.86			

Table 65. Average cost savings for 60% WHES in Title- 24 region

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	California Code Home	Prototype	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	44.6	29.0	10.1	77.4%	65.2%	14.7%	10.3%	\$313.13
Space Cooling	82.3	57.0	23.0	72.0%	59.7%	25.2%	18.6%	\$536.93
DHW	18.9	15.2	8.1	57.4%	47.0%	4.6%	3.9%	\$159.59
Lighting	28.8	24.9	8.0	72.1%	67.8%	8.8%	9.2%	\$190.75
Appliances and MELs	60.1	57.2	43.0	28.5%	24.8%	7.3%	7.7%	\$212.63
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%	\$0
Total Usage/ Savings	234.7	183.3	92.1	60.7%	49.7%	60.7%	49.7%	\$1,413.02

	Energy Efficiency Feature	Builder Cost	10% Markup	Total	Annual Mortgage Cost vs. Code
	R-42 Attic Insulation	\$597	\$60	\$657	(\$52)
	R-42 Wall Insulation (2x6 24" @ o.c.)	\$4,145	\$414	\$4,559	(\$364)
	R-42 Floor (Above Garage) Insulation	\$158	\$16	\$174	(\$14)
	R-10 Slab Insulation	\$0	\$0	\$0	\$0
	Radiant Barrier	\$512	\$51	\$563	(\$45)
	Improved Envelope Sealing and Testing	\$746	\$75	\$821	(\$66)
	5/8" Drywall	\$83	\$8	\$91	(\$7)
	Highly Efficient Windows	\$766	\$77	\$843	(\$67)
	7.7 HSPF/15 SEER to 11 HSPF/20 SEER Mini-Split Heat Pump	\$1,000	\$100	\$1,100	(\$88)
	98% EF Tankless Water Heater	\$700	\$70	\$770	(\$61)
	ENERGY STAR® Appliances	\$750	\$75	\$825	(\$66)
	100% CFL Lighting	\$20	\$2	\$22	(\$2)
	Totals	\$9,478	\$948	\$10,425	(\$832.32)
	Net Annual Cash Flow to Consumer				\$580.70

Table 66. Average cost savings for 60% WHES in IECC region

“Should Meet” Gate Criteria -- Least Cost

The recommended technology pathway for 60% WHES in this report have been demonstrated to cost-effectively increase energy savings when compared to conventional approaches. Several building features were studied for possible use in the 60% WHES technological pathway, including traditional split system AC, gas furnace and tank hot water heaters, but did not provide the necessary energy savings to achieve a cost benefit. The incremental cost of the 60% WHES technology package is less than those alternatives, based on sum of utility bills and energy-related increases in mortgage costs. Builder partner feedback concurs, given the currently available, market-ready products, the 60% WHES provides the least cost technological pathway for production builders.

“Should Meet” Gate Criteria -- Marketability

Based on builder partner feedback, there are no barriers to the marketability of these improvements. Although the 60% WHES technological pathway includes many non-conventional building features, these houses will be almost indistinguishable from a typical code-built home on the surface. This would lessen any reluctance a buyer may have to buying a “green” home and similarly, reluctance builders might have to producing them. Most energy saving building features will not be seen on a daily basis, such as high R-value insulation, high efficiency, low-E windows, and tankless water heaters. That being said, one of the most obvious energy efficient building features includes the ductless mini-split system. The indoor air handler will be noticeable; however, by highlighting the energy savings capabilities of the system, homeowners can “show-off” the home’s energy efficiency, similar to a PV array.

“Should Meet” Gate Criteria - Gaps Analysis

A significant gap in achieving the 60% WHES level is planning and developing the required building features during the design process (pre-construction). The advanced envelope requires modification to traditional architectural plans to account for the additional material. Such features as windows frames and door jams will need to be adjusted to accommodate wall thickness.

In the Hot/Mixed-Dry climate zone, a possible gap involves the learning curve associated with builders who are unfamiliar with advanced wall framing or optimal value engineering (OVE). Addressing builders’ concerns for OVE options such as 2x6 @ 24” o.c. and SIPs will be important for reaching future PMM. Once the technique becomes more familiar, it should prove to be more cost-effective as it reduces material cost and construction time. Additionally, if a SIP product is chosen as part of a 60% technology pathway, research regarding local training and warranty restrictions should be completed.

Another potential barrier to successfully implement the advanced wall framing technique is inspection and permitting issues from local building departments. Due to the relatively

unknown nature of OVE, some building departments have resorted to denying permits. Advanced wall framing can add complication to the inspection process if the building department is not familiar with the building practice. BIRA recommends working with the local building department during the beginning stages of planning and devolvment in an effort to avoid such situations.

Task 2B: Stage Gate 1B – System Performance Evaluations

Subtask 2B.1- Systems Evaluation Plans in Builder Prototypes in Multiple Climate Zones

In Task 2B.1, the BIRA team identified research opportunities that would benefit from NREL field test assistance. The technologies of focus were:

- CSIPS (Concrete structural integrated panels),
- MELs,
- PVT (combined photovoltaic and solar thermal system), and
- SunCache (solar hot water)
- High R-Value Walls (SIP)
- OASys Cooling Systems
- Ground Coupled Heat Pumps
- Home Energy Management
- Heat Pump Water Heater
- Solar Thermal
- PVT

The preliminary time frame, design specifications, research questions, and NREL's recommended role in the testing are identified and reported. The table below is a summary of the prototype opportunities.

House/Location	Builder/Contact	Design Features	Climate
Citihouse II Fresno, CA	AlvisProjects, Inc./Marlin Alvis	SunCache Solar Water Heating CSIP Walls	50% Hot/Mixed
Citihouse III Fresno, CA	AlvisProjects, Inc./Marlin Alvis	ICF Walls PVT	50% Hot/Mixed
Kennecott Land Salt Lake City, UT	Gold Medallion	PVT	40-50% Cold
Reno Project Reno, NV	Sweeney Architecture & Idea Development	ICF Walls Others TBD	40-50% Cold
Idaho Project Southwest Idaho	Chuck Miller Construction	Residential Economizer Heat Pump	50% Cold

House/Location	Builder/Contact	Design Features	Climate
Snow Creek Cottages Park City, UT	R & O Builders	SIP walls and roof, Ground-Coupled Heat Pump Heating	50% Cold
Salt Lake County Affordable Housing Salt Lake City, UT	Salt Lake County Affordable Housing	High R-Value Walls OASys Evap Cooler	50% Cold
Geos Neighborhood Arvada, CO	Geos Development	Above Grade Walls: R-28 SIPs Ceiling: R-40 SIPs	50% Cold
Zero Energy Idea House Bellevue, WA	Shirey Contracting	High R-Value Walls Evacuated tube solar collector supplying DHW and space heating via radiant floor heating with a high efficiency electric tank water heater	50% Cold
SIPs House Portland, OR	David Cohan/Kaya Construction	Walls and Floors: R-30 SIPs Ceiling: R-45 SIPs Flat plate collector supplying DHW with high efficiency electric tank water heater	50% Cold
Gold Medallion Homes – Daybreak Salt Lake City, UT	Gold Medallion Homes	OASys	40% Cold
Artistic Homes Albuquerque, NM	Artistic Homes	Home Energy Management System	50% Hot-Dry/Cold
Kaneohe Marine Base Oahu, HI	Forest City HI	Home Energy Management System	50% Hot Humid
Occupied Residence Stockton, CA	ConSol	Heat Pump Water Heating	Hot/Mixed Dry
Queen City Eco Village	Martha Rose Construction, Inc.	Evacuated tube solar collector supplying DHW 92% EF gas	50% Marine

House/Location	Builder/Contact	Design Features	Climate
		tankless boiler and space heating with hydronic radiators	
"Newport" South Jordan, UT	Gold Medallion Homes	PVT Solar	50% Cold

Table 67: Prototype Opportunities

Citihouse II

The City of Fresno, California sponsored a "Green Building Demonstration Project" to highlight the feasibility of marketable, sustainable housing. The city contracted with multiple parties to build, monitor, evaluate, and publicize these homes. Citihouse II is the second of three affordable, three-bedroom, 1,300 sq. ft. single-family homes built under this project.

Citihouse II is in the Hot/Mixed Dry Climate Zone (Fresno, Central Valley of CA) and BIRA is working with the city and the builder (Alvis Projects) to achieve a 50% WHES.

Citihouse II features several advanced systems including the Sun Cache solar water heating system, CSIP walls, passive solar design and a plenum crawlspace. This prototype home is an application of a 50% Hot/Mixed Dry strategy.

Citihouse II is a single story, 1300 square foot home. Energy features include hydronic heating using a tankless water and a sealed, insulated, unvented crawlspace. HVAC equipment will be located in the crawlspace with no ducts. Heating and cooling will be supplied to the home through floor registers. The SunCache SCH-50 and ICS solar water heater will supply hot water with a tankless backup. Ventilation cooling will be employed using a NightBreeze system. To maximize the passive solar elements in the home, concrete-SIPS (C-SIPS) will be utilized and with 2" concrete floor. Citihouse II will have a metal roof with foam insulation adhered to roofing.

Citihouse III

Citihouse III is the third home in the City of Fresno's "Green Building Demonstration Project" to highlight the feasibility of marketable, sustainable housing. Like Citihouse II, it is an affordable, three-bedroom, 1,300 sq. ft. single-family home.

Citihouse III has the same footprint as Citihouse I and II. This home will be slab on grade. The energy features will include ICF walls, high efficiency furnace, 15 SEER A/C, and the focus of our research is a photovoltaic thermal (PVT) system. The PVT will be supplied by PVT Solar. Citihouse III will be built by BIRA's Builder Partner, Alvis Projects.

The objective of BIRA's work with CitiHouse III is to determine if PVT is ready for the production environment and to evaluate the effectiveness of PVT in this climate. Detailed research questions for the PVT system are contained in system evaluation plan for PVT.

Kennecott

Kennecott Land is the developer of the parent company Rio Tinto, a mining buffer-land on which they propose to build 200,000 homes over the next 100 years. Kennecott developed their own sustainability guidelines based on Energy Star; they recently enlisted the help of BIRA to provide assistance in improving their next phase of sustainability guidelines. In preparation, Kennecott Land asked four builders to participate in the Salt Lake City Parade of Homes centered on Green Design; Kennecott and their builders worked hard with BIRA to be the highlight of the Parade, which was held on August 1- 16 . BIRA assisted these builders in providing design and construction assistance. BIRA saw this project as having dual opportunities: 1) working with Kennecott and the builders at Kennecott in researching strategies for 40% and 50% WHES savings in this cold climate, and 2) providing key data for assisting Kennecott in development of new, higher-efficiency design guidelines for the Daybreak community.

Gold Medallion Homes built the most efficient of the Parade Homes, achieving a 67% WHES level, featuring all-SIPS construction, indirect-direct evaporative cooling, solar hydronic space heating, and a PVT system. The PVT system is the Stage Gate 1 focus of this Prototype home, and will provide savings in water heating, and supplemental space heating as well as ventilation cooling for the home.



Figure 43: Gold Medallion Parade Home 40%+ PVT

BIRA's field testing objective is to determine if PVT is ready for the production environment and to evaluate the effectiveness of PVT in this climate. Data will be gathered to compare actual performance with analytical results. Detailed system research questions are contained in Evaluation plan for PVT.

Reno Project

Sweeney Architecture and Idea Developments have asked for the assistance of the BIRA team in building four homes in the Reno, Nevada area. BIRA will work with them in a 40%, possibly a 50%, Cold climate prototype home strategy.

These homes are still being designed but will incorporate passive solar elements at the request of the BIRA partner. Systems under consideration include ICF walls and other high performance features that are yet to be determined.

Detail objective of BIRA's field testing will be determined as more specific energy efficiency measures are defined. In general, testing will be designed to determine which systems are ready for the production environment and whether the systems, in a whole house context, achieve the analytically derived 50% cold savings level.

Idaho Project

The Idaho Energy Division (IED), with builders, proposes to develop and demonstrate a

residential economizer for safe, automatic and comfortable night cooling. These systems will be installed on five homes located in Southwest Idaho—the third largest new housing market in the Pacific Northwest and the one with the largest cooling load. If the technology is successful, it will be promoted by Idaho Power and IED as a means of reducing Idaho Power’s energy and peak load. In addition, the IED will recruit a site and provide technical assistance to the builder and HVAC Company for a Hallowell Cold Climate Heat Pump.

The night cooling system will be installed on five test homes. Two homes will be Northwest ENERGY STAR, two homes will be built above Northwest ENERGY STAR to the Building America standard and the fifth will be a standard practice home. During the test period, one Northwest ENERGY STAR and one Building America home will not use standard air conditioning to determine whether night cooling can replace air conditioning, and if so, on which homes.

The goal of the BIRA field testing will be to determine if the night cooling system is ready for the production environment and whether the system, in a whole house context, achieves the analytically derived 50% cold savings level.

Heat Pump Water Heater (HPWH) Evaluation Plan Budget

The overall objective of this study is to evaluate an integrated Heat Pump Water Heater (HPWH) system, relative to the Building America (BA) Program Stage Gate 1B criteria (available in Appendix A of the final report). This study will identify costs and net energy benefits, construction impacts, as well as key factors that are essential for the system’s viability in home production, including the retrofit marketplace. The HPWH will be evaluated in a residential environment to test its overall energy efficiency, ability to consistently meet domestic hot water demands and cost advantage in a long term study. The HPWH tested is the General Electric (G.E.) GeoSpring™ hybrid water heater Model # GEH50DNSRSA.

Figure 44 below shows G.E.’s Online Savings Calculator, estimating savings of \$461.62 annually using the GeoSpring™ in hybrid mode, compared to a standard electric water heater based on California’s state average energy cost of \$.1526 per kWh. Currently, we have no modeling software that properly models HPWH’s relevant to climate zone. Since HPWHs use heat from the surrounding air as an energy source, it can be assumed that weather conditions will have a significant impact on performance. Our study will attempt to quantify actual savings in the Stockton, CA, BA climate zone of Hot/Mixed-Dry.

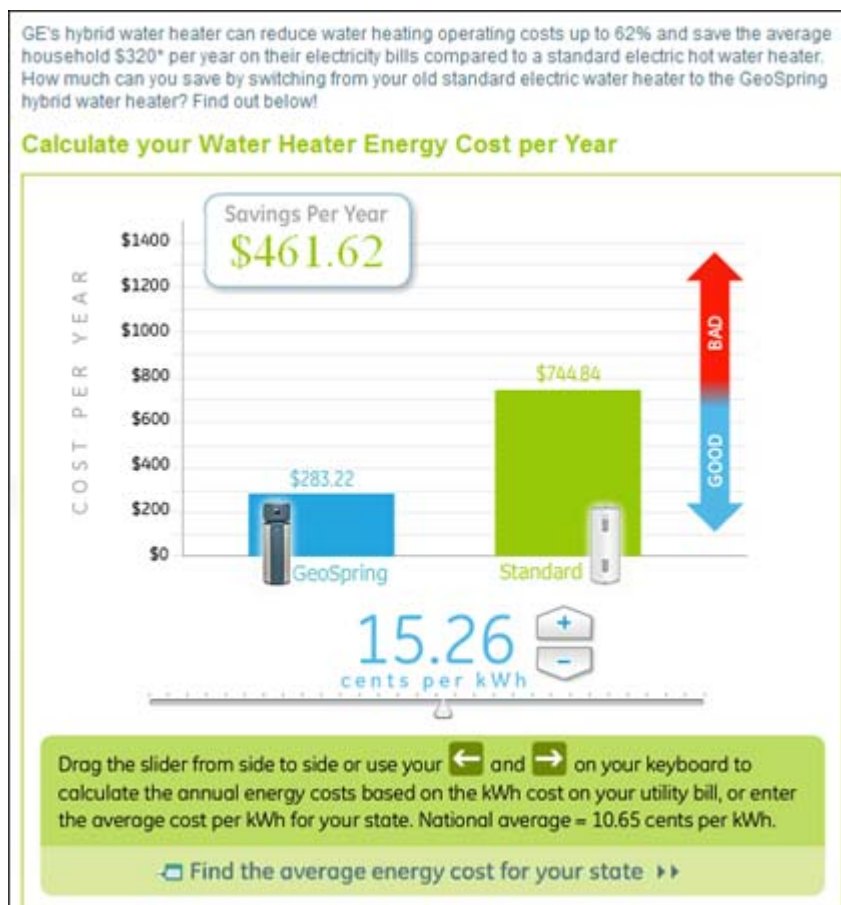


Figure 44. General Electric online savings calculator

Other areas of interest in the study will be the GeoSpring's performance compared to gas and other heat pump water heaters, specifically the AirTap™ add-on HPWH. For the BA goal of net-zero energy homes to be achieved, the actual performance of high efficiency electric water heaters (e.g. heat pump water heaters) could play an important role in terms of efficiency and because their electric-energy use can be compensated by net-metered renewable electricity produced on site.

We would also like to study how relative humidity impacts the performance of the heat pump technology.

We will set up the G.E. Hybrid water heater at a nearby house of a ConSol team member to determine the on-site efficiency of the GeoSpring™. This particular site was the location of a previous study for the AirTap™ add-on HPWH. A new 50 gallon propane gas water heater with an energy factor (EF) of .58 was installed at the site and then instrumented with gas and water meters, as well as inlet and outlet (hot) water temperature sensors to provide baseline gas energy use. We have been collecting performance data on the AirTap™ for approximately one year. We will use this data as a comparison to the G.E. GeoSpring™ that will be installed in place of the current water heater. The GeoSpring™ unit will be instrumented with electric-

power, water flow meters, ambient air and relative humidity sensors, as well as inlet (cold) and outlet (hot) water temperature sensors. Data will be collected using Onset Computer HOB0 data loggers and will be read approximately each week by one of the team members and then transmitted to the team for analysis.

The original selection of the study site was primarily based on the fact that it is a nearby site with occupants showing consistent water use. By using a team member's house, we have welcoming access to the house for installing equipment and frequent ability to gather data. This location will also allow the opportunity to accurately track changes to the various operating modes available with the GeoSpring™ as weather and hot water demand requires. This will help us to understand how the various modes impact performance and make comparisons between operating modes. It's anticipated that occupancy will remain constant during the duration of the test period.

Overview

Most conventional water heaters for the residential market today use either gas burners or electric heating elements to heat water for use in the home. The HPWH works similarly to a conventional heat pump by taking heat from the surrounding air and using it to heat low-pressure liquid refrigerant in the heat pump's evaporative coil, changing the liquid to a low pressure gas. The refrigerant then passes through a compressor which raises the pressure, and thus the temperature as well. The heated high pressure gas passes through the heat pump condenser where it gives off its heat and condenses back to a liquid state. The cooled liquid refrigerant then passes through an expansion valve where the pressure is reduced and the cycle is repeated.

The GeoSpring™ hybrid water heater unit uses a compressor to extract heat from the surrounding air and sends this heat through condenser coils which are wrapped around the water tank to transfer the heat into the tank and heat the water. According to GE's customer support center, the minimum draw of the compressor and fan unit is 550 watts.

The GeoSpring™ relies on two 4500 watt back-up heating elements, one upper and one lower, to heat water when ambient temperatures are inadequate to provide heat energy to the heat pump.

The GeoSpring™ has roughly the same footprint and installation requirements of most electric resistance water heaters using 240V, 30amp electrical power, and purportedly can be used to replace existing electric heaters with little or no modifications. Unlike conventional electrical water heaters, the GeoSpring™ requires at least 700 cubic feet of space to operate due to the heater using the surrounding air to heat the water. If the space is not adequate, louvers or vents will be necessary to provide the sufficient air to operate the heat pump.

Since moisture or condensation is a by-product of the GeoSpring™ hybrid water heater, the

installation of a condensate drain line is necessary with a drain in close proximity to the unit or the installation of a condensate pump. There are two drain hoses that are attached to the back of the heater. The primary drain hose is intended to carry all condensate away. If it is clogged or kinked, the condensate will exit the secondary drain tube and onto the floor. This is intended as a notification to the user that the primary drain is clogged.

The manufacturer claims the GeoSpring™ can reduce water heating costs up to 62% over a conventional electric resistant water heater.

The GeoSpring™ has a First Hour Rating of 63 gallons and an Energy Factor rating of 2.35 in the default Hybrid mode and is ENERGY STAR® qualified making it eligible for the 30% Federal tax credit through the end of 2010.

Other utility and local rebates may also be available.

GeoSpring™ has earned an Underwriters Laboratory (UL) listing, file # SA32593.

“Must Meet” Gate Criteria - Source Energy Savings and Whole Building Benefits

Research Question 1A

- Does the system demonstrate energy savings and additional benefits when compared to simulated results for a standard/high efficiency gas and electric tank water heaters, solar water heaters or field results of the AirTap?

Technical Approach

- Since there is currently no modeling software that can accurately model HPWH's relative to climate zones, and using the manufacturers Energy Factors (EF) rating will not give us an accurate “real world” picture of energy savings due to the wide variation in climate zones, we will not be modeling expected savings as outlined in BA's Gate 1A Research Objective. The only baseline expectations we can use is GE's online calculator. Obtain expected annual performance data from the manufacturer for baseline performance expectations.
- Collect performance data of the GeoSpring™ using:
 - Cold water inlet temperature
 - Hot water outlet temperature
 - Domestic hot water flow rate
 - Water heater environment temperature
 - Water heater environment relative humidity
 - Water heater energy consumption
- Compare overall performance with previous data collected on the AirTap. Has the GE performed worse, equal to or better than AirTap when comparing energy input to

output and has the system provided adequate hot water to the residence when compared to the AirTap?

- Using data collected, develop a hot water draw profile that can be modeled in energy simulation software to use as a comparison to gas and electric resistive water heaters.
- Convert energy data to British Thermal Units (Btus) to compare performance to gas heaters.
- Using developed hot water draw profile and energy conversion data, model energy use estimates through energy modeling software for:
 - Standard electric resistive water heaters
 - Tankless water heaters
 - Solar water heaters
 - Gas water heaters

Research Question 1B

The GeoSpring™ has the capability to easily switch between operating modes. BIRA will identify which operational mode could be implemented during various weather conditions to maximize savings and still keep up with demand.

- How should the system be operated in order to maximize energy savings?

Technical Approach

- Using manufacturer's documentation, identify recommendations for optimum performance.
- Using data obtained, identify installation or operational parameters that may impact the overall effectiveness of the unit.
- Identify and implement changes necessary to maximize performance.

"Must Meet" Gate Criteria - Performance-Based Code Approval

For the purposes of our study it can be assumed that the GeoSpring™ complies with applicable health, safety and fire codes based on the UL listing and approval for sale in the U.S.

Research Question 4A

- What if any code, both performance and prescriptive, concerns or possible violations need to be overcome in order for the GeoSpring™ to be utilized in the production building industry?

Technical Approach

- Research applicable local codes in regards to water heating requirements and energy

code restrictions.

- Attempt to receive feedback from various jurisdictions regarding code compliance.
- Discuss with the manufacturer any concerns to either get further clarification on code issues or get feedback on how the manufacturer plans to address possible code violations.

“Should Meet” Gate Criteria - Cost Advantage

This area of the research will answer Gate 1 cost criteria. In order to estimate if the GeoSpring™ is a neutral cost to the homeowner and is a “least cost” alternative, certain assumptions will be made such as the unit will require no major repairs outside of warranty if not required during the test period and the unit will continue to perform as tested throughout the estimated lifespan of the unit.

Research Question 2A

- What is the total installed cost of the GeoSpring™, including infrastructure and incidental costs for the monitored system?

Technical Approach

- Obtain a detailed cost estimate from the manufacturer and contractors for ordering, shipping, storing & handling, preparing for installation, actual installation and startup.
- Log actual costs or assessed retail value, including labor time, all incidental parts (nuts, bolts, brackets etc.) and transportation costs.
- Compare all cost projections with actual expenditures.
- Identify, note and quantify any additional cost items which were not originally anticipated.
- Identify possible credits and/or rebates from federal, state or local authorities or utilities.
- Report final, all-inclusive expenditures and projected future expenditures.

Research Question 2B

- What are the anticipated maintenance and repair costs of the system over the life of the unit?

Technical Approach

- Identify the anticipated life span of the product based on manufacturer’s research or warranty.
- Obtain a detailed cost estimate from an installation/servicing contractor or the manufacturer's designated service organization for repairs and service during the

warranty period.

- Provide maintenance and warranty information as available.

Research Question 2C

- Is this a neutral cost investment for a homeowner?

Technical Approach

- Using data gathered, calculate energy saved using the GeoSpring™ when compared to other systems modeled and calculate the monthly dollars saved based on current utility rates provided by the home owner.
- Estimate the additional monthly payment that would be generated into a typical 30 year fixed mortgage, based on total installed cost of the system compared to an industry standard system and anticipated lifespan.
- Report the final comparison of additional monthly payment versus energy dollars saved.

Research Question 2D

- Is this a “least cost” alternative?

Technical Approach

- Gather cost estimates and model energy use for comparable water heating technologies and compare to the total cost and energy use calculated for the GeoSpring™.
- Report the final comparisons.

“Should Meet” Gate Criteria - Reliability Advantage

Research Question 3A

- How reliable is the system?

Technical Approach

- Document occupant’s impressions, such as:
 - Has there consistently been sufficient hot water?
 - What was the overall impression of the controller? Ease of use? Did the controller impact behavior related to energy savings (vacation settings, etc.)?
 - Are there any other issues, e.g., noise, cold air in the surrounding space, etc.?
 - Does the manufacturers recommended maintenance match operation in the field?
- Follow up with the homeowner after the first month, and every quarter thereafter until the research is complete to verify satisfactory operation.

- Document performance variations relative to ambient temperature and relative humidity.
- Establish if there have been any reported concerns or issues with the GeoSpring™ using internet research and manufacturer's websites.
- Document any performance issues encountered.

"Should Meet" Gate Criteria - Manufacturer/Supplier/Builder Commitment

Research Question 5A

- Is the logistical support (warranty, supply, installation, maintenance support) sufficient for widespread implementation?

Technical Approach

- Assess and evaluate the level of support and service provided by the manufacturer, suppliers and contractors.
- Assess current availability from the manufacturer and suppliers.
- Assess current availability of qualified installers.

Research Question 6A

- What do production builders think about the GeoSpring™?

Technical Approach

- Identify personnel who would represent the production builders who have experience assessing or implementing the technology for the purpose of conducting interviews. Identify any concerns the stakeholders may have, including but not limited to:
 - What problems, if any, were encountered during installation?
 - What measures could be taken to streamline the implementation process in future installations?
 - What are some of the unique requirements of the GeoSpring™ system that need to be addressed for successful implementation, ongoing operation and energy performance?
 - What additional time, if any, could be added to a builder's overall construction schedule as a result of installing the GeoSpring™ system?
- Conduct interviews with the stakeholders.
- Obtain installers' feedback. Learn what the installer thinks of the technology and its feasibility, viability, practicality and identify any potential installation issues relating to plumbing and other trades.

Research Question 6B

- Is this system viable and cost-effective for implementation in a production building environment?

Technical Approach

- Using data and information obtained through the study, assess the viability of the GeoSpring™ in a production building environment.

Research Question 7A

- Do the energy savings and benefits of the GeoSpring™ warrant its use for retrofit applications?

Technical Approach

- Using data obtained from the study, do an analysis to compare savings, benefits and cost using the GeoSpring™ to replace existing water heaters in retrofit applications. Areas of interest should include replacing existing water heaters of various types, vintages and energy efficiencies, including:
 - Resistive electric tank type and tankless
 - Gas heaters, both tank type and tankless

Research Question 7B

- What possible barriers need to be overcome specifically for retrofit applications?

Technical Approach

- Using data obtained, identify possible barriers and solutions in the retrofit market.

“Should Meet” Gate Criteria - Gaps Analysis

Research Question 8A

- What are the potential barriers that need to be bridged to make future projects more successful?

Technical Approach

- Using gathered data, research and other information obtained, we will identify possible barriers and gaps in GeoSpring’s potential to be used in a production and retrofit building environment.

Proposed Test and Analysis Procedure & Schedule

Table 68 shows the preliminary schedule for the HPWH evaluation. Appendix A in the final report contains detailed system diagrams and monitoring equipment specifications.

- Install HPWH according to the manufacturer's instructions to be operated as recommended by the manufacturer. Install sensors.
- Collect data for two (2) months for 2010 interim system performance report. Data collection will continue for at least one year.
- Perform analysis and write System Report

2010					2011						
Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July
Install HPWH and sensors. Begin data collection				Continued data collection and system monitoring.							Complete Data Collection
Complete initial research			Interim System Report								System Report

Table 68. Preliminary test and analysis schedule

Analysis of HPWH system

Monitoring of the HPWH system will be continuous for up to one year. The parameters of interest will be:

- Energy consumption of the HPWH unit (electrical input)
- Input Btu/h (temperature of input water)
- Output Btu/h (temp of output water)
- Domestic hot water flow
- Water heater environment temperature and relative humidity

Using the collected data we will:

- Calculate energy used by the HPWH unit
- Calculate output energy in Btu/h
- Determine ambient air temperature and relative humidity's impact on performance.
- Compare with provided data for existing technologies

Subtask 2B.2- Stage Gate 1B Report: Results of Research on Systems for Prototype Homes

BIRA performed systems evaluations and performance analysis relative to the Stage Gate 1B criteria. Three of the systems are scheduled for continued analyses and one system did not satisfy the Stage Gate 1B criteria.

Advanced System	System Status BP1 (2008)
CSIPs	CSIPs are still in Gate 1B. They have analytically shown to provide a better thermal envelope than standard R-19 walls, but did not shift the peak load to off-peak utility rates. The thicker the interior layer of the CSIP, the lower the peak load.
MELs	Gate 1B research for MELs will continue into 2009, expanding the test group and testing bigger and more sophisticated systems, as well as developing integrated MELs systems into projects like Home of the Future.
PVT	PVT remains at the Gate 1B and is awaiting more cost data and feedback from contractors. Diverse actual application data from various climate regions is still needed, which will be obtained either from the manufacturer or through test monitoring.
SunCache	The SunCache system remains in Stage Gate 1B. While some actual operational data has been provided by Eric Lee of Harpiris Energy, additional data monitoring is needed to further determine energy savings.

Table 69: Summary of Stage Gate 1B Advanced Systems Analysis for BP1

Advanced System	System Status BP2 (2009)
High R-Value Walls (SIP Walls)	Performance still needs to be evaluated since construction of the homes are not yet complete
OASys Cooling Systems	Additional summer data is needed to accurately evaluate source energy and whole building benefits.
Ground Coupled	Performance still needs to be evaluated since construction of

Heat Pumps	the homes are not yet complete
Home Energy Management	Baseline performance data is now being collected from installed systems; After six months, the system's features will be fully activated to provide the most energy savings possible for evaluation.
Heat Pump Water Heater	AirTap™ has provided substantial site energy savings over the propane fired water heater. However this particular product fails the Stage Gate 1B criteria based on warranty and cost.
Solar Thermal	This ongoing work is examining three solar thermal systems and remains at Stage Gate 1B pending more thermal monitoring data, simulation analysis, cost data and stakeholder feedback.
PVT	PVT theoretically completed the Stage Gate 1B Criteria. Actual system performance testing to continue in 2010.

Table 70: Summary of Stage Gate 1B Advanced Systems Analysis for BP2

Advanced System	System Status BP3 (2010)
High R-Value Walls (SIP Walls)	Performance of the advanced wall system has been analyzed and is included in the system performance interim report.
OASys Cooling Systems	The OASys system successfully satisfied criteria for Stage Gate 1B. Refer to the completion report for more details related to performance results.
Ground Coupled Heat Pumps	Performance will be evaluated in 2011 as monitoring equipment installation was completed late November.
Home Energy Management	The baseline performance data has been collected for a full year without the installation of the HEMs. As of October 2010, the HEMs have been activated and are currently gathering data from the utility bills in order to quantify the energy savings impacted by the HEMs itself.
Heat Pump Water Heater	The heat pump water heater manufactured by General Electric (GE) was installed in an existing home earlier this year. Currently BIRA has gathered a minimum of two (2) month's data. Refer to the heat pump water heater interim report for further details.
Solar Thermal	The solar thermal system performance analysis has been completed and is referenced in the completion report satisfying criteria for Stage Gate 1B.
PVT	The PVT report has been completed but is not ready to move forward from Stage Gate 1B

Table 71: Summary of Stage Gate 1B Advanced Systems Analysis for BP3

CSIPS Budget Period 1 (2008)

One of the largest energy usages for a single family residence is the energy required to operate the HVAC system. Perhaps more importantly, the peak energy demand throughout the western states comes from air conditioning, and residential air conditioning is often the major contributor to summer peak electricity demands. Typically, the HVAC system runs during the hottest periods of the day when the price for electricity is at its peak. Shifting the HVAC system usage period could reduce the energy cost to the homeowner. In addition, reducing summer peak electricity demands can save large amounts of money for the electricity providers – these savings can be key drivers to utility support of residential energy efficiency programs. It is postulated that adding concrete for thermal mass to the house will shift the home's HVAC usage period into the late morning and evening, when electricity rates are no longer at their peak. This objective cannot be readily achieved with today's building practices as lightweight wood frame construction does not provide sufficient thermal mass to shift the peak HVAC operation period. The goal of this systems research is to determine how effective Concrete/Cementitious Structural Insulated Panels (CSIPs) with an optimized interior concrete thickness are in shifting the period of HVAC usage to off peak electrical rates.

The BIRA team is investigating thermal mass effects because the results from the prototype homes in Borrego Springs, California showed a reduction in heating and cooling load, but the DOW Chemical 10" T-Mass system used was expensive and cumbersome to install. The cost to install the T-Mass system at Borrego Springs was 75% more than the standard 2"x 6" wood frame construction. Finding a cost-effective alternative with similar benefits is what CSIPs is anticipated to show. The interior concrete layer thickness of the CSIP was varied to determine an optimal thickness for cost effectiveness.

The ProTEC CSIPs consist of a 4" extruded or expanded polystyrene foam core and 0.25" Util-A-Crete backer boards on both sides of the core. The panels come in sizes of 3' x 8', 9', and 10'. The weight of the 3' x 8' panel with 0.25" backer boards is 102 lbs., approximately 4.25 lb/ft²; whereas, weight is not an issue with wooden stick frame wall construction. The panels are fitted together using galvanized 18 or 20-gauge steel C-channels, H-channels, and splines, which are completely enclosed in the ProTEC CSIP panel. The panels are secured using proprietary fasteners.

Key Results

The CSIP walls with 0.5" interior thickness showed a 21% reduction in cooling load compared to a comparable house using standard R-19 construction. The CSIPs did not exhibit peak load shifting to non-peak utility rates. The weight of the wall with 0.5" interior concrete thickness

could prove to be problematic when being installed by manual labor. The weight increases from 100 lbs. to about 150 lbs. The cooling energy load reduction will help achieve the whole house energy reduction target. The ProTEC CSIP walls have been approved in several jurisdictions. The CSIP walls can withstand the elements and will not warp or swell if left unprotected.

Gate Status

CSIPs are still in Gate 1B. They have analytically shown to provide a better thermal envelope than standard R-19 walls, but did not shift the peak load to off-peak utility rates. The thicker the interior layer of the CSIP, the lower the peak load. Analytical energy and cost comparison to the Building America Benchmark will be done in the future. Testing and monitoring of indoor conditions as well as wall temperatures will be done next year in the CitiHouse #2 project by Alvis Projects. Cost between walls with 0.5" and 0.25" interior thickness will be investigated in the future from manufacturer data. Contractor estimates will also be collected to show realistic costs to the homebuilder. CSIPs have been approved by jurisdictions, but investigation is needed to determine whether they are being approved under prescriptive or performance based codes.

Conclusions

Based on the analytical results obtained from the various models, the CSIP walls, at an optimum interior concrete thickness of 0.5", will provide an average of 21% reduction in the cooling load compared to standard R-19 construction. The reduction in the heating and cooling load will be related to an energy savings compared to the Building America Benchmark at a later time. The analysis of CSIP walls did not provide a time shift in peak load but did reduce the peak cooling load.

From researching the IRC, the CSIP wall panels meet the performance and prescriptive based code. Even though CSIP walls are not explicitly allowed in the code, the CSIP characteristics meet the standards of the IRC.

When compared to standard wood frame construction, the materials cost of CSIP walls is estimated to be less expensive. However, when including the manufacturing of the panels they are more expensive due to its complexity and the panels' size for shipping. By factoring in the installation cost and construction material clean-up cost, the overall cost for CSIP walls in a mature market is anticipated to be equal with standard wood frame construction and provide additional thermal benefits. Further research is needed to verify actual cost figures. CSIP walls are more resilient against impact forces as well as the natural elements when being stored at a job site. Also, CSIP walls form a tighter building envelope reducing drafts and air leaks, which is normally needed in standard construction to dry out interior wall moisture.

From interviews with the manufacturer, training classes are provided on the job site or at the

manufacturing site for new contractors, builders, and architects to CSIPs. Throughout a client's first project, the manufacturer will provide thorough and in depth help to walk the client through the process of constructing a home with CSIPs. Full time telephone support as well as jobsite field agents are available for aid as well. The field agents also perform inspections.

Some of the major barriers that would prevent CSIPs from becoming a mainstream method of building homes would be its exposure in the market and lack of builder's education. If builders knew about the cost and thermal benefits as well as CSIP's durability, they would be more willing to use them. Another step that is needed to bring about more exposure to CSIPs is to explicitly describe the conditions of use in the building and energy codes. Having CSIPs specifically stated in the building and energy codes would increase builder's confidence in using the material. By dissemination and education of its beneficial characteristics, CSIPs could become a more viable building material. Builders also need to have a resource to go to if they have issues or problems with the CSIP panel system. Providing adequate customer service and support will help the CSIP industry increase the use of CSIP panels in residential energy-efficient construction.

"Must Meet" Gate Criteria -- Source Energy and Whole Building Benefits

A prototype CSIP house, located in Fresno, California, was modeled in TRNSYS with ProTEC CSIPs, 4.5" Structural Insulated Panels (SIPs), and standard R-19 walls. The prototype house was 36'x36' with 8' tall ProTEC CSIPs. The living space has vaulted ceilings and also is above a plenum crawlspace. The TRNSYS analytical models were reviewed by Thermal Energy System Specialists (TESS) for quality assurance to establish reliable results.

Through analytical modeling in TRNSYS energy usage to heat and cool the prototype house was reduced by 21% when using CSIPs (0.5" interior concrete thickness) compared to standard R-19 wood frame construction at 16" on center (O.C.) as well as SIPs. The outdoor design temperature was 102°F, which occurred on July 15th. The indoor temperature was mechanically maintained at 76°F and below. The results from the analytical runs are shown in the table below.

	CSIPs (0.50")	CSIPs (0.25")	SIPs	R-19
Peak Cooling Load	6,179	6,724	7,136	7,866
Time of Peak Load	6:00 PM	5:00 PM	5:00 PM	5:00 PM

Table 72: Analytical Peak Cooling Load (Btuh) for CSIPs vs. Standard Constructions

A key potential of the CSIP is the thermal mass used for heating and cooling storage. From the analytical test, the thermal mass was not enough to offset the peak cooling load on the simulation peak cooling day which was July 15th. The optimal thickness of the interior concrete

layer of the CSIP remains as 0.25" since there is not enough thermal benefit in the 0.5" interior thickness. The added thickness also adds to the weight of the panels helping to negate the ease of installation. Standard construction with interior 5/8" thick gypsum board lacks the thermal mass capability, which prevents it from being able to shift the peak load to after the on-peak electricity rate. The tightness and the high insulation value of the CSIP wall system were able to reduce the amplitude of the peak load. The reduction in peak load allows for reduced peak energy charges (assuming time of use electrical rates); therefore, saving the homeowner money. Widespread application of this technology could serve to reduce the electrical utility's peak, as well.

Some additional benefits include minimal on-site debris, rapid construction, better quality control, rot and mold resistance, excellent sound proofing properties, and reduced exposure to rising wood prices. The CSIP panel system also allows fewer air leaks and less thermal bridging that will reduce the heating and cooling loads on the house, saving the homeowner in utility costs. Mechanical ventilation may be required due to the tighter construction as well as applicable building codes, adding to construction costs.

"Must Meet" Gate Criteria -- Performance Code Based Approval

CSIP walls are not explicitly described or allowed in the International Code Council's (ICC) International Residential Code (IRC); however, T-Clear submitted their ProTEC CSIP wall system to the ICC-Evaluation Service (ES) for evaluation and code approval. The ICC-ES has approved the ProTEC CSIP wall in Legacy Report NER-581 allowing for compliance under the 1999 Standard Building Code and the 2000 International Residential Code. CSIP walls are also not listed under the 2006 International Energy Conservation Code (IECC) sections for wood frame walls or under mass walls. Since CSIPs are not explicitly described in the IRC or IECC, CSIPs must conform to the criteria designed for traditional wood frame houses. (Hagerman, *Preliminary...*). As described for above grade walls in Table 404.5.2(1), CSIP walls must meet a U-Factor of 0.057 or lower. The nominal U-Factor for a CSIP wall is 0.050. The 4" foam core section of the panel is R-20 and with the 1/4" cement backer boards applied to both sides, the R-value increases to about R-23.

As recently as May 2007, the ProTEC CSIPs were reviewed by NTA, Inc., a third-party code compliance company. NTA, Inc. found that the ProTEC CSIPs were compliant with the 2003 IRC, in report TCC121205-17, under the following conditions:

1. Shall not be used in areas classified as High Velocity Hurricane Zones as indicated in the reference codes
2. Shall be designed by a registered design professional
3. Engineering calculations, floor plans, and relevant details are to be submitted to the code official when application is made for a permit
4. Design loads shall be determined based on the design loads in the applicable code
5. Heat producing fixtures shall not be installed in the panels unless protected by a method

approved by the code official

6. Panels are manufactured under a quality control program approved by NTA, Inc.

“Should Meet” Gate Criteria -- Prescriptive Based Code Approval

Per section 402.2.3 of the 2006 IECC, CSIP walls would qualify as mass walls since “at least 50 percent of the required insulation R-value is on the exterior of, or integral to, the wall.” The greatest required R-value of R-19 occurs in climate zones 7 and 8, which CSIPs exceed as it has a nominal rating of R-20. The Partnership for Advancing Technology in Housing (PATH) states that mechanical ventilation is needed when building with CSIPs and the air change rate should not be less than the local code requirement or 0.35 ACH when no code exists. (Simpson)

“Should Meet” Gate Criteria -- Cost Advantage

Although the initial cost of the materials for CSIP wall panels is more expensive than traditionally wood frame wall construction, the overall cost when labor is factored in shows that CSIPs are a more cost effective wall system. The analytical material cost for CSIP walls, in current market conditions, with 0.25” thick concrete and 4” thick core is 37% less than traditional R-13 wood frame walls on a \$/lin. ft. scale. 6” core CSIP costs 27% less than traditional R-19 wood frame walls. When comparing the R-20, 4” core CSIP with an R-19 wood frame wall, the CSIP wall materials costs about 58% less; however, the total cost for CSIP is about 50% less than for wood frame walls when the labor costs are included. This cost analysis was conducted with RS Means 2008 Building Construction Cost Data - Western Edition. Actual contractor bids to the builder will vary. Experienced CSIP contractors and builders will be interviewed for cost data.

CSIPs are more cost effective because it provides a greater thermal barrier and thermal mass storage than standard wall construction. The thermal barrier and storage properties reduce the design load of the house by creating a tighter thermal envelope with less infiltration and less thermal bridging between the outside environment and the interior space. With the smaller heating and cooling design loads, a smaller, less expensive HVAC system can be installed. CSIP walls also do not require gypsum board to be applied to the interior for fire protection, unlike regular SIPs and standard construction.

Mature market cost cannot be stated at this time because of nonexistent data to substantiate any figures. T. Clear could not provide a mature market price for their product as there are too many unknown variables. Mature market costs are assumed to be lower than the aggregate prices for the standard wall construction. With this assumption coupled with the savings in labor cost, reduced on-site construction waste, and a potentially smaller HVAC system brings the overall cost of a CSIP house to about the same price as a standard construction home, but with increased value and reliability

Using CSIP wall panels will be cost neutral or even cost less when compared to standard

construction. The initial material cost for the CSIP is projected to cost less than standard construction walls, will cost more to ship since there are currently few distribution points. Where CSIPs lower the overall cost margin is on the back end of the building process. CSIPs require less labor time to install and less waste results from construction. Compared to a standard framed house, a similar CSIP house can be erected in half the time cutting construction time and expenses. The panels can also be custom cut to reduce the associated waste even more. Also, with the anticipated expansion of CSIP manufacturing and distribution points, mature market shipping costs will decrease.

“Should Meet” Gate Criteria -- Reliability Advantage

Reliability will be measured based from input from contractors who have used CSIPs and vendors who provide the products. From interviews with the installing contractors, information about the reliability and feasibility of the CSIP will be determined. Important criteria would include resiliency and ease of installation. The proprietary U-channel system and the panel field modifications need to be viable features of the CSIP that the installing contractors can use for quick installations.

The materials arrived on time to meet the building schedule of the project. The wall panels were also resilient enough to withstand the elements of the outdoors as well as accidental impacts and collisions. The panels are rated and tested to ASTM E 72 standards. Per the Federation of American Scientists, the allowable axial load for a 4” thick CSIP panel is 3,555 plf (pounds per linear foot) and 247 plf for allowable racking shear, as determined by ASTM E 72 Standards. The ProTEC CSIP panels have the following loading properties:

Loading Test	Ultimate Strength	Allowable Load	% Better
Axial Loading	4,747 plf	3,555 plf	34%
Transverse Loading	146.47 psf	N/A	N/A
Racking Shear	702 plf	247 plf	184%

Table 73: Ultimate Loading Strength - 4” Thick ProTEC CSIP Panel

The code allows for small deflections due to wind or transverse loading on the panels. The allowable load for a CSIP panel, per Table R301.7 of the 2006 IRC, is 1/240th of the span length. The ProTEC CSIP panels allow for an undetermined deflection, which will be further investigated. Section R614.5 of the 2007 Supplement to the IRC dictates that the wall must withstand a roof load of 7 psf and a ceiling load of 5 psf. That translates for a 3’ foot wide by 4” thick wall to a roof load of 7 lbs. and a ceiling load of 5 lbs.

Extruded and expanded polystyrene are a closed cell forms which do not allow for air to pass through them, unlike the fiberglass insulation that is used in standard construction. The closed cell structure maintains its R-value throughout time; whereas, fiberglass insulation needs to allow air to pass to dry out any moisture that could cause rotting or mold. The passing of air

over or through the fiberglass insulation reduces its effectiveness as the temperature differential between the outside and indoor air increases. Fiberglass insulation is more susceptible to poor installations, such as gaps and pinching. Poor installation of fiberglass insulation reduces the effective R-value of the wall.

CSIP panels can be stored on site in varying conditions for extended periods of time. SIP panels become susceptible to sun and moisture if not properly stored and protected, resulting in swelling to the oriented strand boards. (SIP Supply) Any wood product, framing timber or OSB, is susceptible to moisture causing rotting or swelling. The concrete boards will not swell or rot if exposed to the elements.

Per the ICC-ES AC04, Section 3.5, plumbing and waste lines may extend through the wall panels but may not run vertically through the core. Plumbing and waste lines shall not interrupt splines or panel plates unless specifically permitted by ICC-ES. Plumbing with CSIPs will have to be done in one of two ways. The first way would be to create a wood frame wall construction where the plumbing is to run and insulate as best as possible. The other method is to create furred walls in those same locations. Using either of these methods would not compromise the structural, thermal properties, or warranty of the CSIP.

“Should Meet” Gate Criteria -- Manufacturer/Supplier/Builder Commitment

From interviews with T. Clear’s representatives, they have local representatives and certified contractors throughout the United States, mainly in Florida and Ohio. With more representatives and certified contractors, the use of CSIPs in residential housing will grow and be able to provide faster assistance when needed.

Typical problems or defects are not currently available as there have not been any reported incidents. T-Clear has stated that they will cover material and workmanship defects for 15 years.

When product warranty claims are submitted, the installing contractor is the first party contacted by either the homeowner or the builder sales staff. It is up to the installing contractor to determine the reason for the defect or malfunction. If it is a product issue and not an installation issue, the claim would then be sent on to the product manufacturer.

“Should Meet” Gate Criteria -- Gap Analysis

One of the most significant barriers that were noticed about CSIP wall systems in the new residential housing market is its lack of exposure and use. Builders have used the traditional wood frame method of constructing building walls and they continue to use that method because it is tested and proven to work. A lot of builders may feel a CSIP wall system would cost too much. What needs to be emphasized more is the money saved overall when factoring in the reduced labor and waste cost. One of the most important points directed toward the home builder is that the quality of construction by using CSIP walls will add value to the homes.

Another barrier preventing CSIP wall constructions from becoming widely known and used is its absence from the energy code. Builders and contractors tend to default to the building and energy codes when it comes to using new technologies. Without CSIP walls being explicitly mentioned in the codes, builders and contractors may be hesitant to use CSIP walls in large residential construction developments.

Acceptance of CSIP walls will have to take a similar road that SIP walls have taken. SIP walls were first introduced in their current form in the 1960s. They were first used in prototype and demonstration homes to showcase their benefits. The Structural Insulated Panel Association (SIPA) was formed in 1990 to promote the use of and educate the industry about SIPs. SIP walls have been accepted into the 2006 IRC under the 2007 Supplement to the IRC, Section R614. Likewise, CSIPs would need an organized effort to get its explicit approval in the IRC.

Part of the appeal and marketing strategy is that the ease of installation reduces the need for skilled labor. Without the need of skilled labor, installation costs will decrease as a builder can hire lower on-site construction wage workers. The less skilled workers would not need extensive training to be qualified for the CSIP wall installation. They would simply need to be shown how to erect, secure, and modify the panels by the manufacturer’s field staff. The reduction of skilled labor can be used if the panels had arrived on-site undamaged and ready to install with little to zero modifications needed. (FAS) Currently, no certification is needed to install.

Another potential problem would be not having an established and reliable support system from the CSIP manufacturer. The CSIP manufacturer needs to have a support structure so their customers can have readily available help when problems arise on the job site. Issues such as receiving damaged panels or a lack of installation instructions can cause delays in construction as well as add to construction costs. (FAS Habitat) When most CSIP panels arrive damaged and need to be field modified with circular saws, dust gets thrown into the air which could be a hazard to the workers if they are not wearing masks or respirators. In a “mature market” situation, one possible method to providing a reliable support system is to have regional or local manufacturing plants. Having multiple locations will reduce the shipping time as well as increase the likelihood of the panels arriving at job sites undamaged and ready to install

Combined Solar: Photovoltaic and Thermal (PVT Solar) Budget Period 1 (2008)

A relatively recent solar industry innovation uses special configurations of solar photovoltaic cells, combined with solar thermal collectors, to convert the sun's radiation into electricity and heat simultaneously in a single system. These Solar "Photovoltaic Thermal" systems (PVT) combine elements of both PV-only and thermal-only solar systems to generate and capture useful electrical and heating energy to benefit the homeowner.

The "PVT Solar System" utilizes thermal energy generated from solar photovoltaic (PV) modules to provide domestic water heating, space heating, and preheated ventilation air. Ambient air is drawn in underneath the PV array, and collects some of the heat dissipated from the PV panels. The air can then be further heated by air thermal solar modules before being pulled into ductwork, located within the attic space. This heated air is then used for water, space heating, or as pre-heated ventilation air, as the need demands.

Key Results

Actual installed system data has shown significant electrical and thermal energy production. Code approvals have been achieved in several jurisdictions with ease; therefore, the PVT product conforms to the building, energy, and fire codes. Some local jurisdictional codes may still restrict certain solar products. Solar Rating and Certification Corporation (SRCC) approved PVT systems also qualify for tax credits (30% federal tax credit), helping to reduce the cost. The warranty for the PVT defaults to the individual part manufacturers. The PVT system has not been through enough year cycles to accurately gauge defects or failures.

Gate Status

PVT remains at the Gate 1B and is awaiting more cost data and feedback from contractors. Diverse actual application data from various climate regions is still needed, which will be obtained either from the manufacturer or through test monitoring. Analytical data is also still needed and will be obtained in the future from the manufacturer. Determining whether or not the PVT was approved under the prescriptive or performance code is still needed and will be completed through interviews with the manufacturer and city officials. Continued monitoring will provide feedback on any potential defects and failures as well as provide more diverse actual use data.

Conclusions

Testing indicates that installed PVT systems saved an average of 25% on space heating and 80-85% on water heating in a typical home in milder climate areas such as Boulder, Colorado and San Francisco, California. PVT system provide 2-3% more electrical output than the standard Building Integrated Photovoltaic (BIPV). PV temperatures and electrical energy generation efficiencies are still needed for the existing installations. Temperatures and efficiency will be

monitored in future installations.

The PVT systems have not had any issues with approval by local jurisdictions. The system complies with the applicable building, energy, and fire codes. The cost of a PVT system is approximately 25% more than a regular PV system, but is considerably less expensive than a combined, side-by-side PV and Thermal array. When incorporating the rebates and subsidies that are available, the overall cost coupled with the energy benefit is very promising. The PVT has a shorter payback time than a comparable PV system, which should also be considered when analyzing the cost effectiveness. In addition, the PVT system has a smaller footprint, taking up less roof space. The smaller footprint is particularly important when trying to apply a renewable to a multi-family project where the roof space per living unit is much smaller than the roof space for a detached, single family home.

“Must Meet” Gate Criteria -- Source Energy and Whole Building Benefits

A PVT analysis in TRNSYS has not been completed as there is not an established model for the current version of the PVT product. The manufacturer possesses the most up-to-date model and that is currently being reviewed for accuracy. Until then, actual operational data will be analyzed. A PVT installation in Reno, Nevada has been monitored since January 2008. The data taken from this 5.6 kW system was acquired on the five clearest days for each month. The average peak daily electrical output, DHW production, and space heating production for the PVT system on these five clearest days of the season are shown in the table below.

Season	Electrical (kWh)	DHW (kWh)	Space Heating (kWh)
Winter	83.6	36.4	51.3
Summer	188.5	75.8	0.0

**Table 74: Average Daily Peak PVT Production
Reno, Nevada Installation**

Based on performance results per vendor information done in Boulder, Colorado and Tucson, Arizona, water heating potential energy savings are 82% and 98% respectively. The potential space heating energy savings are 16% and 46%, respectively. The Tucson, Arizona energy savings were much greater than the Boulder, Colorado savings due to its higher climate temperature. The higher climate temperature results in heating losses by the water heater and smaller space heating load. The PVT vendor, PVT Solar, tested a 3 kW solar electric system with thermal installation in San Francisco, California which showed an 84% increase in generated energy (estimated 7,160 kWh) when heating the domestic water over the standard 3 kW PV-only module. When heating the domestic water and the living space, there was a 107% increase in generated energy (estimated 8,073 kWh).

Projected performance for the 2.25 kW PVT installations in South Jordan, Utah at the Gold Medallion project by Kennecott Land is 2,960 kWh of electrical, 105 Therms for domestic hot

water, and 20 Therms for space heating. Currently, BIRA is monitoring the energy production and conditions of the living space¹³. Further details can be found in Appendices A and C of the final report.

Conventional solar “PV-Only” systems utilize the sun’s power to generate useful electrical energy only; however, the PV operation temperature increases due to solar heat gain and waste heat generation from the PV modules which negatively impact the efficiency and performance of the modules. The optimal PV module operating temperature range is 60 - 68°F. For every 1.8°F of temperature increase, the PV module loses 0.5% in efficiency. In a PVT system, heat is drawn away from the PV modules by passing air under them to help reduce the operating temperature of the modules thus increasing their energy efficiency. Increase in PV generation has been shown to be 2-3% above standard BIPV modules, which lay flush with the building’s roof (Plaisted, 2008). BIPVs may also transfer the unwanted PV generated heat to the building which could increase its HVAC cooling load.

The heated air that is produced from the PV modules can be directed for additional energy savings. Thermal modules are used to further increase the temperature of the air which can help heat domestic water as well as partially meet space heating needs. The thermal module air handler takes in tempered outside air to supply the living space with fresh air to improve the indoor air quality. The ventilation air is essential with more advanced and tighter homes to help maintain the indoor air quality.

“Must Meet” Gate Criteria -- Performance Code Based Approval

PVT modules are not explicitly described or mentioned in any code, but PVT systems, ranging from 2.6 kW to 4.6 kW, have been installed in at least nine U.S. locations as of 2010, and have been permitted by local jurisdictions. These locations include:

- Salem, OR
- Reno, NV
- San Francisco, CA
- Thousand Oaks, CA
- Fontana, CA
- Honolulu, HI
- Kennebunk, ME
- South Jordan, UT
- Las Vegas, NV
- Phoenix, AZ

PVT was installed and test monitored at Kennecott Gold Medallion in South Jordan, Utah, a BA

¹³ See sections *Combined Solar: Photovoltaic and Thermal (PVT Solar) Budget Period 2 (2009)* and *PVT Budget Period 3 (2010)* in this report for updates.

“lab house”. Shortly thereafter UT builder Garbett Homes made PVT a standard on a community of 20 homes. The homes and PVT systems were very well accepted by the market, and monitoring results showed them to work well. Installations increased in 2009 (BP2) and 2010 (BP3 – see those sections later in this report). PVT systems shall be installed per Chapter 23 of the 2006 International Residential Code. They must also meet the performance guidelines as described in the 2006 International Code Council Performance Code. PVT is currently undergoing Solar Rating and Certification Corporation (SRCC) approval. PVT was approved by the Solar Rating and Certification Corporation (SRCC) for their OG-100 rating.

“Should Meet” Gate Criteria -- Prescriptive Based Code Approval

PVT must meet the existing prescriptive based codes for existing PV and Solar Thermal units. PVT must conform to local fire safety codes for proper roof access and emergency electrical PV disconnection. All systems shall be grounded and wiring weatherproofed. Other criteria for PVT are unknown.

“Should Meet” Gate Criteria -- Cost Advantage

The cost of mounting a PVT system is not significantly more than installing a conventional PV-only system except for additional thermal-only modules. The additional cost is about 25% more than the conventional PV-only system, but has a much shorter payback time because of the added thermal energy savings. The PVT payback time varies depending on the array size and environmental conditions.

As previously mentioned, the Boulder, Colorado and Tucson, Arizona installations exhibited potential water heating energy savings of 82% and 98%, respectively. The potential space heating energy savings are 16% and 46%, respectively. The potential water heating and space heating energy savings correlate to lower energy bills for the homeowner. The exact monetary savings will vary depending on the utility rate schedule. These results show a potentially shorter payback period than a conventional PV system due to additional savings in reducing the space heating loads and domestic hot water loads. Lower energy consumption by the end user also spells savings for the utility companies as well.

According to the Department of Energy, homeowners can receive a 30% tax credit for SRCC approved solar electric systems that are placed in service from January 1, 2006 through December 31, 2016 under the Residential Renewable Energy Tax Credit. They can only receive 30% up to \$2,000 if the system was installed between January 1, 2006 and December 31, 2008. (ENERGY STAR®, 2008) After that, the \$2,000 limit no longer applies. Another tax credit available to them is receiving 30% back up to \$2,000 for a SRCC approved solar water heating system. They must show that half of the energy used for domestic water use comes from the sun.

Homebuilders also qualify for a tax credit under the Energy Policy Act of 2005. If they can show

that the homes they build and sell from January 1, 2006 through December 31, 2009 have a 50% reduction in the heating and cooling load with 1/5 of the energy savings coming from enhanced building envelope, compared to an equivalent house under the 2003 IECC and supplements, then they can apply for a \$2,000 tax credit.

The tax credits for the homeowner and homebuilder should be enough incentive to use the PVT system. The homeowner will see a return in the money spent to install the system if the system is installed after January 1, 2009 (Consumer Tax Incentives, 2008). The tax credit for the homebuilder is quite substantial as it is \$2,000 for each home built. These are only federal tax credits. With the addition of federal and state tax credits or utility rebates, the installation cost of the PVT system can greatly be reduced.

“Should Meet” Gate Criteria -- Reliability Advantage

One advantage with using a PVT system with air is that the system does not fail if there is an air leak. PVT systems that use water as a heat transfer medium have the potential for water damage on the roof from leaks or freezing. Non-corrosive materials such as aluminum are used extensively for longer lasting usage.

PVT also easily integrates with existing proven PV modules and off-the-shelf blowers & coils, which makes PVT easily integrated into the current building process. Currently, the PVT installation process can be done in a segmented manner in which each trade installs their respective component of the PVT. Otherwise, a qualified solar contractor can perform the installation in its entirety.

Having a quality installation is one of the keys to maximizing the benefits of the PVT system. The inspection process will also help ensure that the system performs to the stated specifications. The inspection includes checking of panel temperatures, azimuth, pitch, and shading. Inspections can be performed by qualified representatives from the manufacturer or from certified third party inspectors.

One disadvantage, like all other PV systems, is that the PVT efficiency is susceptible to degradation if shaded or covered. Other factors that might carry over from when PV systems were first being used were subpar installations or poor planning. Mostly these poor installations were due to lack of experience. Simple education about PVT and their installation methods, either through the manufacturer or an organization like the North American Board of Certified Energy Practitioners (NABCEP) coupled with inspections would help ensure the quality of installation.

“Should Meet” Gate Criteria -- Manufacturer/Supplier/Builder Commitment

PV modules are highly reliable – and because PVT is an integrated system, it does not modify or void the third party PV manufacturer’s warranties in any way. Installing the PVT system would

eliminate the separate warranties that the homebuilder require if installing PV-only and Thermal-only systems. Installation also should be performed by a certified NABCEP contractor to help ensure a proper installation.

The PVT warranty covers the mounting system for 10 years and the finish for 5 years. The mechanical component warranties are not through PVT Solar, but through the respective manufacturers, which range from 18 months to 10 years.

“Should Meet” Gate Criteria – Gap Analysis

The three main market drivers for the PVT are available roof space, profitability, and building integration. Houses in America are getting larger and larger, allowing for larger roof areas. With the larger roof areas, PVT systems can easily be installed as opposed to the side-by-side PV and Thermal units, which require more space for the equivalent kW production.

Marketing to a currently unstable environment could potentially hold back the PVT. Builders are looking to build a cost effective home and the additional cost of a PVT system could dissuade them from using it; however, the cost for PV systems has shown a steady decline in price as manufacturing processes become more efficient as well as the influx of foreign PV modules into the market. PV modules already have a foothold in the building industry. If PV manufacturers added PVT to their product line, PVTs would have a smoother introduction into the market. PVT would be marketed by established companies with credible reputations. (Solar Electric Power, 2001). Another alternative for homebuilders is to build houses that are PVT-ready. Preparing the home by installing all the necessary components without the PVT system itself would reduce the cost to the homebuilder and give the homeowner the option for the future. The homeowner can then take utility rebates or subsidies for themselves. Rebates and incentives can be found at www.dsireusa.org.

Rebate programs or subsidies from the government or utility company could help persuade homebuilders and homeowners to purchase and install PVT systems (Solar Electric Power, 2001). Builders do not have incentive to take the big step toward energy efficiency. Having federal or state government energy efficiency regulations and standards would push the homebuilder to explore emerging energy technologies, like PVT. California has established a set of energy reduction standards with Assembly Bill (AB) 32, which requires all sectors, including the building sector, to reduce carbon emissions.

A potential issue that needs to be researched is the impact of potential parasitic losses of the added fan-coil and circulating pump. Also, the added benefits of the use of night cooling and thermally driven cooling need to be investigated analytically or with real life test data.

Creating a PVT system that can seamlessly integrate into the standard building systems would make PVT much more appealing to the homebuilder. As stated before, PVT Solar’s product can either be installed by a certified solar contractor or by the individual trades themselves. Either

party would have the knowledge to successfully integrate their portion of the PVT into the rest of the building systems. PVT systems that take a similar approach would also have building integration success.

SunCache Budget Period 1 (2008)

BIRA investigated the preconstruction goals and tasks needed to evaluate the Harpiris Energy's SunCache Solar Water Heater. Delays in construction and installation prevented a full analysis of this system. This interim report discusses the work completed to demonstrate that SunCache, an Integrated Collector Storage (ICS) solar domestic hot water heating system, is an efficient and cost effective means of reducing energy use and greenhouse gases produced by using standard tank-type water heaters.

After space conditioning, water heating is typically the largest energy user in the home. According to the Center for Sustainable Energy, "In California, about 40% of natural gas used to heat water could be saved through the use of clean, renewable solar water heating systems." SunCache is a domestic solar water heating system developed by Harpiris Energy in conjunction with SunEarth, Inc. Harpiris Energy is a subsidiary of the Davis Energy Group (DEG). Supporting its development is the National Renewable Energy Laboratory (NREL).

SunCache is one of many varieties of an ICS solar domestic hot water heating system. ICS systems are generally passive systems that require no additional pumps and rely solely on existing pressure in the domestic water system. They combine a solar collector with an integral storage tank. Incoming cold domestic water is pre-heated through a copper heat exchanger, which is located completely within a roof-mounted collector/storage unit.

Unlike many ICS units that heat the potable water directly, the SunCache system is an indirect system. Water in the roof-mounted collector/storage unit is heated by the sun. This water serves as thermal storage and the medium that transfers heat to the potable water in the copper heat exchanger. The roof-mounted collector/storage container consists of a black thermoplastic shell covered with a plastic glazing. The 50 gallon storage container is filled with unpressurized water, and once it is initially filled, and it remains there does not re-circulate. The sun's heat, gained from the solar collector/ storage container, is then transferred to the water within the heat exchanger, thus "pre-heating" the domestic water before it enters the conventional water heater. From the water heater, hot water flows to the homes plumbing fixtures as needed.

Key Results

According to the SRCC, 65 therms are saved annually in California's climate zone 13. Data collected from previously installed SunCache units yielded 75 therms per year saved. SunCache systems are estimated to cost \$3,500, and that figure can be reduced through a 30% federal tax credit and other incentives. The SunCache is eligible for the federal tax credit because it is SRCC

OG-300 certified. Installation of a SunCache system should take about 2 hours. However, SunCache systems are not recommended to be installed in climates susceptible to freezing temperatures.

Gate Status

The SunCache system remains in Stage Gate 1B. While some actual operational data has been provided by Eric Lee of Harpiris Energy, additional data monitoring is needed to further determine energy savings. Monitoring was planned to begin in 2009 at Alvis Project's CitiHouse II to determine actual energy savings. However, CitiHouse II funding was never approved. No additional work was performed by BIRA on the SunCache system.

Conclusions

The SRCC estimates that 65 therms per year will be saved in California's climate zone 13. However, actual installed data has shown that 75-80 therms can be saved per year. Further analysis will be needed to better determine actual energy savings.

Some jurisdictions require a structural report to install SunCache units onto the roof. An alternative materials application may also be needed if it is to be installed in a jurisdiction that does not allow pex piping. Otherwise, SunCache units are anticipated to meet prescriptive and performance based code approval.

The SunCache unit should cost \$3,500 before incentives and federal tax rebates. Further cost analysis of similar systems is needed to determine if their low-cost alternative claim is valid or not.

SunCache units come with a two-year warranty, but have a life expectancy of 15-20 years. The absence of moving parts results in little maintenance required.

Harpiris Energy can meet any size order if they are given a three month period from order date to shipment date. Harpiris is continually making enhancements to the SunCache system to minimize installation issues. Contractors in Hawaii have installed a SunCache unit in two hours without any prior exposure to SunCache systems.

Because SunCache lacks a drainage system in its roof mounted storage, it is not recommended to install SunCache systems in climates susceptible to freezing temperatures. Further research by the manufacturer will be needed to determine if it is feasible to install SunCache systems on flat roofs.

"Must Meet" Gate Criteria -- Source Energy and Whole Building Benefits

According to the SRCC, a SunCache system will save 65 therms annually in California's climate

zone 13 (ratings reflect model number SCG-50-GS). Preliminary data from units that have been installed yielded 75-80 therms per year saved annually. Data monitoring will be needed before further reaching a conclusion, as climate zone and household water usage can vary results.

“Must Meet” Gate Criteria -- Performance Code Based Approval

Solar water heaters are not specified in the 2006 IECC. However, they are listed in the California Energy Code (CEC). In CEC section 150.j.4, solar water heating systems and/or collectors shall be certified by the Solar Rating and Certification Corporation (SRCC). SunCache is SRCC OG-300 certified (SRCC certification # 300-2008-009A).

“Should Meet” Gate Criteria -- Prescriptive Based Code Approval

SunCache systems shall be installed per Chapter 23 of the 2006 International Residential Code. The installation shall conform to all federal, state, and local regulations, codes, ordinances and standards, and governing solar water heating system installations.

Some jurisdictions may require structural calculations, depending on roof materials, roof pitch, and additional live loads. Also, some jurisdictions do not allow the usage of pex piping without the approval of an Alternative Materials Application.

“Should Meet” Gate Criteria -- Cost Advantage

One of the biggest claims to the SunCache unit is that it is a less expensive option for solar water heating. There are no parasitic power requirements due to the absence of additional pumps, which helps keep manufacturing costs down. Each unit is projected to be \$2,000 wholesale at a mature market price. Contractors who have previously installed SunCache units at a site were said to charge \$940 to install a SunCache unit. After builder markup, a SunCache unit is estimated to be \$3,500 for residential new construction houses. Because SunCache is SRCC OG-300 certified, it is eligible for a 30% federal tax credit. Certain states, such as California, Louisiana, and Hawaii, also allow additional rebates; a SunCache unit can cost as low as \$2,500 in California after all incentives have been taken into account.

SunCache has also been recently recognized by the California Air Resource Board (ARB) with the Innovative Clean Air Technology (ICAT) program. The ICAT program co-funds the demonstration of innovative technologies that can reduce air pollution and will provide qualified homeowners in Southern California with free SunCache systems and \$500 towards installation costs.

Using the SRCC’s rating of saving 65 therms per year in California’s climate zone 13, and PG&E’s \$1.20/therm rate, the SunCache unit will have a reported payback period of 32 years. Further research would be needed to determine payback period, as Harpiris Energy had estimates of a 10.6 year payback period.

“Should Meet” Gate Criteria -- Reliability Advantage

Each SunCache unit has a life expectancy of 15-20 years. Many aspects of its construction add benefit to the reliability of the system: An all copper heat exchanger allows heat absorbed in the panel to transfer into potable water. A seamless rotationally molded medium tank decreases chances of leak. Pex piping reduces the likelihood of pipes bursting, as is common when water freezes inside copper piping. Each unit is QA tested, including leak testing, at the factory. The SunCache is a passive system and relies on pressure and gravity to circulate water. This eliminates the need for moving parts such as pumps, thus decreasing the maintenance required. The water collector on the roof will need to be topped off with water after every 5 years, but no other major maintenance is expected.

In addition to the current glazing installed with the unit, in 2009, Harpiris Energy will introduce an optional glazing material (polycarbonate glazing). Initial cost estimates have not been provided, though it is expected to add to the cost of a standard SunCache unit. It will have a shorter warranty compared to the standard glazing (10 years), but the optional glazing will be more resistant to cracks and damage and will essentially be bulletproof.

The SunCache’s integrated collector storage on the roof does not have an easy method to drain the water. Thus, it should be noted that SunCache is not recommended to be installed in climates susceptible to freezing.

“Should Meet” Gate Criteria -- Manufacturer/Supplier/Builder Commitment

From interviews with SunCache representatives, their factory is able to handle any demand given a turn-around time from request to product shipment of three months. Each SunCache unit has a two-year warranty. According to its maintenance manual, SunCache will reimburse up to \$100 in the first year for field labor to repair or replace any defective SunCache units. They also state that a lot of the required maintenance is simple and can be done by the homeowner, reducing the need for service calls.

Harpiris Energy is continually improving its product as more units are installed in homes. The mounting bracket is currently in its 5th or 6th generation, with each revision decreasing the likelihood of encountering errors and problems during installation. Harpiris Energy has also improved the way SunCache units are shipped. Damaged units were uncommon in previous shipping methods, but they have developed a new, sturdy box that reduces the risk of units being damaged while in transit.

There have been a few contractors that have had experience with installing SunCache units. Among them are contractors located in San Luis Obispo, CA, Monterey, CA, and Hawaii. The contractors in Hawaii have been reported to install a SunCache unit in two-hours without needing any additional assistance from Harpiris Energy. Funds are being allocated to provide training to more installers in Southern California.

“Should Meet” Gate Criteria -- Gap Analysis

One of the most significant barriers for the SunCache unit is the apprehension of home builders to include solar water heating into their houses. Solar water heaters are traditionally expensive, and in the current state of the housing market, builders are reluctant to add the cost of solar water heaters despite their benefits. Solar water heaters may also take up garage floor space and look unattractive if a storage unit is installed on the roof. However, with a product pricing goal set to be lower than other similar products, SunCache hopes to turn solar water heating into a viable, cost effective option. It take no floor space and is design to make the integrated collector storage unit on the roof mimic a skylight.

Another significant barrier that prevents SunCache from becoming more widely known and used is its lack of a drainage system in its integrated collector storage. The risk of freezing prevents SunCache from being installed in cold climates or other areas susceptible to freezing.

Sloped composition shingle roofs are the ideal site for a SunCache unit installation. While there have been units installed on clay tiled roofs, installation is a little more costly and takes a little longer than a typical installation. However, with proper planning, a space can be cleared on the roof to allow space for a SunCache unit. SunCache units have yet to be installed on flat roofs or roofs with Concrete/Cementitious Structural Insulated Panels (CSIPs).

SunCache systems can be installed on various water heaters. Storage water heaters are the most common and easiest to install. Tankless water heaters and indirect radiant boilers are also compatible with SunCache systems, although they may require more time to install than on standard storage water heaters

Miscellaneous Electric Loads (MELs) Budget Period 1 (2008)

Miscellaneous Electric Loads (MELs) (a.k.a. phantom loads, plug loads) are associated with unnecessary electrical consumption by appliances and consumer electronics. As loads are reduced in cooling, heating, lighting and water heating, MELs are becoming a more significant overall load, representing 25% of the total load of a 40% hot/dry BA benchmark home as shown in Figure 45, below.

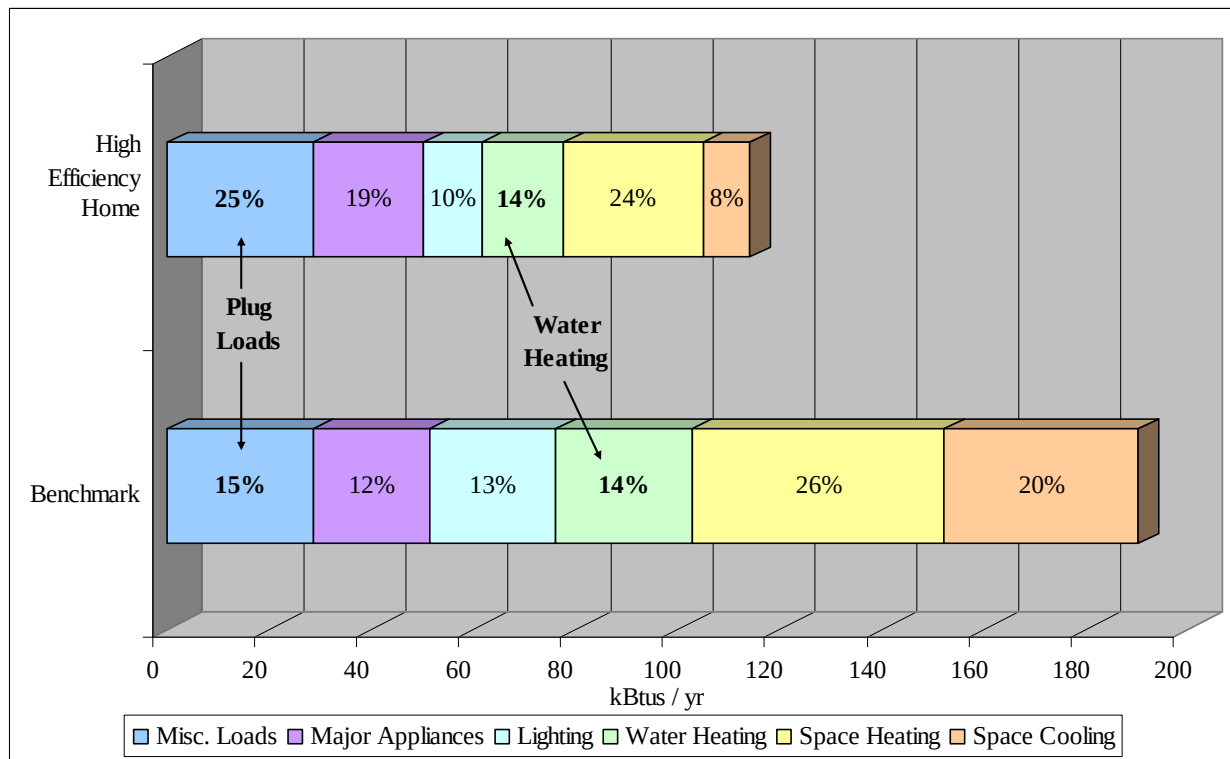


Figure 45: 40% High Efficiency Home vs. Building America Benchmark (Hot/Mixed Dry)

BIRA is investigating the electrical savings potential from the introduction of controls and consumer education into Building America homes, aimed at small appliance and consumer electronics. Both manual and occupancy based controls will be evaluated.

Research Goals

The present focus of this research effort is on builder-implementable strategies for MELs reductions. As these strategies have the potential to also reduce non-MEL energy usage, cost-benefit analyses will include the impact on whole house energy usage. Opportunities to reduce MELs fall into three general categories discussed below.

Individual component efficiency improvements

Many improvements in the efficiency of individual products and components are expected to occur as a result of ongoing investments by product manufacturers, utilities, public interest organizations, and federal, state and local governments. Examples include recent progress by Energy Star such as an updated specification for Energy Star televisions that addresses standby and active power consumption and a new specification for Energy Star digital-to-analog converter boxes, which are currently being introduced to the market in preparation for the transition to digital broadcasting.

Recommended technical approaches with respect to this category include:

- Tracking product performance trends to ensure use of “best available” products in BA projects
- Providing recommendations for improvements in product performance based on experience in BA projects
- Acting as technical advisors on research efforts funded by other organizations
- Conducting targeted tests of new products when performance data is not otherwise available to verify benefits relative to BA performance goals

Whole House Control Systems

Approaches in this category include programmable timers, occupancy detectors, whole house control switches, and adaptive controls. These systems may be implemented through a dedicated household wiring strategy, existing electrical wiring, wireless switching, and tie-ins with other control hardware in the home, such as insulating blinds, lighting systems, space conditioning systems, building security systems, and utility load-management/demand-response controls.

Recommended technical approaches with respect to this category include:

- Tracking product performance trends to ensure use of “best available” products in BA projects
- Providing recommendations for improvements in product performance based on experience in BA projects
- Using lighting systems, space conditioning systems, switchable power outlets, and other devices that allow for occupancy based control
- Using control systems, receptacles, or other devices that control one or more outlets based on the power used by the main (master) outlet
- Using manual whole house switches that provide occupants a tool to disable selected plug loads and lighting and change thermostat settings indefinitely or for prescribed time periods (e.g., 2 hours, 4 hours, 8 hours, extended vacation, etc.)

Developing standardized energy use modes for implementation in home automation and control system software and user displays.

Occupant behavior changes

Approaches in this category include occupant education in household energy usage and product selection and real-time feedback to occupants regarding energy usage. (*While it is important to provide consumers with the information required to reduce energy end-uses,*

occupant behavior changes are considered to be largely outside the scope of the system research and technology development tasks of the Building America Program.)

Opportunities with respect to this category include:

- Including information about energy efficient home operation and product selection with homeowner's manuals and operating guides
- Including energy feedback displays in Building America homes

Table 41 summarizes an estimate of the average source energy savings relative to the Building America performance goals for a whole house control system that captures savings from MELs, lighting, and HVAC. It is currently estimated that an average 6% whole house source energy savings relative to the Building America Benchmark will result from this approach.

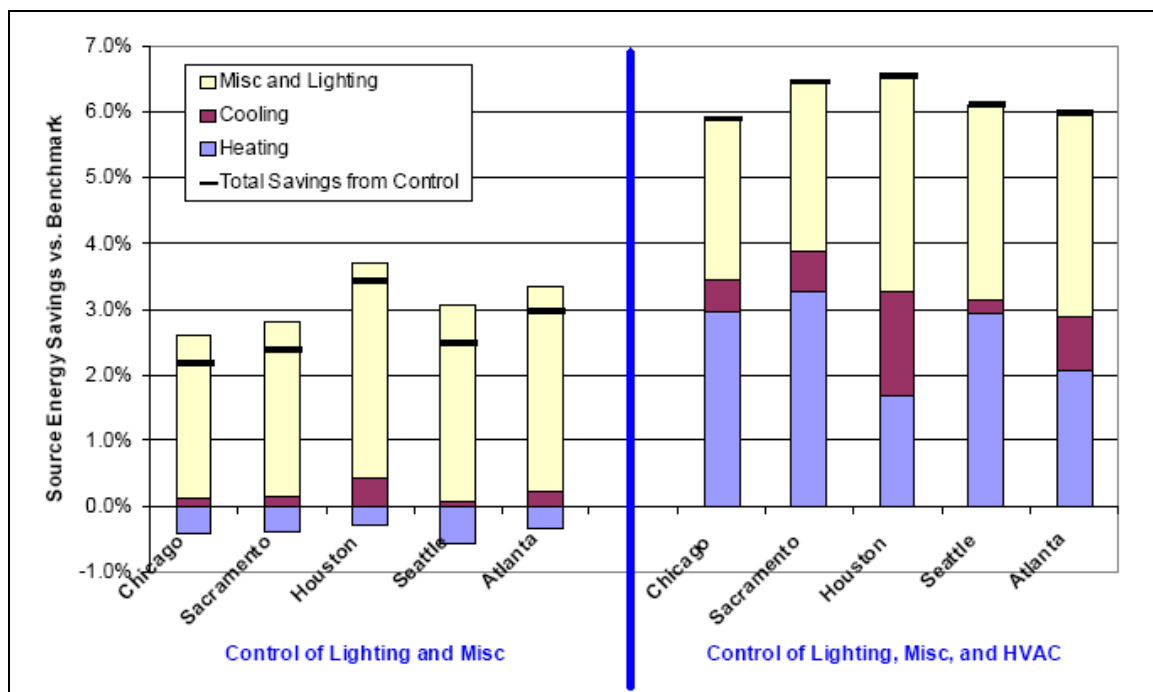


Figure 46: Estimated Average Source Energy Savings for Whole House Control Systems in Each of the Major Climate Zones

The proposed research effort consists of six tasks and incorporates the Building America Stage Gate decision process.

- Task 1 - Identify existing MEL reduction strategies, review related work being done by other groups, and define requirements for development of advanced MEL reduction solutions beyond existing offerings.
- Task 2 - Stage Gate 1A evaluation of MEL reduction strategies: Within a whole building context and technology package, estimate the system's contribution to BA energy

performance and neutral cost targets using energy simulations and currently available performance data. Results from SG1a will be used to prioritize MEL reduction strategies for research efforts.

- Task 3 - Stage Gate 1B evaluation of MEL reduction strategies: Test performance benefits of whole house energy control systems.
- Task 4 - Stage Gate 2 evaluation of MEL reduction strategies: Test ability to integrate advanced systems with production building practices.
- Task 5 - Stage Gate 3 evaluation of MEL reduction strategies: Test performance of final production building designs and evaluate performance of occupied BA communities.
- Task 6 - Coordinate and track progress toward meeting program goals across the DOE-funded research in this area by all the participating teams. Track product performance trends to ensure use of “best available” products in BA projects

MELs Categories

Research must be done to reduce MELs in general. However, the category is very broad and must be divided up to better focus improvements. For the purposes of the BIRA work, MELs have been divided into five categories with different strategies for each area. These general MELs categories include:

- Small Appliances - Toaster, coffee maker, rice cooker, microwave
- Home Entertainment Centers - TV, DVD player, satellite/cable box top, stereo equipment
- Home Offices - Desktop/laptop, monitor, printer, scanner, router, cable/dsl modem
- Consumer Electronics - wireless phone, video game systems, ipod/phone/pda chargers
- Large Appliances - Refrigerator, AC unit, washer/dryer, dish washer

MELs Reduction Strategies

Miscellaneous electric loads are largely impacted by the occupant and their lifestyle. Home owners want to enjoy their home, and fill it largely with consumer electronics to entertain themselves. Fortunately, there are numerous strategies that can be implemented to mitigate the consumption of the different MELs categories, as well as methods to alter occupant lifestyles. Some strategies to mitigate MELs loads include:

- Appliance Efficiency Regulations and Protocols
- Education and Ergonomics Research
- Automated and whole house Controls
- Feedback meters

Appliance efficiency regulations and protocols is a top down approach to mitigate electrical loads from the design and manufacturing level. Working with industry leaders and consumer

electronics associations will help to create more energy friendly appliances and consumer electronics, reducing energy consumption from the top-down. This trend has already begun for large appliances such as washers, dryers and refrigerators, and it is only logical to continue this progression to consumer electronics such as televisions, cable box tops, DVD players, computers and recharging devices.

Education is an important energy reduction strategy in all MELs categories. Any strategy involving the user must be accompanied by a good consumer education program. Consumer education enables the homeowner to modify their behavior and make informed choices about their energy use. When armed with knowledge, the consumer can be further empowered with tools that give them feedback and that help them more seamlessly control their consumption.

Educating users to make knowledgeable decisions about their energy use is a key to modifying occupant behavior, a major factor in MELs reduction strategies. Targeted information through education packets, mail inserts, web-based information, and homeowner manuals can help the consumer make knowledgeable decisions on energy use. Education packets can demonstrate energy saving strategies for each of the target MELs categories, as well as impact heating and cooling loads through advanced pre-cooling and ventilation methods.

When a consumer is educated about MELs and energy use in general, providing them feedback through displays and control through automated or manual devices will allow them to make informed choices on their energy use. Displays can provide a consumer with real-time feedback about the cost of their decisions. “Green Switches” and intelligent power strips can help these users to be proactive in their energy choices.

Automated and whole house controls will help to turn off components when they are not in use. Automated systems use low energy occupant sensors to determine, for example, if someone is in fact sitting in front of the TV while it is on, and if not, turns it off. Whole house controls such as the “green switch” provide a master on/off switch to turn off a specific circuit, allowing occupants to turn off selected phantom loads when they leave.

Feedback meters and devices are similar to miles-per-gallon displays being installed into new vehicles. They alert the driver of their current fuel efficiency, based on their driving habits, and allow them to improve the economy of their driving if they so desire. Similar devices are available for the home and present current energy usage/costs to the occupants in a variety of useful ways. Feedback systems allow the consumer to better budget energy usage and improve their economics of energy consumption. An important piece of the feedback puzzle is understanding the ergonomics of displayed information. For example, “What is useful to the consumer in the display?” What makes it more “friendly” and understandable?” “Where is the line for information overload?”

Test and Analysis Objectives

BIRA research focused on specific MELs categories to evaluate the performance benefits and specifications for specific mitigating solutions. Target categories include:

- Home Entertainment Centers - TV, DVD player, satellite/cable box top, stereo equipment
- Home Offices - Desktop/laptop, monitor, printer, scanner, router, cable/DSL modem

The home entertainment center and home office were selected because of their large potential impact on centralized consumer electronics equipment. Both the home entertainment and home office centers have a national average daily usage greater than eight hours a day. Table 42 and 43 detail the unit electrical consumption for the average home entertainment and office centers¹⁴. Using the average usage and unit electrical consumption data, the home entertainment center accounts for 800-1200 kWh/yr, and the home office accounts for 500-600 kWh/yr. These two target areas consume approximately 1500 kWh/yr., more than half of the total MELs load.

	"Off"	Standby (W)	On (W)
Cable Box	n/a	21	21
DVR	n/a	27	27
DVD Player	1	8	12
Stereo	3	43	45
First Digital TV	n/a	4	192

Table 75: Home Entertainment - Unit Electrical Consumption

	"Off"	Standby (W)	On (W)
Cable modem	0	0	6
Router			10
Home Phone	2.3	3.3	4.0
Black and White laser Printer		20	830 (peak)
Color Laser		20	1200 (peak)
Scanner		10	20
LCD Monitor (19")	1	1	35
Desktop Computer	2	20	95

¹⁴ (Roth et al., TIAX LLC, 2008)

Table 76: Home Office - Unit Electrical Consumption

Both target areas produce considerable loads, and are also largely impacted by occupant behavior. This presented the unique opportunity to evaluate MELs systems as well occupant impact on the target areas.

Systems Tested

BIRA focused on two MELs reduction strategies: automated and manual control systems. This represents the two predominant system types currently available on the market. Automated systems represent solutions as simple as motion controlled light switches, and as complex as control systems for whole house lighting, security, outlets, thermostat, etc. Manual control systems have the ability to control a set of outlets from a centralized location. Power strips are the simplest manual control system, but they are usually unreachable to consistently shut down. “Green switches” are the more complex systems using a master switch to control numerous objects in the house from one centralized location.

BIRA tested two control systems to determine their effectiveness at reducing MELs loads in both the home entertainment center as well as home office, and to get user feedback on each system. The two systems were:

1. LCG3 Smart Strip Power Strip

The LCG3 Smart Strip Power Strip is produced by SmartStrips, and features ten outlets total: one (1) control outlet (always hot), three (3) constant hot (1 transformer, 2 standard), and six (6) switched (3 transformer, 3 standard) outlets. The control outlet is the master outlet with an internal CT that detects current and controls the switched outlets appropriately. If the control outlet is on, the switched outlets are on as well and vice versa. The LCG3 also features three (3) always on outlets, for components that must always be on, i.e. a cable box top and TIVO, or cable modem and router.



Figure 47: LCG3 Smart Strip Power Strip

2. Isole IDP-3050 Plug Load Controller

The IDP-3050 is a motion sensor control power strip, and has two (2) constant hot transformer outlets, and six (6) switch (1 transformer, 5 regular) outlets. The switch outlets are controlled by the motion sensor, which is equipped with a variable timer, 30 sec to 30

min. The power strip will not operate unless the motion sensor is connected, preventing tampering.



Figure 48 : Isole IDP-3050 Plug Load Control

Test Methods/Technical Approach

Systems

A preliminary background search was done to determine if MELs loads could accurately be modeled in any of the approved software simulations packages, and none were capable. This is presumed to be largely because MELs cannot be completely controlled since they are largely based on occupant life style. While a completely automated and pre-programmed whole house control system might be effective at reducing MELs, it would most likely receive a negative response from the occupants due to poor occupant comfort.

To determine the effectiveness of the two systems, a preliminary prototype test was done using four selected test homes. Due to time constraints, the test was limited to a 3-week study:

- Week 1 - Determine baseline loads in both the home entertainment center and the home office;
- Week 2 - Test the IDP-3050 on the home entertainment center and the SmartStrip on the home office; and
- Week 3 - Test the IDP-3050 on the home office and the SmartStrip on the home entertainment center.

The control systems were logged by Hobo's set to collect data every minute, and using 50amp CT's. Custom boxes were built to simplify the installation of the data loggers. Twelve (12) gauge electrical wire was spliced for the CT's, and run through a watertight case. The case enclosed the CTs and the Hobo to prevent tampering or damage. This test was used to determine the source energy savings provided by the systems, as well as determine if the systems meet the "Must Meet" and "Should Meet" criteria.

Surveys

A survey was conducted of the test subjects, to gain vital ergonomics and occupant response to both systems. Both a pre- and post-survey was conducted to determine the occupants knowledge of MELs and its mitigating systems. The goal of the survey was to determine the occupants prior knowledge of MELs or either of the systems being introduced into their test homes, as well as occupant demographics. Minimal instructions were given to the occupants, with the purpose of requiring them to figure out how to install and take advantage of the systems. The surveys were used to evaluate occupant feedback for each of the systems.

Must Meet Criteria -- Source Energy and Whole Buildings Benefits

The prototype tests were very valuable in learning about the capabilities of both of the MELs control systems. While the test wasn't large enough to determine statistical variances, the results were very beneficial none the less. Additionally, only the phantom load savings number can accurately be attributed to the MELs systems, since total kWh is also dependent on occupant usage which can't be controlled.

Home Entertainment

The motion sensor controlled IDP-3050

- Reduced total kWh for the week by a combined 3.325 kWh, and average of 0.831kWh per test home. This was a 6.8% savings.
- Reduced phantom load draw by a combined 57.55 watts, 14.39 watts per test home. This was a dramatic 46.7% average reduction in phantom load draw.

The LCG3 SmartStrip control power strip

- Reduced total kWh for the week by a combined 9.830 kWh, an average of 2.457 kWh per test home. This is a 26.7% savings over the baseline.
- Reduced phantom load draw by a combined 48.505 watts, 12.126 watts per test home. This is a 38.4% savings in phantom load draw.

Results are summarized in Table 44: Home Entertainment Center with IDP-3050 Results and in Table 45: Home Entertainment Center with LCG-3 Results.

	Baseline	IDP 3050	Savings, IDP 3050	% Difference
Total kWh				
Tester 1	12.28544	9.880602	2.404838	19.6%
Tester 2	7.797246	6.28073	1.516516	19.4%
Tester 3	4.75883	5.83751	-1.07868	-22.7%
Tester 4	4.500052	4.017584	0.482468	10.7%
				6.8%
Phantom Loads (watts)				
Tester 1	43.2	18.36	24.84	57.5%
Tester 2	33	9.48	23.52	71.3%
Tester 3	19.8	19.8	0	0.0%
Tester 4	15.79	6.6	9.19	58.2%
				46.7%
Operating Draw (watts)				
Tester 1	120	104	16	13.3%
Tester 2	110	94.97516	15.02484	13.7%
Tester 3	173.6	164.76	8.84	5.1%
Tester 4	64.0446	64	0.0446	0.1%
				8.0%
Hours operated				
Tester 1	50.81	72.51687	-21.70687	-42.7%
Tester 2	22.68	21.9333	0.7467	3.3%
Tester 3	6.833	15.98	-9.147	-133.9%
Tester 4	24.28	35.18333	-10.90333	-44.9%
				-54.6%

Table 77: Home Entertainment Center with IDP-3050 Results

	Baseline	LCG-3	Savings, LCG-3	% Difference
Total kWh				
Tester 1	12.28544	4.48435	7.801	63.5%
Tester 2	7.797246	7.66619	0.131	1.7%
Tester 3	4.75883	4.16274	0.596	12.5%
Tester 4	4.500052	3.1978	1.302	28.9%
				26.7%
Phantom Loads (watts)				
Tester 1	43.2	11.04	32.160	74.4%
Tester 2	33	25.68	7.320	22.2%
Tester 3	19.8	19.8	0.000	0.0%
Tester 4	15.79	6.785	9.025	57.2%
				38.4%
Operating Draw (watts)				
Tester 1	120	59.3331	60.667	50.6%
Tester 2	110	110	0.000	0.0%
Tester 3	173.6	159.576	14.024	8.1%
Tester 4	64.0446	59.286	4.759	7.4%
				16.5%
Hours operated				
Tester 1	50.81	35.25	15.560	30.6%
Tester 2	22.68	31.6	-8.920	-39.3%
Tester 3	6.833	5.5166	1.316	19.3%
Tester 4	24.28	31.95	-7.670	-31.6%
				-5.3%

Table 78: Home Entertainment Center with LCG-3 Results

Home Office

The motion sensor controlled IDP-3050

- Reduced total kWh for the week by a combined 3.325 kWh, and average of 0.831kWh per test home. This was a 6.8% savings.
- Reduced phantom load draw by a combined 57.55 watts, 14.39 watts per test home. This was a dramatic 46.7% average reduction in phantom load draw.

(Test home 1 had an equipment malfunction, and no data was recorded for it.)

The LCG3 SmartStrip control powerstrip

- Reduced total kWh for the week by a combined 9.830 kWh, an average of 2.457 kWh per test home. This is a 26.7% savings over the baseline.
- Reduced phantom load draw by a combined 48.505 watts, 12.126 watts per test home. This is a 38.4% savings in phantom load draw.

Results are summarized in Table 46 and Table 47.

Total kWh

	Baseline	IDP 3050	Difference, IDP 3050	% Difference
Tester 1	6.150362	0	6.150362	-
Tester 2	5.792944	4.914642	0.8783016	15.2%
Tester 3	9.311119	1.637814	7.673376	82.4%
Tester 4	12.82467	8.126	4.69867	36.6%
				44.7%

Phantom Loads (watts)

Tester 1	13.92	0	13.92	-
Tester 2	9.48	5.16	4.32	45.6%
Tester 3	16.8	5.16	11.64	69.3%
Tester 4	11.316	8.04	3.276	29.0%
				47.9%

Operating Draw (watts)

Tester 1	31.44	0	31.44	-
Tester 2	84	80	4	4.8%
Tester 3	220	180.82808	39.17192	17.8%
Tester 4	81.795	81	0.795	1.0%
				7.8%

Hours operated

Tester 1	114.86	0	114.86	-
Tester 2	117.15	109.1833	7.9667	6.8%
Tester 3	44.66	2.35	42.31	94.7%
Tester 4	113.31	261.66	-148.35	-130.9%
				-9.8%

Table 79: Home Office Center with IDP-3050 Results

Total kWh				
	Baseline	LCG-3	Difference, LCG-3	% Difference
Tester 1	6.150362	5.432294	0.718	11.7%
Tester 2	5.792944	5.211139	0.582	10.0%
Tester 3	9.311119	8.3156	0.996	10.7%
Tester 4	12.82467	10.06965	2.755	21.5%
				13.5%
Phantom Loads (watts)				
Tester 1	13.92	12.48	1.440	10.3%
Tester 2	9.48	6.6	2.880	30.4%
Tester 3	16.8	12.48	4.320	25.7%
Tester 4	11.316	9.48	1.836	16.2%
				20.7%
Operating Draw (watts)				
Tester 1	31.44	31.44	0.000	0.0%
Tester 2	84	43.44198	40.558	48.3%
Tester 3	220	204.36	15.640	7.1%
Tester 4	81.795	81	0.795	1.0%
				14.1%
Hours operated				
Tester 1	114.86	103.0667	11.793	10.3%
Tester 2	117.15	104.55	12.600	10.8%
Tester 3	44.66	32.1	12.560	28.1%
Tester 4	113.31	113.183	0.127	0.1%
				12.3%

Table 80: Home Office Center with LCG-3 Results

“Must Meet” Criteria -- Performance Code Based Approval

The LCG3 and IDP-3050 MELs controls are not explicitly described or mentioned in any building code, and are considered a consumer electronic. Therefore, they are permitted by all codes.

“Should Meet Criteria” -- Prescriptive-based code approval

The power strips meet all manufacturers health and safety requirements for use with electrical components.

“Should Meet Criteria” -- Cost effectiveness

Both systems demonstrated a reduction in total kWh for both the entertainment center and office, as well as a reduction in phantom loads. However, the study was arguably not lengthy enough in duration to accurately contribute total kWh savings to the control systems, rather than a simple reduction in occupant usage. The control systems were compared to a standard surge protector capable power strip, which averages around \$20. The incremental payback period of each system was calculated.

Calculating cost effectiveness based solely on phantom load reduction, in the home

entertainment center, the IDP-3050 saved an average of 14.39 watts per home. Using the national average of a television being operated 8 hrs./day¹⁵, this saves an estimated 84.023 kWh per year. At \$0.12/kWh, this equates to \$10.08/year. The IDP-3050 has a MSRP of \$90, an incremental cost of \$70, so it would take approximately 6.94 years to pay back. Alternatively, the LCG-3 saved an average of 12.126 watts per home, saving 70.816 kWh per year, or \$8.50/year. The LCG-3 has an MSRP of \$32, \$12 incremental cost, and would take approximately 1.41 years to pay back.

In the home office, the IDP-3050 saved an average of 8.289 watts per home. Using the national average of PC usage at 8.13 hrs./day¹⁶, this saves an estimated 48.014 kWh/year or \$5.762/year savings on utilities, with a payback period of 12.15 years. The LCG3 only reduced phantom loads by 2.619 watts per home or 15.17 kWh/year. This equates to a utility bill savings of \$1.82/year with a payback period of 6.59 years.

Using the reduction in phantom load numbers only, these systems are cost effective however the payback period is quite long. Determining the savings the IDP-3050 provides from shutting down equipment while no one is present could greatly improve its cost effectiveness.

“Should Meet Criteria” -- Reliability Advantage

Smart Strip offers a 30-day unconditional return; 2-year guarantee on manufacturer defects; and lifetime return policy for damage caused by a power surge. The IDP 3050 has a lifetime warranty and a \$25,000 connected equipment warranty. Additionally, both of the systems double as surge protectors.

“Should Meet Criteria” -- Manufacturer commitment

Both systems are readily available, off the shelf components currently on sale by numerous retail distributors.

“Should Meet Criteria” -- Gaps Analysis

A post-test survey was given to the test group to determine the strengths and weaknesses of each of the systems, and ways in which they could be improved. The LCG-3 received a lot of positive feedback from its simple installation and operating principles, as well as its non-invasiveness. All participants would use the control device on both their entertainment system and their office, as well as recommend it to a friend. The device was valued from \$30-\$80.

The IDP-3050 received mostly negative feedback in everything from installation to

¹⁵ Tiax LLC – *Residential Misc Electric Loads: Energy Consumption Characterization and Savings Potential in 2006 and Scenario-based projections for 2020*

inconvenience. The test group had difficulties installing the motion sensor in a location that could always detect them and was not sensitive enough to detect minor movements. Additionally, the timer was too short (max is 30 min). The test group complained that the motion sensor was shutting off their TV's in the middle of programming. The worst example was watching DVD's, and having the entire system shut down in the middle of a movie. Since the DVD player was basically unplugged, it didn't save progress, forcing the tester to re-find the scene they were at. A few participants said they would use the device for their home office, but no one would use it on their entertainment center, or recommend it to a friend. It was valued from \$30-\$40.

Another common problem between the two devices was determining what should be plugged into the uncontrolled "always-hot" outlets to optimize energy savings but minimize invasiveness. In the case of the home office, there was a clearer distinction since only the computer and networking devices needed to stay powered. However, for the entertainment center it was much harder to determine what to control. This led to the greatest amount of frustration in the installation of the equipment, and was important information for this research in the event that a large scale test is conducted.

Conclusions

Miscellaneous electric loads are a significant consumer in residential homes, and their overall portion of end use is increasing as homes are engineered to be more efficient. BIRA divided MELs into more manageable segments including:

- Appliance Efficiency Regulations and Protocols
- Education and Ergonomics Research
- Automated and whole house Controls
- Feedback meters

Segmenting MELs into subcategories will help to develop customized strategies to mitigating their loads. For this period of research, BIRA tackled automated and whole house control systems, as well as education and ergonomics research. This preliminary MELs study was very beneficial in determining what sorts of technologies could be implemented in a home. The main options have been occupant control switches that shut off personal electronics, or automated control systems that perform a similar function but are controlled by occupancy sensors. Both systems have their own benefits and problems, but it will be important to develop both solutions in order to mitigate MELs loads.

As MELs systems, and specifically automated and manual whole house control systems progress, it will be important to simplify the controls of these systems to be as intuitive as possible. These control systems have to simplify home owner's lives, instead of burdening them with another complex piece of equipment. The systems would also be much more beneficial if they controlled multiple systems in the home, such as security, thermostat and

sprinklers. This would also share the cost burden and increase its value.

MELs reduction strategies continue to develop, and progressing towards the next decade of 2000 and closer to our goal of Zero Energy Homes, BIRA is working hard to develop cost effective solutions to this problem.

SIP Systems - Status Report Budget Period 2 (2009)

Snow Creek Cottages, 2061 Park Avenue, Park City, UT 84068, is a planned affordable housing project located at a site adjacent to Snow Creek, consisting of 13 energy efficient buildings. The project will not be serviced by natural gas – electricity is the sole energy source provided by a utility.

To reduce the overall energy use, several energy saving/producing building technologies have been employed. These include SIPs exterior walls from foundation to roof bearing, SIPs roof structure, photovoltaic (PV) cells, ground coupled heat pump heating, solar hot water systems, clearstory roof windows, and heat recovery ventilation. This report is in regards to the SIP walls and roof panels.

Structural insulated panels (SIPs) are engineered laminated panels for structural and exterior thermal envelope applications. SIPs are fabricated with solid polystyrene or polyurethane foam cores and structural wood panel sheathing on each side, typically with oriented strand board (OSB). The rigid OSB sheathing, bonded to the foam, provides structural support. Closed-cell foam is an excellent insulator and SIPs walls far exceed traditional batt or cellulose cavity insulation values for similar wall and ceiling insulation thicknesses. They also offer an air-tight envelope, decreasing cold air infiltration.

In this study, the performance of SIPs in the two house configurations (Deer Unit, #11 and Fox Unit #10) will be evaluated based on Building America's Must Meet and Should Meet Criteria

Key Results

Thermocouples have been installed on inside and outside surfaces of the SIP panels at four different locations in both houses (refer to Addendum D of the final report).

Park City was unfamiliar with SIP construction and therefore followed the code standard, which was congruent with Premier submittals. This led to delays in the submittal and permitting process.

Foundations were poured only after submittals were provided and permitting process was reviewed and accepted by all parties. If the panels had been designed and submittals had occurred during site preparation and excavation there would not have been the month delay due to design, submission and code review miscommunications.

The framing contractor came in late because R&O Construction could not find a framing contractor with SIP experience. The site architect reports that the gap between supply and install is great from a code and submittal perspective.

Gate Status

The SIPS system performance still needs to be evaluated since construction of the homes are not yet complete.

Conclusions

Delays in schedule were due to difficulties with SIP submittals and code review. Additional familiarization with SIP building would likely alleviate that problem. Initially, the framing contractor began SIPs installation at a rate slower than standard installation. However, as assembly techniques improved, the framing contractor moved more quickly to finish the exterior wall and roof installation than if using standard framing construction techniques.

The SIPs thermocouple infrastructure is now in place. Outside siding and inside drywall is now being installed over temperature sensors.

Builder/Project Overview

Park City is the developer of the 13 unit affordable housing development in Snow Creek. Park City has a Sustainability Team that connects the missions of various departments in order to achieve a balance between meeting the goals of economic development, community development, and environmental impact reduction. It has set up a website that allows its citizens to download reports on carbon emissions as a function of City operations. Residents of the City may also visit the interactive tool on the website to calculate their own carbon footprint including energy consumption. Park City is therefore committed to affordability and environmental sustainability in its operations and future developments. The Snow Creek development is in line with the mission of the City to reduce energy consumption in its operations and facilities.

Elliott WorkGroup is the Architect on the project and R&O Construction is the contractor. Roger Durst of Elliott WorkGroup is National Green Building Standard Certified and implemented passive and active design strategies in the design of the houses. The architect does not, however, have experience in SIP construction or GCHP technologies. R&O Construction is primarily a commercial builder and was hired because of the volume of building that was being bid out. R&O does not have any experience to date with energy efficient building techniques including SIP Construction and GCHP.

The SIP supplier is Premier Building Systems out of Montana and the installer is AKI Framing. Premier is the largest polystyrene SIP manufacturer in the U.S. with 9 plants in 9 states. AKI

Framing does not have experience with SIP construction. For this project, AKI has hired the installer of SIPs from the Gold Medallion Home in Daybreak, Utah, a current Building America Home that is being monitored. The SIPs panels have been installed by AKI and instrumented with thermocouples in the two units of interest. Siding and sheetrock can now be installed without any problems. The University of Utah team is working with Park City, R&O, Elliott WorkGroup, Premier, and AKI to gather information on delays, costs, schedules, and performance specifications.

“Must Meet” Gate Criteria -- Source Energy Savings and Whole Building Benefits

Energy data provided by sensors installed in the Snow Creek Prototype units, energy simulation models against the Building America (BA) benchmark, and collection of whole building performance data will provide targeted source energy savings estimates based on BA performance analysis procedures and energy performance measurements. This will be accomplished through calculations based on the following assumptions:

- The evaluations will be contrasted against the BA Building America Benchmark House of identical size and configuration as the case houses in Snow Creek. The benchmark house will be modeled and simulated for performance and stand as the control for comparison to the monitoring data from the case houses. The Benchmark is generally consistent with mid-1990s standard practice, as reflected in the Home Energy Rating System (HERS) Technical Guidelines (RESNET 2002). A reference guide is provided by the DOE Building America Program that aids in defining the parameters of the Benchmark House for a given climate, and design configuration.
- Space heating, water heating, and standard electrical energy needs (refrigerator, lights, electronic equipment) are the primary energy demands to be evaluated. The temperatures in Park City during most of the year are cold, and there are only a few weeks where cooling may be required. During those times, it is assumed that the homes will utilize passive natural ventilation systems to remain cool and not rely on any mechanical active cooling.
- The options and possibilities for various types and combinations of finishes are unlimited. In order to remain consistent in the comparison of the benchmark house to the houses at Snow Creek, the same finishes will be modeled in the simulation as occur at the Snow Creek Houses respectively.

Two methods will be utilized in order to better understand the energy use in the two houses. The first method is to conduct an overall energy balance on each unit. The second method is to model each unit and compare the model results with models of houses with the same configurations but with conventional construction and energy systems (as controls). The conventional comparison will utilize the BA Benchmark House as the baseline. The overall energy balance will include data on the SIPs R-values, temperatures on exterior and interior surface of SIP on each floor, and temperatures on interior and exterior of roof panels on north and south slopes.

All temperature and electrical use data will be collected automatically using a data logger that can be accessed remotely via a dial-up modem. Units 10 and 11 have been fully fitted with thermocouple wires that include 12 points on each unit. Much effort was taken to route wires through precut chases in the SIP panel exterior walls, however the holes were not lined up from floor to floor and required drilling and fishing continually. See Addendum D for points list and as built locations of sensors on the exterior and interior surfaces of the panels and other locations within the parameters of the building proper (excluding geothermal sensors).

In order to verify the performance of the test houses, R-values of the High Walls (SIPs panels), the data from the performance monitoring of the two houses will be compared to performance of simulated models of BA Benchmark House with identical size and configurations. The spatial data (3-D) from the architect, given in a Revit file or developed new in a 3D software platform, will be transferred to EnergyPlus for energy simulation for Park City climate scenario. Other software tools including BEopt, Energy Plus, etc. will be used as necessary in order capture as accurate analysis of the benchmark house as possible. It is assumed that the orientation, location, and outdoor design conditions will be similar. Previous studies by Building America teams have used DOE-2 as the benchmark simulation tool. For this study Energy Plus will be used to evaluate the capacity of the tool to model residential buildings and the feasibility of such for future Building America and Department of Energy research in residential building performance using Energy Plus. No modeling has been completed at this time. This is a task for year 2010.

“Must Meet” Gate Criteria -- Performance-Based Code Approval

Several issues were identified that impacted prescriptive or performance safety, health and building code requirements for new homes:

- Park City was unfamiliar with SIP construction and therefore followed the code standard, which was congruent with Premier Building Systems submittals. BHB Structural Engineers wanted a slightly different system that consisted of additional hold downs and provisions for additional lumber and structure on the interior of the SIP panels. These specifications were not standard and therefore led to delays in the submittal and permitting process.
- Foundations were only poured once submittal and permitting process was reviewed and accepted by all parties. If the panels had been designed and submittals had occurred during site preparation and excavation there would not have been the month delay due to design, submission and code review miscommunications.
- AKI Framing in late because R&O Construction could not find a framing contractor with SIP experience. Contractors with experience in the installation of SIPs in Utah are still relatively few. The architect reports that the gap between supply and install is great from a code and submittal perspective.

“Should Meet” Gate Criteria -- Prescriptive-Based Code Approval

In order to verify that SIPs meet prescriptive safety, health and building code requirements for use in new homes, critical design details, construction practices, training, quality assurance, and quality control practices are being documented. To accomplish this task, equipment is routinely inspected to determine whether the each energy saving technology device is being installed according to design specifications. In addition, personal interviews have been conducted with the SIP supplier, R&O construction, Park City and the architect. The following has been determined:

- Gaps exist between the sill plate and the concrete stem wall foundation. This can be attributed to the lack of quality control in the foundation pour. AKI, the installing contractor for the SIP panels, did not know how to mitigate this discrepancy and was prepared to grind the concrete. Shims have been used to make up the gap structurally, but foam was not used to mitigate air infiltration. It is suggested that mastic be placed between the sill plate and concrete as well as a foam insert to remove the thermal transfer and potential air infiltration gap. Air infiltration gaps are also present in many locations of fenestration (i.e. window and door openings). These gaps in the fenestration have been sealed with spray in foam insulation. Verification is needed to ensure that sealing has occurred at the sill to foundation location.
- The plan for construction was inefficient. The contractor requested one crew per house. However this led to great inefficiencies in the first 2 weeks of erection until the crews became knowledgeable of the system. It is estimated that house 14 and 13 took 2 weeks to install compared with the anticipated 5 days to install. Roof panels were the most difficult due to geometrical challenges. This was mitigated in the last units that estimated under a week to erect according to onsite observation.

“Should Meet” Gate Criteria -- Cost Advantage

It is expected that the use of SIPs has a strong potential for cost benefits relative to current systems within a whole building context. The incremental annual cost of energy improvements, when financed as part of a 30 year mortgage, will be compared to the annual reduction in utility bill costs relative to the BA Benchmark. It is expected that the incremental annual cost of energy improvements should be less than or equal to a reduction in energy bills.

Cost reporting from Dave Gustafson at Park City has not been obtained to date. This data will be necessary to evaluate the total capital cost of the SIPs. The overall budget for the project is estimated at \$3.2 million. Each home is then projected to cost \$200K or \$130 / S.F. More cost information will be gathered in year 2010 as construction continues to May. Each energy-saving technology has other impacts besides energy reductions, namely construction schedule modifications. Data will be gathered to compare traditional construction to energy efficient construction to determine the schedule and cost impacts of the 2 homes.

- What are the actual schedule impacts of installing each of the energy saving technologies?
- What scheduling difficulties were encountered in the process? This will be obtained through the interview cycle with the other two projects: SIPs and Ground-Coupled Heat Pumps.

“Should Meet” Gate Criteria -- Reliability Advantage

It is expected that SIPs will meet reliability, durability, ease of operation, and net added value requirements for use in new homes. SIPs should require no maintenance and are passive with respect to operation. One advantage of SIPs is that picture hanging is more convenient in exterior walls given the OSB board under the sheetrock.

“Should Meet” Gate Criteria -- Manufacturer/Supplier/Builder Commitment

Premier SIPs should be available for continuing support and Park City has committed to cooperating with the research team to relay any issues identified in these homes. Thus, the SIPs installation should have sufficient logistical support (warranty, supply, installation, maintenance support) to be used in prototype homes.

“Should Meet” Gate Criteria -- Gaps Analysis

One potential gap in cost and scheduling information has been identified. As issues regarding cost over runs and budget are frequently discussed in the weekly site meetings, the University team has been asked to not attend. Meeting notes and minutes are being collected, but there exists some uncertainty about what information might be missed by not attending the meeting. Hopefully, this change will not affect the evaluation of major technical and market barriers to achieving the targeted performance level. R&O Construction will not use SIP construction again in their opinion. Understanding that R&O are largely commercial builders and prior to this project had no experience with SIPs. The Framing contractor hired by R&O had claimed experience with SIPs, unfortunately that was not very accurate. The difficulties with the process have permeated to other builders in the region. Damage control is being pursued on part of the researchers to inform builders concerning SIP benefits and disadvantages.

To evaluate construction methodology and to identify problems that can be documented and analyzed to learn from for future projects, Tuesday meetings in Park City have been attended where we will take notes and photos and catalog in an archive for later reference during the analysis period.

Attendance at weekly meetings occurred up through the middle of October when the research team was asked to not attend. The reasoning for the request was that in our presence, the contractor and architects were not able to talk as freely or candidly concerning budgetary concerns with the owner. Although the research team has not been able to attend weekly

construction meetings, weekly site visits continue to occur with a walk around the site accompanied by the contractor and architect. Construction documentation has been thoroughly carried out to determine the challenges of the energy saving systems as compared with traditional construction.

Construction was stalled initially due to issues with dewatering the site and the submittal process surrounding the SIPs a total of 2 months. Accordingly the completion date has been moved back to May 2010 in order to avoid some winter months. Currently, siding is being placed on the exterior of the houses and it is unclear when interior plasterboard will be installed.

The SIP design, engineering, submittal, and installation difficulties contributed to schedule delays on the site of 1 month. The SIP panels have been promising and problematic due to the following issues:

DESIGN:

- The houses were designed to maximize interior volume and minimize exterior surface area. The houses are 2 – 3 stories for heating efficiency.
- The houses were initially designed to have stick framing with batt or foam insulation, but the bid for SIPs was competitive and attractive to the design team and owner. The SIPs design promised fast installation, durability, easy to install due to prefabrication, environmentally friendly due to recycled material content, all while decreasing on-site labor.
- SIP walls are 6.5" and roof is 12" with a polystyrene core.
- Because it is not originally designed for SIP construction, the house does not adopt efficiencies of SIP module, and is over structured - excess lumber exists within the SIP envelope, adding to thermal bridging problems.
- Coordination between the architect, engineer and SIP manufacturer was non-existent
- during design, leading to coordination problems all the way through design to install process.

SUBMITTALS:

- The SIP panels were specified by BHB Structural Engineers for Seismic D Zone. Premier Building Systems produces Seismic A, B & C rated panels but not D rated panels. Premier was the low bidder and not accustomed to doing larger residential or commercial work that require a higher level of submittal specification and clarity.
- Submittals were not detailed enough for the architect and structural engineer, including locations of post and beam embeds in walls in drawings being left out, having no connections to foundation or transitions at fenestrations, and the specification submissions were also generic and not specific to the project.
- BHB Structural Engineers wanted a bit different design than what Premier could

produce. BHB wanted a Seismic 'D' zone rating including locations of hold downs. The design process went back and forth between the two, resulting in pushing the City submittal date further back.

- The majority of the problem is the unfamiliarity with SIPs from the architect and engineer which led to multiple revisions in the design submittal. Also, the SIPs supplier, Premier, did not have much experience working directly with architects and engineers, and therefore had difficulty in meeting their requests.

Ground Coupled Heat Pump - Status Report Budget Period 2 (2009)

Snow Creek Cottages, 2061 Park Avenue, Park City, UT 84068, is a planned affordable housing project located at a site adjacent to Snow Creek consisting of 13, energy efficient buildings. The project will not be serviced by natural gas – electrical energy is the sole utility energy source. The units will be heated using Ground-Coupled Heat Pumps (GCHPs), with ground heat coupling provided via U-tube boreholes. Two units will be evaluated, Fox A (#10) and Deer A (#11), each with unique features:

Test Home Details	
Fox A (#10) Unit Description	Deer A (#11) Unit Description
• Two story, single family detached unit	• Three story, single family detached units
• 2 bedrooms, 2 baths	• 3 bedrooms, 3 baths
• single car parking in garage	• single car parking in garage
• 26' x 30' footprint	• 26' x 30' footprint
• Approximately 1,560 square feet of living and utility space	• Approximately 2,340 square feet of living and utility space
• 3 U-Tube Boreholes to 100'	• 4 U-Tube Boreholes to 100'

To reduce the overall energy use by 50%, several energy saving/producing building technologies have been employed. These include:

- SIP exterior walls from foundation to roof bearing
- SIP roof structure
- Photovoltaic (PV) cells
- Ground-Coupled Heat Pump Heating
- Solar hot water systems
- Clearstory roof windows
- Heat recovery ventilation

This report focuses on the energy, costs, and construction schedule implications of using GCHP

heating. Data will be gathered to compare traditional construction to energy efficient construction to determine the schedule and cost impacts of installing GCHP systems in each of the two homes. As the houses are still being constructed, this Stage Gate 2 Prototype Home Evaluation documents some of the findings and identifies the status of critical-path tasks. This report describes the evaluation plans to assess the system performance of Ground-Coupled Heat Pumps relative to the Building America Stage Gate 1B criteria. This research will provide a detailed evaluation of the performance of U-tube boreholes for heat recovery from an aquifer to the heat pump, compared with ambient air coupling, a traditional gas furnace, and a passive thermosiphon system.

Key Results

Most of the field work required to evaluate the U-tube borehole performance has been completed:

- The GCHP design has been obtained and reviewed with Frederick Broberg from Colvin Engineering Associates, Inc., Project Manager for the Snow Creek development. The installation to date meets all design specifications.
- Thermocouples were successfully installed on the methanol liquid lines at 6 points on the tubing within a U-tube borehole in two locations (one for each unit), and the exit and entering points of the tubing of other two or three U-tube boreholes supplying the ground coupling for the heat pumps. These data points will allow calibration of heat transfer models to assess the GCHP performance potential and limitations.
- Installed a passive thermosiphon heat pipe and two valves to divert the methanol liquid through the thermosiphon condenser. Thermocouples were placed at three different fixed points. Operation of the thermosiphon will provide performance data that can be compared to U-tube borehole heat transfer as a means of assessing Gate 1 performance criteria.
- Installed ½ inch PEX pipe in the two instrumented U-tube boreholes (and adjacent to the thermosiphon) to allow detailed manual interrogation of vertical temperature profiles. These data points will allow calibration of heat transfer models to assess the GCHP performance potential and limitations.
- Observed borehole installation details. Those observations verified that the installation met the design specifications obtained from Colvin Engineering Associates, Inc.
- Obtained soil logs (data). Soil logs will give indications of permeability and thermal conductivity.
- The hydraulic gradient is that of the adjacent creek. Groundwater was observed in the trenches carrying the borehole piping near the tops of the U-tube boreholes.
- Heat pumps are now being delivered to the site, and once the models are identified, their rated performance characteristics will be obtained and compared to design specifications.

Gate Status

The GCHP evaluation studies are in Gate 1B status. The installation to date has met performance-based code approval, and is on track to meet prescriptive-based code approval. Sensors are installed to allow detailed whole building energy performance evaluations. Monitoring to begin first quarter of 2010.

Conclusions

The U-tube boreholes, the test thermosiphon, and the horizontal piping to the houses were installed according to industry standards. The geology at the site is challenging with shallow groundwater, variable soils types, and numerous 6" size boulders underground. These features made drilling difficult on the site, resulting in days of down-time for repair of the drill rig. Thus, site conditions are such that higher than average installation costs are expected.

Subsurface temperature monitoring sensors were successfully installed and thermocouple wires have been bundled and run in PVC conduit to the data acquisition unit location. Once operational, GCHP performance data from this installation will provide both overall energy savings and cost data for "must meet" whole building benefit evaluation, and detailed evaluation data for potential design improvements that might be realized in other installations.

The next steps are to connect the thermocouple wires to the data logger, install thermocouples in the methanol/water solution inlet and exit lines of the heat pump, and establish the methanol/water solution flow rates for energy and coefficient of performance calculation purposes. Once the heat pumps are operational, data acquisition will begin first quarter of 2010.

Builder/Project Overview

Ground-Coupled Heat Pumps (also called Ground Source Heat Pumps) is a type of heating system that uses heat pumps to transfer energy between the conditioned space and the earth. Flexible tubing, bent into a U-shape, is inserted into vertically drilled boreholes (U-Tube Borehole). The loop of tubing is then connected in series to a standard fluid pump and a heat pump. The tubes are typically filled with an antifreeze mixture.

GCHPs utilize the fact that the ground can be treated as a reservoir that stays at a relatively constant temperature. GCHP systems use the ground as a heat sink during the summer when the ambient air temperature is higher than the ground temperature. During the winter when the ambient air temperature is lower than the ground temperature, GSHP systems use the ground as a heat source. The aim of the ground coupling is to dissipate energy and if improperly designed, excessive heating or cooling of the soil near the borehole will decrease the system's thermodynamic efficiency.

The antifreeze fluid exchanges thermal energy with the soil and groundwater near the borehole. The energy expenses are the work of pumping the fluid and the work input to the heat pump. For residential heating, the energy transferred from the ground plus the energy powering the pump and heat pump replaces the energy from natural gas burned in a conventional gas fired furnace. If the antifreeze liquid returns from the U-tube borehole field with a temperature near that of the groundwater, the overall efficiency of the heat pump will be maximized.

The homes are being constructed near Snow Creek where the groundwater is relatively shallow (several feet depending on season), the groundwater gradient is high, and the subsurface geology mixed with both clays and gravels. The U-tube boreholes were grouted with a bentonite/silica sand mixture to provide sufficient heat transfer from the U-tubes to the surrounding soils and to prevent vertical flow of water along the U-tubes in the borehole. The supposed high convective groundwater fluxes at the site are expected to dissipate the cooling load placed through the U-tube boreholes. It is not known how these features factored into the final design.

The installation of the GCHP boreholes and horizontal tubing was completed by Palace Geothermal. Mechanical contractors will soon be on site to hook the heat pumps to the ground coupled tubing inside the buildings. The research team from the University of Utah will assist in the GCHP commissioning including flow rate measurements, pressure balancing, and inlet/outlet temperature measurements at the methanol inlet and outlet ports of the heat pump. The research team from the University of Utah will also assist in the air flow rate measurements across the condenser in the air duct.

“Must Meet” Gate Criteria -- Source Energy Savings and Whole Building Benefits

Each energy-saving technology has other impacts besides energy reductions, such as construction schedule modifications and costs. Whole house source energy savings and whole building performance benefits will be calculated based on BA performance analysis procedures and energy performance measurements. Specifically, the field tests, construction monitoring and energy simulations will answer the following questions:

- Can GCHP be used to reduce source energy consumption, decrease the carbon footprint, and lower the cost of heating residences compared to a low efficiency and a 90+ AFUE gas furnaces? This question will be answered by measuring key parameters such as temperatures, power consumption and fluid flow rates to quantify actual energy uses. The performance will be compared to the performance of conventional HVAC systems based on example component specifications.
- Can the heat transfer coupling to the subsurface be improved in terms of cost effectiveness and performance if the U-tube boreholes are replaced with thermosiphon heat pipes? A U-tube borehole will be instrumented with temperature measuring devices to obtain detailed information on the heat transfer from the ground to the U-

tube. A thermosiphon heat pipe, fitted with a condensing heat exchanger on its top to heat the methanol, will also be installed near the instrumented U-tube boreholes and monitored to provide a comparison between conventional and emerging technologies.

- What modeling detail is necessary to define the dominant heat transfer interactions that control the overall heat transfer from U-tube boreholes and thermosiphon heat pipes? Our working hypothesis is that thermal interactions between the inlet and exit sections of the tubing in the borehole limits the overall heat transfer effectiveness in installations relying on a high groundwater flux for energy dissipation. Detailed temperature data, combined with analytical and numerical modeling, will quantify those dominant interactions for both U-tube and thermosiphon heat transfer.

The evaluations will be based on the following assumptions:

- Ground source heat pump energy supply and cost are measured in relation to standard or high efficiency gas powered furnaces.
- The heating system in the residences is a condensing heat exchanger placed in the ducting of a central heating system. The condenser replaces a conventional furnace.
- Since the heat pump will be located in the conditioned space, the energy transfer to the house is the sum of the thermal energy from the ground to the methanol (measured at the inlet and outlet tubes inside the space), the electrical energy into the heat pump, and the electrical energy into the methanol pump.

Data from the temperatures and flow rates of the methanol to the heat pump and the power to the heat pump will be used to calculate the effective COP of the heat pump system on nearly a continuous basis and compared to a gas furnace (available in Appendix B of the status report). The COP will be compared to the COP from the design study/documents, and any discrepancies will be explained. The evaluation will consist of two steps:

- Evaluate the cost and performance differences of U-tube boreholes and thermosiphon heat pipes.
- Compare the measured performance and temperatures to the U-tube and heat pump models, including the interaction of the piping with the ground and the pipe-pipe interaction in the U-tube case.

Remaining field tasks include connection of thermocouple wires to data loggers, connection of thermosiphon heat exchanger loop to antifreeze flow network, and monthly interrogation of vertical temperature profiles in PEX tubing once heating system becomes functional. Ground/tubing heat transfer modeling work is being conducted at the University of Utah.

“Must Meet” Gate Criteria -- Performance-Based Code Approval

The critical design details have been defined, and construction practices, training, quality assurance, and quality control practices required to successfully implement new systems with

production builders and contractors have been observed.

Palace Geothermal appears to be practicing industry standards, meeting all building codes and passing all inspections. The U-tube boreholes were carefully grouted and grout samples were collected and sent for testing as specified in the construction detail. Due to the difficult geology of the site, the drilling equipment was frequently undergoing repair, extending the drilling time beyond that expected. It is not known if that delay affected the schedules of other contractors. There is no evidence that the installation of the boreholes and horizontal trenching had a negative effect on the overall project.

“Should Meet” Criteria -- Prescriptive-Based Code Approval

On-going observations of the work of the mechanical contractor installing the heat pumps will allow documentation that the installations meet prescriptive safety, health and building code requirements for use in new homes. Our work is benefitted through attendance at the weekly, Tuesday meetings in Park City, where we take notes and photos and receive meeting minutes for later reference during the analysis period.

Observations made during the installation of the U-tube boreholes and the horizontal trenching allowed the evaluation of whether the GCHP system was installed according to specifications. These observations included builder feedback in a practical setting. Through interviews, we learned what the builder thinks of the design with respect to its feasibility, viability, and practicality. Personal interviews are occurring with the following groups:

- Architect / Design teams
- Suppliers / equipment vendors
- Builder
- Job superintendent
- Installing contractor and individual crew members
- Coordinating trades, i.e. plumbers
- Building inspector
- Homeowner
- Post-installation service technician

Those interviews will include the following questions through post-construction evaluation:

- What problems, if any, were encountered during the installation? Were there problems with coordination between contractors?
- What measures could be taken to streamline the implementation process in future installations?
- What solutions might exist for problems encountered?
- What criteria do the building inspector expect to be met?

- Is there homeowner satisfaction with the performance of the GCHP?

“Should Meet” Criteria -- Cost Advantage

It is expected that GCHPs provide strong potential for cost benefits relative to current systems within a whole building context. To evaluate this expectation, the incremental annual cost GCHPs, when financed as part of a 30 year mortgage at 7% interest, will be used as the basis for cost evaluations. Those yearly “mortgage” costs should be less than or equal to the annual reduction in utility bill costs relative to the BA Benchmark. This basis will identify whether the initial capital investment in a GCHP system is worth the potential savings in operating costs.

To make this assessment, the costs of installing the GCHP system will be tracked and the total cost will be compared to “bids” for typical heating systems prepared by partners. Specifically, the plan is to:

- Obtain a detailed bidding cost estimate from the builder and all affected subcontractors for ordering, shipping, storing and handling, preparing for installation, profit and actual installation and startup.
- Obtain a detailed cost estimate from the installing and servicing contractor (or from the manufacturer's designated service organization) for warranty, service and replacement costs.
- Compare all cost projections with actual expenditures during and after system implementation. Identify, note and quantify any additional cost items that were not originally anticipated.
- Obtain quotes for the purchase and installation of standard efficiency and high efficiency furnaces.

Park City, as the project manager, will provide the researchers with data regarding costs of the project. This data will be compared against the monitoring data on energy consumption to determine the ROI for the GCHP system. In addition, this comparison will allow us to quantify the contribution of the GCHP to reaching or exceeding the zero-energy goal.

The final report will document all expenditures and projected future expenditures. Given the experience of both Palace Geothermal and Colvin Engineering, and the number of U-tube boreholes being installed on the site, the actual design and installation expenditures at the Snow Creek site are likely to be near industry averages for the region.

“Should Meet” Criteria -- Reliability Advantage

The reliability, durability, ease of operation, and net added value requirements of GCHPs for use in new homes will be documented once the buildings are occupied and the heating systems have been functioning for a year or longer. Issues such as excessive soil cooling over the winter heating season due to insufficient groundwater flow past the U-tube boreholes will be explored

in detail.

“Should Meet” Criteria -- Manufacturer/Supplier/Builder Commitment

Between the mechanical contractor, Colvin Associates, the heat pump manufacturer and Palace Geothermal, sufficient logistical support (warranty, supply, installation, maintenance support) will likely exist for prototype homes. This will be closely tracked once the buildings are occupied.

“Should Meet” Criteria -- Gaps Analysis

GCHP gaps analyses, lessons learned, and evaluation of major technical and market barriers to achieving the targeted performance level are ongoing. Currently, it is believed that there exists sufficient duplicity in the subsurface temperature measure system to accurately assess the thermal performance of the ground coupling. Incomplete access to all cost data may be a potential gap. Preliminary research implies that initial installation cost and construction site disruption are market barriers to GCHP installations.

Home Energy Management Systems Budget Period 2 (2009)

This is an interim report for home energy management system (HEMS) performance relative to the Building America Stage Gate 1B Criteria. For this interim report, one home energy management system is being evaluated to compare energy savings, cost effectiveness, user impressions, consumer education, and occupant impact on energy consumption. This research will build on NREL’s *System Research Plan for Reduction of Miscellaneous Electrical Loads in Zero Energy Homes* to identify viable control options and anticipated savings.

Key Results

Verve systems were installed into two Artistic homes in the summer of 2009 and are currently being monitored based on the Home Energy Management System Evaluation Plan. Three more system will be installed into Forest City homes in 2010.

The Verve systems are accumulating baseline test information on occupant energy usage. After six months, the system’s features will be fully activated to provide the most energy savings possible.

Gate Status

Stage Gate 1B “Must Meet” criteria are incomplete at this time; The Verve system passes the “Should Meet” criteria. Research for HEMs will continue into 2010, expanding the test group and determining what other systems are available to be evaluated.

Conclusions

BIRA has completed a preliminary study of currently available HEMs. The Verve Living system has been installed in a few test homes are establishing baseline data. Additional installations scheduled in early 2010. Performance testing will begin as the baseline performance is established.

Overview

This is an interim report for home energy management system (HEMS) performance relative to the Building America Stage Gate 1B Criteria. Stage Gate 1B Criteria can be found in the appendix of the final report. BIRA is investigating the electrical savings potential from the introduction of controls and consumer education into Building America homes, aimed at small appliance and consumer electronics. Both manual and occupancy based controls will be evaluated.

Based on BEopt simulations, a 6% reduction in whole house energy use is possible with whole house energy management systems. Whole house energy management systems with smart metering provide a means for addressing peak loads while minimizing disruptions to occupant comfort. Figure 49 summarizes an estimate of the average source energy savings relative to the Building America performance goals for a whole house control system that captures savings from HEMs, lighting, and HVAC showing an average 6% whole house source energy savings.

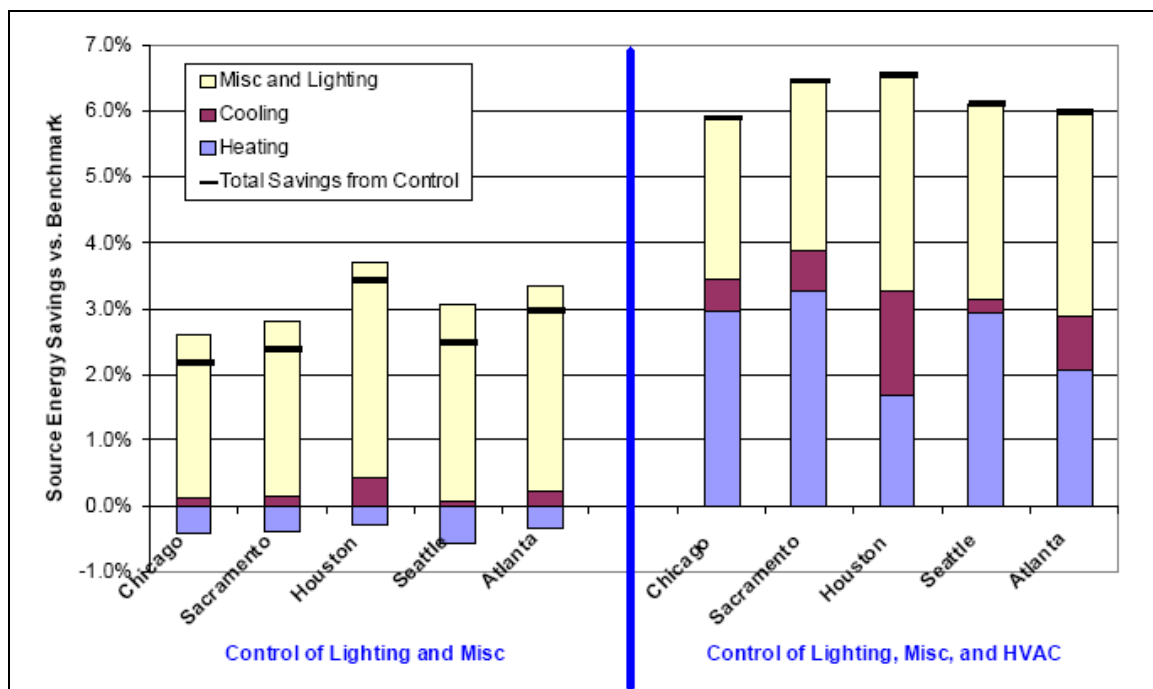


Figure 49: Estimated Average Source Energy Savings for Whole House Control Systems in Each of the Major Climate Zones

The present focus of this research effort is on builder-implementable strategies for MELs reductions. As these strategies have the potential to also reduce non-MEL energy usage, cost-benefit analyses will include the impact on whole house energy usage. Opportunities to reduce MELs fall into three general categories discussed below.

Individual Component Efficiency Improvements

Many improvements in the efficiency of individual products and components are expected to occur as a result of ongoing investments by product manufacturers, utilities, public interest organizations, and federal, state and local governments. Examples include recent progress by ENERGY STAR® such as an updated specification for ENERGY STAR® televisions that addresses standby and active power consumption and a new specification for ENERGY STAR® digital-to-analog converter boxes, which are currently being introduced to the market in preparation for the transition to digital broadcasting.

Recommended technical approaches with respect to this category include:

- Tracking product performance trends to ensure use of “best available” products in BA projects
- Providing recommendations for improvements in product performance based on experience in BA projects
- Acting as technical advisors on research efforts funded by other organizations
- Conducting targeted tests of new products when performance data is not otherwise available to verify benefits relative to BA performance goals

Home Energy Management Systems

Approaches in this category include programmable timers, occupancy detectors, whole house control switches, and adaptive controls. These systems may be implemented through a dedicated household wiring strategy, existing electrical wiring, wireless switching, and tie-ins with other control hardware in the home, such as insulating blinds, lighting systems, space conditioning systems, building security systems, and utility load-management/demand-response controls.

Recommended technical approaches with respect to this category include:

- Tracking product performance trends to ensure use of “best available” products in BA projects
- Providing recommendations for improvements in product performance based on experience in BA projects
- Using lighting systems, space conditioning systems, switchable power outlets, and other devices that allow for occupancy based control
- Using control systems, receptacles, or other devices that control one or more outlets

based on the power used by the main (master) outlet

- Using manual whole house switches that provide occupants a tool to disable selected plug loads and lighting and change thermostat settings indefinitely or for prescribed time periods (e.g., 2 hours, 4 hours, 8 hours, extended vacation, etc.)

Developing standardized energy use modes for implementation in home automation and control system software and user displays. Verve fits into this product category.

Occupant Behavior Changes

Approaches in this category include occupant education in household energy usage and product selection and real-time feedback to occupants regarding energy usage. *(While it is important to provide consumers with the information required to reduce energy end-uses, occupant behavior changes are considered to be largely outside the scope of the system research and technology development tasks of the Building America Program.)*

Opportunities with respect to this category include:

- Including information about energy efficient home operation and product selection with home owner's manuals and operating guides
- Including energy feedback displays in Building America homes
- The proposed research effort consists of six tasks and incorporates the Building America Stage

System Description

For this interim report, one home energy management system, Verve Living Systems, is being evaluated to compare energy savings, cost effectiveness, and user impressions. Information on consumer education and occupant impact on energy consumption will also be collected. This research will build on NREL's *System Research Plan for Reduction of Miscellaneous Electrical Loads in Zero Energy Homes* to identify viable control options and anticipated savings.

The Verve Living System is produced by Verve (hereafter referred to as "Verve"), a subsidiary of Masco Corporation. The system features a ten switch controller with accompanying switches, motion sensors and lumens sensors. Each channel can control up to 300 watts at 10 amps, and channel 1 and 2 can be bridge to double the capacity. The system itself only uses 4 watts.

The Verve Living Systems relies on an extraordinary technology developed by EnOcean GmbH, a Siemens Corporation spin-off. The technology is based on a simple discovery made by EnOcean scientists: enough energy is created by a simple act like turning a switch on and off to allow the transmission of radio signals across distances as great as 300 feet.

EnOcean created a small wireless sensors that can collect ("harvest") tiny amounts of energy. When Verve came across the technology, they immediately recognized its potential for radically

changing the dynamics of home control. Verve have used it to create a wireless, energy-harvesting, whole-house lighting control system that can turn on both incandescent and compact fluorescent lights, dim them and turn them off without having to wire the switches to the lighting sources, thereby making the switches totally movable.

The Verve System uses a trunk and branch type configuration from its central controller. Each controller has 10 channels, which can be used to control either lighting, fans or plug loads. The unique dimmable controllers are wireless, and can be programmed and placed anywhere in the house, allowing for a whole house shutoff “green switch” when leaving or going to bed. The controller can also utilize occupancy or lumens sensors to shutoff various loads. Verve also includes a programmable thermostat that can be combined with their controls to setback or shut off the HVAC system.

Verve Marketing Materials and Quick Start Guide are available in Appendix B and Appendix C of the final task report.

The Verve system allowed BIRA to focus on two MELs reduction strategy: automated and manual control systems. This represents the two predominant system types currently available on the market, and fortunately the Verve system is capable of using both control mechanisms. Automated systems represent solutions as simple as motion controlled light switches, and as complex as control systems for whole house lighting, security, outlets, thermostat, etc. Manual control systems have the ability to control a set of outlets from a centralized location. Power strips are the simplest manual control system, but they are usually unreachable to consistently shut down. “Green switches” are the more complex systems using a master switch to control numerous objects in the house from one centralized location.

BIRA research will focus on specific house load categories to evaluate the performance benefits and specifications for specific mitigating solutions. Target categories include:

- Home Entertainment Centers – TV, DVD player, satellite/cable box top, stereo equipment
- Home Offices – Desktop/laptop, monitor, printer, scanner, router, cable/dsl modem
- Lighting
- HVAC system

The home entertainment center and home office were selected because of their large potential impact on centralized consumer electronics equipment. Both the home entertainment and home office centers have a national average daily usage greater than eight hours a day. [Table 81](#) and [Table 82](#) detail the unit electrical consumption for the average home entertainment and office centers¹⁷. Using the average usage and unit electrical consumption data, the home entertainment center accounts for 800-1200 kWh/yr and the home office accounts for 500-600 kWh/yr. These two target areas consume approximately 1500 kWh/yr, more than half of the total HEMs load.

¹⁷ (Roth et al., TIAX LLC, 2008)

	"Off"	Standby (W)	On (W)
Cable Box	n/a	21	21
DVR	n/a	27	27
DVD Player	1	8	12
Stereo	3	43	45
First Digital TV	n/a	4	192

Table 81: Home Entertainment - Unit Electrical Consumption

	"Off"	Standby (W)	On (W)
Cable modem	0	0	6
Router			10
Home Phone	2.3	3.3	4.0
Black and White laser Printer		20	830 (peak)
Color Laser		20	1200 (peak)
Scanner		10	20
LCD Monitor (19")	1	1	35
Desktop Computer	2	20	95

Table 82: Home Office - Unit Electrical Consumption

Both target areas produce considerable loads, and are also largely impacted by occupant behavior. This presented the unique opportunity to evaluate HEMs systems as well occupant impact on the target areas.

The lighting and HVAC reduction benefits are bi-products of the capabilities of the Verve system. The reduction in each of the loads will be quantified to determine the total cost savings derived from the Verve system. See Appendix B of the task report for photos of the Verve System

Interim Status

A preliminary background search was done to determine if MELs loads could accurately be modeled in any of the approved software simulations packages, and none were capable. This is presumed to be largely because MELs cannot be completely controlled since they are largely based on occupant life style. While a completely automated and pre-programmed whole house control system might be effective at reducing MELs, it would most likely receive a negative response from the occupants due to poor occupant comfort.

Conversely, there was insufficient data to compare Verve users with a baseline test group. Instead, BIRA will allow the system to be installed but not fully utilized for a 6 month period to accumulate baseline test information about occupant energy usage. The occupancy and lumens sensors will not be used, the “green switch” will not be installed, and the thermostat will not be programmed to setback when the house is empty. While this will not cover the full year, or different usage during long and short day seasons, it should give us an accurate usage pattern. After 6 months, the system will be fully activated to provide the most energy savings possible.

The homes will be fully monitored with Campbell Scientific monitoring units to accurately measure energy usage on each channel. This test will be used to determine the source energy savings provided by the systems, as well as determine if the systems meet the “*Must Meet*” and “*Should Meet*” criteria.

The Verve system was installed into two Artistic homes in the summer of 2009, and is currently being monitored based on the evaluation plan. Home 1 is a 2118 sq. ft. 3 bed/2bath home in Albuquerque, NM and Home 2 is a 1008 sq. ft. 2 bed/2bath home in Farmington, NM.

Three more system will be installed into Forest City homes in 2010: a 1650 sq. ft., 3 bed, 2 ½ bath 50% prototype home, a 1650 sq. ft., 3 bed, 2 ½ bath Zero Energy Home, and a 3500 sq. ft. historic zero energy home retrofit.

“Must Meet” Criteria -- Source Energy and Whole Buildings Benefits

The prototype tests will be very valuable in learning about the capabilities of the Verve system. While the test isn’t large enough to determine statistical variances, the results will be a very good prototype none the less.

Savings results will be provided once the data is available.

“Must Meet” Criteria -- Performance Code Based Approval

The Verve system is hardwired, and must be inspected. However, since the central control panel actually reduces the number of connections, and amount of wire required to complete and electrical installation, it is actually easier to install. Through our interviews with local building officials and through Verve’s experience in other projects, building inspectors think the system is revolutionary and find its actually easier to inspect than a standard installation.

“Should Meet” Criteria -- Prescriptive-based code approval

The Verve system has UL rating, and meets all manufacturer’s health and safety requirements for use with electrical components. To date, BIRA has not run into any problems with local building officials inspecting the Verve system, and neither has Verve in any of its installations.

“Should Meet” Criteria -- Cost effectiveness

Cost effectiveness will be compiled once data is available. The system will be evaluated based on the unit’s incremental cost, as well as time and resource savings from the simplified installation.

“Should Meet” Criteria -- Reliability Advantage

The Verve system has a lifetime warranty for both the controller and the switches, however due to their robust control system, they do not foresee any reliability issues.

“Should Meet” Criteria -- Manufacturer commitment

The Verve System is readily available, and the manufacturer has a great support staff to train a builder/electrician in their first install. Verve technical installation experts provide the preliminary electric schematics, then train builders and their electricians on how to generate their own schematics, program the controllers and finally install the system. The technical experts travel onsite to the installation location to maximize the training and answer any questions either parties might have.

“Should Meet” Criteria -- Gaps Analysis

Through BIRA’s preliminary experience with the Verve system, the only perceived gap is the system’s limitation to new construction. The system is retrofit able, but due to the trunk and branch type installation, the system must ideally be pre-designed for the building, otherwise wall panels will need to be removed to install the system.

A final gaps analysis will be provided after the data collection period.

Conclusions

Home Energy Management systems are the technology that will reduce miscellaneous electric loads in the future. MELs are a significant consumer in residential homes, and their overall portion of end use is increasing as homes are engineered to be more efficient. BIRA divided MELs into more manageable segments including:

- Appliance Efficiency Regulations and Protocols
- Education and Ergonomics Research
- Automated and whole house Controls
- Feedback meters

Segmenting MELs into subcategories will help to develop customized strategies to mitigating their loads. For this period of research, BIRA tackled Verve, an automated and whole house

control system. This interim HEM study was beneficial in determining what HEMs are currently available on the market, and what the advantages and disadvantages of each are. BIRA chose the Verve system due to the diversity of their control system, the ease of its usage and installation, the low cost and the manufacturer's commitment to the Building America program.

BIRA will continue to install and monitor prototype homes with the Verve system in 2010, and determine energy savings, complete cost and gaps analysis.

Heat Pump Water Heater -- AirTap™ - Status Report Budget Period 2 (2009)

Water heating is the third largest energy use in the typical home. One technology available to provide energy savings in this area is the Heat Pump Water Heater (HPWH). Although widely available in Europe, Japan & Australia, HPWH technology has been slow to develop in the United States.

A recent startup company has developed an add-on HPWH for use in the residential market. Although currently targeted as a retrofit for the end user, the technology itself could prove to be a viable option for production home builders. AirGenerate, based in Houston Texas with a manufacturing partner in China, officially launched in January 2008, and as of December 15th 2008 employed 8 people.

The BIRA team investigated hot water production using AirGenerate's AirTap™ model A-7 HPWH to determine energy savings. An important side note in this study is that in order to reach the objective of Zero Energy Homes (ZEH) using electricity generated on-site, efficient means of producing hot water with electricity will need to be accepted in jurisdictions that currently prohibit the use of electric water heaters. The test procedure is being carried out at a single family residence in Stockton, California. The home is a 3500 square-foot, two-story, owner occupied home with 4 bedrooms and 3 ½ baths with two full time occupants.

The AirTap™ unit, designed to work in combination with a conventional tank type water heater, uses a compressor powered by a low-wattage electric current to extract heat from the surrounding air and sends this heat through long double walled copper tubes, acting as the condenser, into the water tank. This in turn heats the water. The manufacture recommends the tanked water heaters heat source be disconnected, thus making the AirTap™ the sole heating source.

The overall objective of this study is to evaluate the AirTap™, relative to the Stage Gate 1B criteria. In addition, BIRA is interested in evaluating the overall costs and net energy benefits of HPWH's through monitoring net energy input and output and comparing it to the benchmark established in the initial propane monitoring stage.

Key Results

The data collected would indicate that the AirTap™ has provided substantial site energy savings over the propane fired water heater. Our comparisons have shown that it took on average 1000 BTU's per gallon of hot water when using propane vs. 400 BTU's when the AirTap was the sole heating source.

Also noteworthy, since the product has not met Stage Gate 1B due to the reason listed below, as a retrofit to an existing installation we found the installation to be relatively simple and the unit would appear to produce hot water according to the manufacturer's claims to this point.

Gate Status

AirTap™ has not passed through Stage Gate 1B due to the following issue. In order to install this system, a heat exchanger, in the form of long copper tubes must be inserted into the water tank, thus voiding the tanked water heater manufacturer's warranty. Also due to the cost of the unit itself and the cost of a new tanked heater and any additional labor costs that may be involved installing the system, the financial advantages of installing the complete system in new residential construction may be outweighed by the costs of some of the integrated HPWH's coming into the marketplace this fall. GE and Rheem have both introduced Energy Star qualified HPWH's into the market place with a list price of approximately \$1250.00 to \$1400.00.

Conclusions

The AirTap™ may still prove to be advantageous when installed as a retrofit on existing water heaters. (AirGenerate recommends the AirTap™ not be installed on heaters older than 5 years.)

BIRA is also interested in HPWH technology itself. Although the construction of the unit may not be the same as the GE or Rheem, we believe the performance may be similar and worth continued research.

For this reason BIRA will continue to collect field data for a period of at least one year from the date of the installation. It's anticipated that the performance of the unit will be impacted during the winter months, so further monitoring is being done to get complete annual performance data.

BIRA will also observe what steps AirGenerate will be taking to address issues related to tank warranty. It's anticipated that AirGenerate will release an integrated unit into the market which will address warranty and installation concerns when approaching production builders with this product.

“Must Meet” Gate Criteria -- Source Energy Savings and Whole Building Benefits

Initial results indicate a substantial site energy savings in BTU’s to operate the AirTap™ over the propane water heater as shown in appendix A of the final report. However due to the lack of annual data at this time it would be too early to draw conclusions as to the actual savings and whole building benefits.

“Must Meet” Gate Criteria -- Performance-Based Code Approval

The 2006 International Energy Conservation Code, Section 404: Simulated Performance Alternative states in table 404.5.2(1) that the standard reference for comparison in energy efficiency for water heaters is “in accordance with prevailing Federal minimum standards”. (See Prescriptive-Based Code Approval-Federal minimum standards)

Furthermore the 2006 International Code Council Performance Code, Section 1203.2: states that “Sanitary water shall be delivered to fixtures, appliances and equipment at temperatures appropriate for the intended use.

Heat Pump Water Heaters are not specifically mentioned in the International Energy Code.

With this in mind, the objective of this study is not to confirm the Energy Factor rating already determined (See Prescriptive-Based Code Approval- GAMA rating) however one of the objectives is to measure the performance of the AirTap™ to see if it consistently meets the hot water demands of the building where it’s being tested. Further clarification is noted in other areas of this report.

Using California’s energy code (Title 24) where the test unit has been installed, the performance code requirements for water heaters are more clearly defined but are dependent on the combined Time Dependent Valuation (TDV) of the water heating budget and space conditioning budget. Therefore AirTap’s™ contribution to the overall performance would need to be factored in on a case by case scenario.

It’s interesting to note that under California’s Title 24 for performance standards, Section 151(b) states that “A building complies with the performance standard if the combined depletable TDV energy use for water heating Section 151 (b)1 and space conditioning Section 151 (b)2 is less than or equal to the combined maximum allowable TDV energy use for both...”

Section 151 (b)1 States “The water heating budgets for each climate zone shall be the calculated consumption of energy from depletable sources required for water heating in buildings in which the requirements of Section 151 (a) and of Section 151 (f)8A for systems serving individual units or Section 151 (f)8C for systems serving multiple dwellings are met ...”

And Section 151 (f)8A states “For systems serving individual dwelling units, a single gas or

propane storage type water heater with an input of 75,000 Btu per hour or less ...shall be installed.

Conclusions could be drawn that according to California Title 24 standards, electric water heaters are rarely installed in new residential low rise construction in the state of California due to a huge energy penalty.

In order for the goal of Zero Energy Homes to be reached, alternatives to off-site energy production for domestic water heating will need to be accepted. One of the stated goals of this report is to determine how well AirTap™ will perform compared to the benchmark set by the existing propane water heater, thus showing if HPWH's in general could be an accepted alternative to help reach Building Americas Stated Goal of ZEH by 2020.

Therefore, we believe that continued research needs to be done to show if the energy performance for a HPWH can at least match or exceed that of a gas fueled unit in order for the technology to be widely accepted.

AirTap™ is listed as complying under California's Appliance Efficiency Regulations.

"Should Meet" Gate Criteria -- Prescriptive-Based Code Approval

AirTap™ has earned a listing from Intertek (ETL). Listing #3058080, therefore for the purposes of this report it is assumed that AirTap™ complies with all applicable electrical, safety and health prescriptive codes.

During our research, we could find no blatant violations of any such codes.

Federal minimum standards: AirTap™ also meets Federal Standard CFR Section 430.32(d), which states that the minimum Energy Factor (EF) as of January 20, 2004 for electric water heaters shall be 0.97

GAMA rating: AirTap™ has earned a Certificate of Product Performance from the Gas Appliance Manufacturers Association (GAMA) #192409 which states an EF of 2.11 and a Recovery Efficiency of 100%

All other prescriptive codes reference installation and insulation practices and are outside of the scope of this report.

"Should Meet" Gate Criteria -- Cost Advantage

BIRA has attempted to get contractor cost estimates for installation of this unit. Unfortunately none of the local contractors contacted that are listed as local dealers by AirGenerate had installed one of these units and could not give us an estimate.

Two members of the BIRA team, Dean Neff and Kevin Blackwell, each with average plumbing skills, installed the unit at the test house. This installation would likely be considered atypical because of the following conditions.

1. The hot and cold water lines were reversed coming down from the ceiling. This had been missed in the previous water heater installation, and therefore the incoming cold water line had to be rerouted to correct this.
2. Additional sections of cold water line had to be installed to accommodate the monitoring equipment.
3. In order to accommodate the propane water heater and the monitoring equipment the AirTap™ had to be installed to the rear of the gas flue and had to be installed backwards in order for the heat exchanger to be installed into the hot water outlet of the water heater.

Due to the additional work involved at the time of the installation, including the rerouting of one of the temperature probes and the resulting verification of data, the installation took approximately seven man hours. Without the additional installation work, Mr. Neff estimates that the 1 to 2 hour installation estimated by AirGenerate, using two qualified personal, is not unreasonable. Mr. Neff also commented that the simplicity of the installation instructions and reviewing the online installation video previous to the installation was helpful.

One unanticipated difficulty was that the hood on the flue had to be trimmed in order for it to fit between the mounting brackets.

The estimated cost for our installation is broken down as follows:

Item	Cost
List price of the AirTap unit	699.00
Shipping	49.00
List price of the Airvent	79.00
Airvent shipping	19.00
Initial cost of the new propane water heater	<u>588.00</u>
Total (Sales Tax not included)	1434.00

Table 83: Installation Costs

All the parts for a typical install were included; any additional costs incurred were due to accommodating the monitoring equipment and the extenuating circumstances of the existing water heater installation.

Anticipated additional maintenance costs for the AirTap™ would be the increased replacement of the anode rod. The tank manufacturer states the sacrificial anode rod should be inspected

once every three years. AirTap™ suggests the anode rod be replaced every two years. Assuming replacement of the Anode rod at time of inspection according to the manufactures recommendation, the rod would be replaced every three years at an approximate cost of \$20.00 to \$45.00. Increasing the cost of anode replacement from \$60.00-\$135.00 to \$100.00-\$225.00 respectively over a span of ten years..

AirTap qualifies for the 30% federal tax credit through 2010 and may be eligible for additional state or utility credits or rebates.

The overall cost advantages to a homeowner are not addressed here due primarily to this system not meeting the Stage Gate 1B.

“Should Meet” Gate Criteria -- Reliability Advantage

Due to the short length of time between the install and the release of this report, determining reliability in the long term is not viable at this time. When purchased in the U.S. the manufacturer carries a one year limited warranty on the entire product, two years additional warranty to replace defective parts and a five year warranty on the compressor. According to the manufacturer, the only maintenance required on the AirTap™ unit itself is cleaning the air filter annually. The air filter is readily accessible.

Below are a few noteworthy points.

- The end user has noticed no decrease in hot water supplied since switching from gas to the AirTap™ unit. The comment made by the home owner was “It’s been seamless”
- Our unit was received damaged, presumable during shipping, even though the packaging was adequate to protect the unit. Trying to reach customer support was a little difficult. We assume this is due to the relatively small size of the company. However when we did speak to a company representative, the unit was replaced with no trouble. AirGenerate shipped the replacement unit before receiving the damaged unit in return and made all arrangements for the return shipment with UPS. The only thing required from us was to go online and print a return shipping label and make arrangements for pick-up at the same time.

“Should Meet” Gate Criteria -- Manufacture/Supplier/Builder Commitment

As mentioned above, (See Cost Advantage) BIRA contacted four of the suppliers/contractors listed by AirGenerate in our area for estimates. Two of the contractors said that they are dealers but have never installed an AirTap™ unit. One stated that he doesn’t do water heater work and the fourth hasn’t returned our call.

Also, as mentioned above, our contact with customer support was slower than we would have liked to see. As researchers we understand that the size of the company doesn’t warrant having

support personnel manning dedicated phone lines for installation or warranty issues, however as consumers, if we were in the middle of an installation, we could take issue with not being able to raise support in a timely manner.

Due to not moving forward to the next Stage Gate at this time, no questionnaires were developed for builders or building officials to receive feedback on the systems implementation.

“Should Meet” Gate Criteria -- Gaps Analysis

Most notable is the water heater tank warranty issue. Our thoughts are that most builders would hesitate to install a product that would impact the manufacturer’s warranty of another installed component unless there were substantial financial incentives. At the time of AirTap’s™ release into the market, there were no other HPWH’s in this cost range and according to AirTap’s™ website, the product has been installed into new construction projects with positive feedback from the builders.

Local jurisdictional energy codes may restrict or penalize the use of HPWH’s due to the use of electricity to heat domestic water.

Our search for installation estimates have shown a lack of qualified technicians in our area that have installed the unit. Although AirGenerate recommends use of only licensed plumbers to install AirTap™, the system could potentially be installed by home owners with average plumbing skills.

Customer and logistical support may be lacking for this product to be widely implemented for production builders across the country at this time.

Marine Climate Solar Thermal - Status Report Budget Period 2 (2009)

Since the late 1970’s solar thermal collectors have been utilized to convert the sun’s radiation to heat for domestic hot water in Marine climate residences of Washington and Oregon State. While a number of these 1970-80’s vintage systems continue to operate reliably today, many systems have been removed as a result of; poor installations, lack of maintenance problems and/or lack of interest, understanding and/or concern by new homeowners. Questions remain today regarding; one vs. two tank pre-heat systems, closed loop vs. drain-back system designs and lack of maintenance impacts on panel stagnation temperature and system long-term performance. Attempts to design solar thermal systems to include solar thermal both DHW & hydronic space heat remain questionable in marine climates where very little solar radiation is collected during much of the heating season. These DHW/space heat systems have been poorly designed, overly complicated to install, commission, operate and maintain.

More recently evacuated tube solar panels are gaining in the solar thermal market place. These panels tend to cost more and perform better than flat plate collectors at higher panel

temperatures, but questions remain regarding how much better for typical marine climate DHW systems and if the additional cost (e.g. typically twice the cost per aperture area) are justified. Costs on evacuated tube panels from China are continuing to drive panels prices down, vs. those manufactured in the USA. However, overall solar thermal system installation costs have increase by as much as \$5000 from the early 1980's to present in marine climates.

This status report provides some insight into the on-going investigating on a variety of solar thermal systems installed in BA high performance homes BIRA homes with partners; Martha Rose Construction, Cohan Residence and Shirey Zero Energy Ideas House. These homes are targeted at 50% marine climate case studies. The experiences monitoring these solar thermal systems as well as "lessons learned" are presented. Systems are compared to 30 year old solar thermal DHW "closed loop" system installed by the author are also discussed.

Slowly more systems are using BTU metering of solar production, to help provide more quantified energy performance for homeowners, and identify problems sooner. Martha Rose Construction and Cohan Residence systems used the Metrima F2 BTU meters. The F2 system cost over \$600 and on-going discussion are underway to look at ways to reduce BTU metering costs such as integration of the BTU meter into the existing solar pump controllers and/or using fixed GPM assumption and measuring solar supply and return temperatures.

Key Results

Case Studies: The solar DHW/Space heating system as installed and monitored at Martha Rose Construction in 2007. BA team found numerous design and installation problem which have limited the system performance. The original system cost \$8,000 before repairs were made in 2008 costing an additional \$3,800 from three solar, mechanical and plumber contractors that assisted in repairing the original system. The solar "expert" touting his belief that considerable solar space heating was achievable with his evacuated tube system and was unwilling to listen to the design suggestions made by the BIRA team, and as a result this 16 tube evacuated tube system provided 1,406 kWh over a Jan-Oct 2009, or 82% of predictions by F-chart simulation software for a typical 2 tank DHW only system. Note this does not include system losses in heated storage tank, or pumping energy. In 2010 the entire Martha Rose solar thermal system may be re-installed as a dedicated solar closed loop two tank system and monitored for another year.

The Cohan residence has is a flat plate drain-back single tank DHW system and F2 BTU meters installed in August 2009. The one tank system was selected due to the limited size of the mechanical room. The system installed for \$7,700 or \$3,500 after the \$1320 Oregon and \$2000 federal tax credits and \$880 utility rebates. Occupancy of the home and monitoring is expected to begin in November 2009 and performance results presented in 2010.

The Shirey evacuated tube solar DHW system installation was completed in October 2009 and occupancy to begin this fall/winter, and reported to BIRA at the end of 2010. The system

installed for \$5,300. Evaluation of the lower cost BTU meter is currently underway for the monitoring of the Shirey solar DHW system in 2010.

Improved Monitoring: During the BIRA/WSU Solar “expert meeting” in August 2009 potential “panel mount” code issues were identified for panels installed on standing seam metal roofs employing B5 mounting systems by building departments in the Portland, Oregon area, that may require site by site structural engineering analysis. Also identified at the meeting was a need in Washington for better educated solar thermal installers and certified approved DHW systems. Finally the meeting identified “solar ready” specification as a potential way to reduce first costs, improve system designs, installation, commissioning and monitoring in new construction. (Lubliner, ASES). Other conclusions from that meeting include:

Discussion of Solar Panel Efficiency:

No single collector that can be labeled ‘the most efficient,’ as the efficiency of collectors depends on the application. For seasonal swimming pool heating, an unglazed collector will outperform a flat plate collector at a fraction of the cost. An unglazed collector performs well because it is heating a pool at 80 °F when it is right about 80 °F outside. Under those conditions, the collector is running at ambient temperature and has no heat loss; therefore, it does not need to be insulated. As temperature requirements increase it is important to insulate the collector against losses. Whereas collectors on seasonal pools operate within 10-20 °F of ambient, domestic hot water (DHW) collectors are designed to run through the colder winters and at higher temperatures in a wide range of 25-125 °F above ambient, depending on location and season. Another solar thermal application is in high-end process heat above 150 °F above ambient. Efficiency plots of the various collector styles against collector inlet fluid temperature above ambient are shown in the figure below. Unglazed pool collectors dominate in low temperature applications 0-25 °F, flat plates perform in the mid-range of 25-125 °F, and evacuated tubes come perform best at 125+ °F. As you move from unglazed to glazed and on to evacuated tubes you move up and up in price. Evacuated tubes could be used to heat swimming pools, but it would not make economic sense to do so given that an unglazed collector is 1/10th the cost and 30% more efficient. The same holds true, to a lesser degree, for using evacuated tubes to heat domestic hot water.

The performance charts shown below are only part of the efficiency equation. The other factor is the amount of sunshine on the collector. The lower the amount of sun, the greater the advantage of glazed over unglazed and evacuated tube over glazed. However, doubling efficiency at low sun doesn’t mean much if there wasn’t much sun to begin with.

Arguments are made about flat plates versus evacuated tubes and the benefits under various operating conditions. Flat plate collectors outperform evacuated tubes by 8,000 BTU’s on sunny summer days, but evacuated tubes outperform flat plate collectors by 4,000 BTU’s on cold cloudy winter days – on mildly cloudy cool days they break even. An apples-to-apples comparison using the SRCC OG-300 system rating compares collectors when they are

connected to actual systems in actual climates.

A typical two panel 50 ft² black chrome flat plate is almost identical to a 50 ft² of evacuated tubes), both connected to the same type of 80-gallon tank. If you look, for example, at the SRCC OG-300 annual performance ratings for Seattle, Washington, which are modeled with real 20-year average weather data you find the following that they all produce 1,800 – 2,200 kWh/year. The flat plate system, which is identical in collector area, outperforms evacuated tubes by 6-22% on annual savings, at less panel cost. The reason is that overall performance depends more on your efficiency when the sun is out and the system is cranking away as opposed to when you can't see your own shadow in the middle of winter.

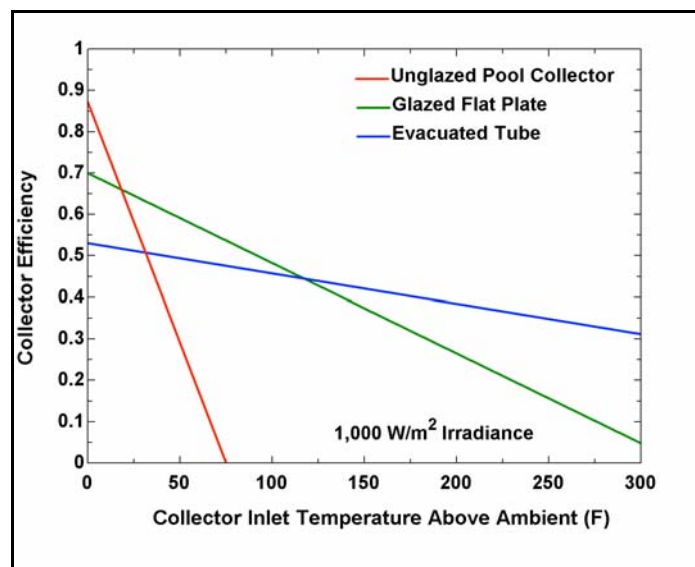


Figure 50: Collector inlet fluid temperature above ambient

Product Model Technology kWh/Year Savings	
Thermomax Evacuated 50 ft ²	<u>1,800</u>
SunEarth Black Chrome 50 ft ²	<u>2,200</u>
SunEarth Black Chrome 40 ft ²	<u>2,000</u>
SunEarth Selective Paint 40 ft ²	<u>1,900</u>

Table 84: Solar Thermal system comparison

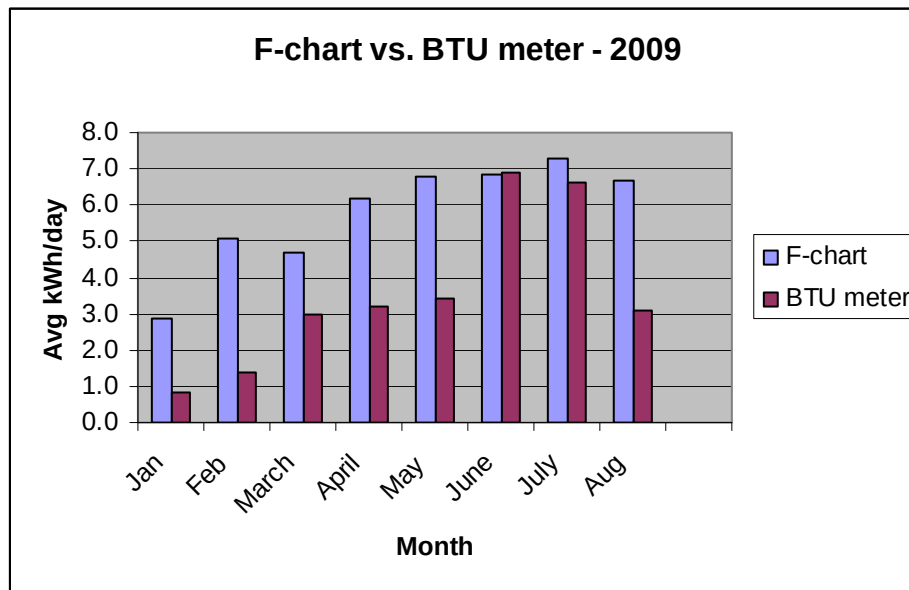


Figure 51: F-chart vs. Actual solar from BTU meter (2009)

Gate Status

The solar thermal case studies remain at the Gate 1B awaiting more thermal monitoring, simulation analysis, cost data and feedback from contractors, homeowners, solar industry stakeholders and state/local government building departments. Preliminary analysis from January to August indicates that the solar panels provided 1184 kWh to the storage tank or roughly 15-20% (227 kWh) lower than the 1411 kWh predicted by F-chart simulations after repairs of installation problems in late 2008. F-chart predicted an annual 47% solar water heating fraction for a family of two total DHW load of 3767 kWh/year (or gas equivalent). Prior to these repairs the solar thermal system was not producing energy savings and cycling heat from storage tank to panels. The “after repairs” reduced performance is likely due to the higher solar tank temperature, which has the greatest impact system performance in winter when outside temperatures are lowest as shown in Figure 2. On-going monitoring and evaluation of system performance and first and repair costs (in case of Martha Rose residence) will provide feedback will help determine the gate status of solar thermal in marine climates. The performance and system cost will be evaluated along with the case studies at Cohan and Shirey in 2010.

Conclusions

Preliminary evaluations of solar thermal systems suggest an average of 40-50% solar DHW fraction as a reasonable target for marine climate systems. Typical costs in the more mature Oregon market are roughly \$6,000-\$8,000 before tax credits and incentives. The preplanning of solar (e.g. Solar ready) may reduce installation costs by \$500-\$1000, depending on the house type and vintage. The use of well designed, installed and maintained solar thermal systems is

critical to achieving expected energy savings and long-term reliability. Closed loop systems require periodic changing of solar anti-freeze fluid, and the frequency of this maintenance in part of function of stagnation events. Drain-back systems tend to be less prone to failure due to stagnation and lack of maintenance, but are less flexible in terms of design and installation in that the panels must drain-back. Some long time solar installers in Oregon, where the market is more mature, then Washington, tend to prefer drain-back systems. Two tank pre-heat systems are believed to perform much better in typically overcast marine climates, however the additional first costs and pre-planning requirements for additional floor area for the solar pre-heat tank, drive many to single tank systems. Regardless of the system type, the need for improved documentation of system operation and maintenance from the installer to the builder/homeowner was continues to be another key issue. It is suggested that on-going lower cost monitoring technologies may help ensure correctly designed, installed and long-term performance. Once a well-designed solar DHW system is installed and commissioned it is essential that proper M&O is conducted to ensure performance over the system potential useful expected useful like to 30+ years.

Combined Solar: Photovoltaic and Thermal (PVT Solar) Budget Period 2 (2009)

A relatively recent solar industry innovation uses special configurations of solar photovoltaic cells, combined with solar thermal collectors, to convert the sun's radiation into electricity and heat simultaneously in a single system. These Solar "Photovoltaic Thermal" systems (PVT) combine elements of both PV-only and thermal-only solar systems to generate and capture useful electrical and heating energy to benefit the homeowner.

The "PVT Solar System" utilizes thermal energy generated from solar photovoltaic (PV) modules to provide domestic water heating, space heating, and preheated ventilation air. Ambient air is drawn in underneath the PV array, and collects some of the heat dissipated from the PV panels. The air can then be further heated by air thermal solar modules before being pulled into ductwork, located within the attic space. This heated air is then used for water, space heating, or as pre-heated ventilation air, as the need demands.

Key Results

Actual installed system data has shown significant electrical and thermal energy production. From December 2008 to September 2009, the PVT system at the Gold Medallion Home in the Kennecott Land's Daybreak development in South Jordan, Utah, has provided 2,280 kWh of electrical production and 835 kWh for space heating. Code approvals have been achieved in several jurisdictions with ease; therefore, the PVT product conforms to the building, energy, and fire codes. Some local jurisdictional codes may still restrict certain solar products. Solar Rating and Certification Corporation (SRCC) approved PVT systems also qualify for tax credits (30% federal tax credit), helping to reduce the cost. Installations proved to be difficult due to steep roof pitches (greater than 6:12) and small clearances in the attic at both Gold Medallion's Parade of Homes houses. The warranty for the PVT defaults to the individual part

manufacturers. The PVT system has not been through enough year cycles to accurately gauge defects or failures.

Gate Status

Diverse actual application data from various climate regions is still needed, which will be obtained either from the manufacturer or through test monitoring. Currently BIRA has been limited to PVT installations in Utah due to the regional interest in renewable energy. The whole house energy savings criterion has been met based on the Gold Medallion Parade home monitoring data. Obtaining data from other climate zones has proved to be difficult with the poor condition of the housing market. The authority having jurisdiction in South Jordan, Utah has approved installations of the PVT system; however, determination of whether the PVT was approved under the prescriptive or performance code is still needed and will be completed through interviews with the manufacturer and city officials. Continued monitoring will provide feedback on any potential defects and failures as well as providing more diverse actual use data outside of the Cold climate region. Once the production housing market begins to accelerate, there will be opportunities for more PVT installations in other climate regions.

Conclusions

Simulation results indicate that PVT systems saved an average of 25% on space heating and 80-85% on water heating in a typical home in mild climate areas such as Boulder, Colorado and San Francisco, California. PVT system provide 2-3% more electrical output than the standard Building Integrated Photovoltaic (BIPV). PV energy production for three quarters of the year has already met the theoretical energy production, which indicates an increased PV panel efficiency. The BIRA monitored thermal energy is not projected to meet the theoretical thermal energy estimated by PVT.

The PVT systems have not had any issues with approval by local jurisdictions. The system complies with the applicable building, energy, and fire codes. The cost of a PVT system is approximately 25% more than a standard PV system, but is considerably less expensive than a combined, side-by-side PV and thermal array. When incorporating the rebates and subsidies that are available, the overall cost coupled with the energy benefit is very promising. The PVT has a shorter payback time than a comparable PV-only system, which should also be considered when analyzing the cost effectiveness. In addition, the PVT system has a smaller footprint, taking up less roof space. The smaller footprint is particularly important when trying to apply a renewable to a multi-family project where the roof space per living unit is much smaller than the roof space for a detached, single family home.

“Must Meet” Gate Criteria -- Source Energy and Whole Building Benefits

The manufacturer possesses the most up-to-date TRNSYS model and it has passed their quality control process. Actual operational data will be analyzed in this report.

The projected performance for the 2.25 kW PVT installations in South Jordan, Utah at the Gold Medallion Home in the Kennecott Land's Daybreak development is 2,960 kWh of electrical, 105 therms for domestic hot water, and 20 therms for space heating. During the nine months of monitoring, the PV section of the PVT system has produced 2,280 kWh; however, the thermal section has only produced 835 kWh (29 Therms) for water heating. PVT Solar's monitoring system shows 1,800 kWh of electrical production, 53 Therms produced for water heating and 13 Therms for space conditioning. The PVT Solar monitoring data range was limited to March to September 2009. Data preceding March was not available due to a new controller installation. The parasitic losses were also monitored. The PVT fan, glycol pump, controller, and dampers used 567 kWh. Most of the energy was consumed by the PVT fan, which used 463 kWh. Further details can be found in Appendices B and D

A PVT installation in Reno, Nevada has been monitored since January 2008. The data taken from this 5.6 kW system was acquired on the five clearest days for each month. The average peak daily electrical output, DHW production, and space heating production for the PVT system on these five clearest days of the season are shown in the table below.

Season	Electrical (kWh)	DHW (kWh)	Space Heating (kWh)
Winter	83.6	36.4	51.3
Summer	188.5	75.8	0.0

Table 85: Average Daily Peak PVT Production

Reno, Nevada Installation

Based on simulation results per vendor information done in Boulder, Colorado and Tucson, Arizona, water heating potential energy savings are 82% and 98% respectively. The potential space heating energy savings are 16% and 46%, respectively. The Tucson, Arizona energy savings were much greater than the Boulder, Colorado savings due to its higher climate temperature. The higher climate temperature results in heating losses by the water heater and smaller space heating load. The PVT vendor, PVT Solar, tested a 3 kW solar electric system with thermal installation in San Francisco, California which showed an 84% increase in generated energy (estimated 7,160 kWh) when heating the domestic water over the standard 3 kW PV-only module. When heating the domestic water and the living space, there was a 107% increase in generated energy (estimated 8,073 kWh).

Conventional solar "PV-Only" systems utilize the sun's power to generate useful electrical energy only. However, the PV operating temperature increases due to solar heat gain and waste heat generation from the PV modules which negatively impact the efficiency and performance of the modules. For every 1.8°F of temperature increase, the PV module loses 0.5% in efficiency. In a PVT system, heat is drawn away from the PV modules by passing air under them to help reduce the operating temperature of the modules thus increasing their energy efficiency. Increase in PV generation has been shown to be 2-3% above standard BIPV

modules, which lay flush with the building's roof (Plaisted, 2008). BIPVs may also transfer the unwanted PV generated heat to the building which could increase its HVAC cooling load.

The heated air that is produced from the PV modules can be directed for additional energy savings. Thermal modules are used to further increase the temperature of the air which can help heat domestic water as well as partially meet space heating needs. The thermal module air handler takes in tempered outside air to supply the living space with fresh air to improve the indoor air quality. The ventilation air is essential with more advanced and tighter homes to help maintain the indoor air quality.

"Must Meet" Gate Criteria -- Performance Code Based Approval

PVT modules are not explicitly described or mentioned in any code, but PVT systems, ranging from 2.6 kW to 4.6 kW, have been installed in seven U.S. locations and have been permitted by local jurisdictions. These seven locations include:

- Salem, OR
- Reno, NV
- San Francisco, CA
- Thousand Oaks, CA
- Fontana, CA
- Honolulu, HI
- Kennebunk, ME
- South Jordan, UT

PVT is currently installed and being test monitored at two Kennecott Land Gold Medallion homes in South Jordan, Utah. Gold Medallion is offering PVT as an option to their homes. Currently, three out of the six homes at Gold Medallion have the PVT option. Garbett Homes will install PVT as a standard feature on twenty (20) of their upcoming homes at Kennecott Land's Daybreak development. Another PVT system is in discussion to be installed at the Webster School Cottages in Magna, Utah.

PVT systems shall be installed per Chapter 23 of the 2006 International Residential Code. They must also meet the performance guidelines as described in the 2006 International Code Council Performance Code. PVT was approved by the Solar Rating and Certification Corporation (SRCC) for their OG-100 rating.

"Should Meet" Gate Criteria -- Prescriptive Based Code Approval

PVT must meet the existing prescriptive based codes for existing PV and Solar Thermal units. PVT must conform to local fire safety codes for proper roof access and emergency electrical PV disconnection. All systems shall be grounded and wiring weatherproofed. Other criteria for PVT are unknown.

“Should Meet” Gate Criteria -- Cost Advantage

The cost of mounting a PVT system is not significantly more than installing a conventional PV-only system. The additional cost is about 25% more than the conventional PV-only system, but has a much shorter payback time because of the added thermal energy savings. The PVT payback time varies depending on the array size and environmental conditions. PVT utilizes a rack mounting system that eases contractor installation. Per Utah Solar, the approximate additional costs for a PVT system on a roof pitch 6:12 and greater is \$1 per kW and \$0.50 per kW on a roof pitch less than 6:12. More cost data will become available after future installations are completed.

As previously mentioned, the Boulder, Colorado and Tucson, Arizona simulations exhibited potential water heating energy savings of 82% and 98%, respectively. The potential space heating energy savings are 16% and 46%, respectively. The potential water heating and space heating energy savings correlate to lower energy bills for the homeowner. The exact monetary savings will vary depending on the utility rate schedule. These results show a potentially shorter payback period than a conventional PV system due to additional savings in reducing the space heating loads and domestic hot water loads. Lower energy consumption by the homeowner also spells savings for the utility companies as well.

According to the Department of Energy, homeowners can receive a 30% tax credit for SRCC approved solar electric systems that are placed in service from January 1, 2006 through December 31, 2016 under the Residential Renewable Energy Tax Credit. They can only receive 30% (up to \$2,000) if the system was installed between January 1, 2006 and December 31, 2008 (ENERGY STAR®, 2008). After that, the \$2,000 limit no longer applies. Another incentive available to PVT is a 30% tax credit (up to \$2,000) for a SRCC approved solar water heating system. They must show that half of the energy used for domestic water use comes from the sun.

The tax credits for the homeowner and homebuilder should be enough incentive to use the PVT system. The homeowner will see a return in the money spent to install the system if the system is installed after January 1, 2009 (Consumer Tax Incentives, 2008). The tax credit for the homebuilder is quite substantial at \$2,000 for each home built. These are only federal tax credits. With the addition of federal and state tax credits or utility rebates, the reduction of installation cost for the PVT system will increase this product's marketability.

“Should Meet” Gate Criteria -- Reliability Advantage

One advantage of using a PVT system with air is that the system does not fail if there is an air leak. PVT systems that use water as a heat transfer medium have the potential for water damage on the roof from leaks or freezing. Non-corrosive materials such as aluminum are used extensively for their durability.

PVT was initially designed to easily integrate with existing proven PV modules and off-the-shelf blowers & coils, which makes PVT easily integrated into the current building process. Currently, the PVT installation process can still be done in a segmented manner in which each trade installs their respective component of the PVT. Otherwise, a qualified solar contractor can perform the installation in its entirety, including installation of the controller and air handler. For the two Gold Medallion homes in Kennecott Land's Daybreak Development, Utah Solar & Alternative Energy has performed the installations.

David Herr from Utah Solar & Alternative Energy stated that the two Gold Medallion homes installations proved equally difficult. The mechanical air delivery of the solar heated air was the hardest part to incorporate into the homes, for both Gold Medallion and Garbett Homes. The added difficulty of the deck mounted Cleanline Racking system and galvalume was also a real time sink, and the steep 7:12 roof pitch almost doubles the cost of installation on the roof. Also, available space in these small homes is at a premium. Adding supplemental systems like PVT really complicates clearances and tolerances. Herr anticipates future installations going smoothly after a process has been established.

After installation, the PVT Solar controller had issues communicating with the third-party air handler due to compatibility issues. The controller and air handler have since been changed to a production model PVT Solar controller and a new air handler that communicates properly with the controller.

Having a quality installation is one of the keys to maximizing the benefits of the PVT system. The inspection process will also help ensure that the system performs to the stated specifications. The inspection includes checking of panel temperatures, azimuth, pitch, and shading. Inspections can be performed by qualified representatives from the manufacturer or from certified third party inspectors.

One disadvantage, like all other PV systems, is that the PVT efficiency is susceptible to degradation if shaded or covered. Other factors that might carry over from when PV systems were first being used were subpar installations or poor planning. Mostly these poor installations were due to lack of experience. Simple education about PVT and their installation methods, either through the manufacturer or an organization like the North American Board of Certified Energy Practitioners (NABCEP) coupled with inspections would help ensure the quality of installation.

"Should Meet" Gate Criteria -- Manufacturer/Supplier/Builder Commitment

PV modules are highly reliable – and because PVT is an integrated system, it does not modify or void the third party PV manufacturer's warranties in any way. Installing the PVT as an integrated system would eliminate the separate warranties that the homebuilder requires if installing PV-only and thermal-only systems. Installation also should be performed by a certified NABCEP contractor to help ensure a proper installation.

The PVT warranty covers the mounting system for 10 years and the finish for 5 years. The mechanical component warranties are not through PVT Solar, but through the respective manufacturers, which range from 18 months to 10 years. PVT Solar systems are ready for production and product shipping.

“Should Meet” Gate Criteria -- Gap Analysis

The three main market drivers for the PVT are available roof space, profitability, and building integration. The historical trend for American homes is to become increasingly larger, providing larger roof areas. With the larger roof areas, PVT systems can easily be installed as opposed to the side-by-side PV and Thermal units, which require more space for the equivalent kW production. However, as David Herr stated that with smaller homes and homes with higher roof pitches, installations become difficult due to the space constraints and fatigue from walking the steeper grade roofs.

Marketing to a currently unstable housing market could potentially hold back the PVT system. Builders are looking to build a cost-effective home and the additional cost of a PVT system could dissuade them from using it. However, the cost for PV systems has shown a steady decline in price with manufacturing processes become more efficient and increased supply from foreign PV modules. PV modules already have a foothold in the building industry. If PV manufacturers added PVT to their product line, PVTs would have a smoother introduction into the market. PVT would be marketed by established companies with credible reputations (Solar Electric Power, 2001). Another alternative for homebuilders is to build houses that are PVT-ready. Preparing the home by installing all the necessary components without the PVT system itself would reduce the cost to the homebuilder and give the homeowner the option for the future. The homeowner can then take utility rebates or subsidies for themselves. Rebates and incentives can be found at <http://www.dsireusa.org/>. Rebate programs or subsidies from the government or utility company could help persuade homebuilders and homeowners to purchase and install PVT systems (Solar Electric Power, 2001). Builders do not have incentive to take the big step toward energy efficiency. Having federal or state government energy efficiency regulations and standards would push the homebuilder to explore emerging energy technologies, such as PVT. California has established a set of energy reduction standards with Assembly Bill (AB) 32, which requires all sectors, including the building sector, to reduce carbon emissions, another possible market driver

Creating a PVT system that can seamlessly integrate into the standard building systems would make PVT much more appealing to the homebuilder. As stated before, PVT Solar’s product can either be installed by a certified solar contractor or by the individual trades themselves. Either party would have the knowledge to successfully integrate their portion of the PVT into the rest of the building systems. PVT systems that take a similar approach would also have building integration success; however, Utah Solar found both of the Gold Medallion installations equally difficult. Future installations should become easier with more experience and an established installation process.

PVT Budget Period 3 (2010)

A relatively recent solar innovation uses special configurations of solar photovoltaic cells, combined with solar thermal collectors, to convert the sun's radiation into electricity and heat simultaneously in a single system. These Solar "Photovoltaic Thermal" systems (PVT) combine both PV-only and thermal-only solar systems to generate and capture electrical and heating.

Conventional solar "PV-Only" systems utilize the sun's power to generate useful electrical energy only. However, the PV operating temperature increases due to solar heat gain and waste heat generation from the PV modules which negatively impact the efficiency and performance of the modules. For every 1.8°F of temperature increase, the PV module loses 0.5% in efficiency (Skoplaki, 2008). In a PVT system, heat is drawn away from the PV modules by passing air under them to help reduce the operating temperature of the modules thus increasing their energy efficiency. Increase in PV generation has been shown to be 2-3% above standard BIPV modules, which lay flush with the building's roof (Plaisted, 2008). BIPVs may also transfer the unwanted PV generated heat to the building which could increase its HVAC cooling load.

The heated air that is produced from the PV modules can be directed for additional energy savings. Thermal modules are used to further increase the temperature of the air which can help heat domestic water as well as partially meet space heating needs. The thermal module air handler takes in tempered outside air to supply the living space with fresh air to improve the indoor air quality. The ventilation air is essential with more advanced and tighter homes to help maintain the indoor air quality.

Key Results

Actual installed system data has shown significant electrical and thermal energy production. Code approvals have been achieved in several jurisdictions with ease; the PVT product conforms to the building, energy, and fire codes. Some local jurisdictional codes may still restrict certain solar products. Solar Rating and Certification Corporation (SRCC) approved PVT systems to qualify for tax credits (30% federal tax credit), further reducing costs. Installations can be difficult with steep roof pitches (greater than 6:12) and small clearances. The warranty for the PVT defaults to the individual part manufacturers. The PVT system has not been through enough annual cycles to accurately gauge defects or failures.

Gate Status

The PVT system provides increased energy production over a stand-alone PV system and has satisfied the code based approval criteria, as jurisdiction authorities in South Jordan, Utah have approved several installations of the PVT system. The incremental cost over a standard PV system is not covered by the energy savings gained from the combined system. PVT Solar remains committed to its product and continues to provide technical support when it is needed. PVT

has satisfied all stage gate criteria.

PVT has satisfied all Stage Gate 1B “must meet” criteria based on installations limited to Utah. More application data from other climate regions is needed. Obtaining data from other climate zones has proven difficult with the poor condition of the housing market.

Conclusions

PV electrical energy production for the 2009 calendar year has not met the PVT Solar provided estimated annual electrical energy production of 2,960 kWh. PVT Solar’s projection does not account for times when the modules are covered with snow.

The BIRA monitored thermal energy for water heating is not projected to meet the thermal energy estimated by PVT. The variance may be due to the accuracy and location of the sensors used to monitor the air temperature or heat loss to the building from the glycol loop. BIRA measured the temperature drop of the glycol loop before and after the solar tank while PVT Solar measured the air temperature drop across the section of the glycol loop in the attic air handler. Also, only two of the three thermal arrays are ducted to the air handler as the third one is located above a vaulted ceiling.

The cost of a PVT system is approximately 25% more than a standard PV system (\$6.44/W), but is considerably less expensive than a combined, side-by-side PV (\$5.16/W) and thermal array. When incorporating the rebates and subsidies that are available, the overall cost coupled with the energy benefit is very promising. The PVT has a longer payback time than a comparable PV-only system, largely due to the additional parasitic losses from the air handler and the glycol pump. In addition, the PVT system has a smaller footprint, which is particularly important when trying to apply a renewable energy system to a multi-family project where the roof space per living unit is much smaller than the roof space for a detached, single family home.

“Must Meet” Gate Criteria - Source Energy Savings and Whole Building Benefits

Gold Medallion “Parade of Homes” at Daybreak PVT Installation

The PVT Solar projected annual performance for the 2.25 kW PVT installations in South Jordan, Utah at the 2008 Gold Medallion Home in the Kennecott Land’s Daybreak development calculated by PVT Solar’s proprietary TRNSYS program is 2,960 kWh of electrical, 105 Therms for domestic hot water, and 20 Therms for space heating. PVT Solar’s program utilizes location weather data, but does not account for snowfall met time; therefore, the program calculates energy production on a clear sky day even with snow covering the panel system. NREL’s PV Watt photovoltaic calculator estimated 2,551 kWh of electrical generation for a typical 2.25 kW PV array in Salt Lake City, Utah facing West and tilted at 27°.

BIRA and PVT Solar have independently collected data from January 2009 to mid-September

2010. During the 21 months of BIRA's monitoring of the PVT system, using relative humidity sensors (accuracy 0.02%) and Type-T thermocouples, the PV section has produced 4,739 kWh; however, the thermal section has only produced 1,949 kWh (67 Therms) for water heating. The thermal energy for water heating under produced compared to the projected performance due to an installation issue. Initially, part of the thermal collector was not ducted since it sat over a vaulted ceiling. Another portion of thermal collector was only partially ducted for the same reason. That second thermal array was eventually fixed so the system had two out of the three. This lack of energy production is also reflected in PVT Solar's monitoring data.

PVT Solar's monitoring system shows 4,308 kWh of electrical production, 3,314 kWh (113.1 Therms) produced for water heating and 426 kWh (14.5 Therms) for space heating. The PVT Solar monitoring data range was limited to March 2009 to mid-September 2010. Data preceding March was not available due to a new controller installation, which allowed for the online dashboard access. Data collected by BIRA between March 2009 and September 2010 was 4,460 kWh of electrical production, 1,946 kWh (66.4 Therms) of water heating, and 276 kWh (9.4 Therms) of space heating.

2008 Gold Medallion Parade Home PVT Installation	Electrical (kWh)	Water Heating		Space Heating	
PVT annual projection	2,960	105 Therms		20 Therms	
BIRA (1/1/09-12/31/09)	2,687	969 kWh	33.1 Therms	N/A	N/A
PVT (6/1/09-5/31/10)	2,481	1,658 kWh	56.6 Therms	41 kWh	1.4 Therms
BIRA (6/1/09-5/31/10)	2,795	1,041 kWh	35.5 Therms	N/A	N/A
BIRA (1/1/09-9/10/10)	4,739	1,949 kWh	67.0 Therms	N/A	N/A
PVT (3/1/09-9/10/10)	4,308	3,314 kWh	113.1 Therms	426 kWh	14.5 Therms
BIRA (3/1/09-9/10/10)	4,460	1,946 kWh	66.4 Therms	N/A	N/A

Table 86: 2008 Gold Medallion PVT Production

Water heating production from BIRA's monitoring data was determined by a BTU meter that measured the glycol flow rate and the difference between the incoming and outgoing glycol temperatures of the basement preheat tank heat exchanger, which shows the energy transferred from the glycol to the water heating tank. PVT Solar calculated water heating production by measuring fan flow rate and the air temperature drop across the heat exchanger coil in the air handler. This method calculates energy transferred to the glycol loop, but not the energy transfer to the water heating tank. There could be heat transfer to the glycol loop, but if the loop is not circulating then the heat energy is not reaching the water heating tank. The uninsulated glycol loop also allows for the possibility of heat losses to the building and not to the water heating tank. These reasons could explain the discrepancies between PVT Solar's and BIRA's results. Energy generated for space heating was not calculated from the BIRA collected

data. Attempts to calculate space heating from BIRA data proved to be unsuccessful as the damper that allowed the warm air to be brought into the house or exhausted outside was in “exhaust” mode from June 2009 to current, which could be a sensor or data logging error. The BIRA incoming air temperatures into the PVT air handler were 7°F lower during the peak hours than the temperatures recorded by PVT Solar’s monitoring equipment; therefore yielding a lower total heat transfer from the heated PVT air to the water heating glycol loop. There was a marginal difference between the electrical production recorded by PVT Solar’s and BIRA’s monitoring equipment, which could be a result of the sensor tolerances.

PVT energy production data recorded by both BIRA and PVT Solar are available in Table D-2 thru Table D-5 in the final report’s Appendix D.

The parasitic losses were also monitored and recorded separately from the gross PV production using current transformers. The total PVT fan, glycol pump, controller, and dampers used 1,344 kWh from January 2009 to September 2010; which was 69% of the BIRA recorded thermal output for water heating and about 30% of the electrical generation. Most of the energy was consumed by the PVT fan, which used 1,076 kWh. There was a substantial increase in PVT fan energy usage in 2010 due to the implementation of radiant night sky space cooling during the summer months. PVT Solar’s online dashboard recorded a production of 221 kWh and 466 kWh of cooling in 2009 and 2010, respectively. BIRA did not monitor the space cooling offset. Further details can be found in PVT’s final report Appendix B and Appendix D.

Garbett Homes “Solaris Collection” at Daybreak PVT Installations

The Solaris Collection by Garbett Homes installations were tilted up PVT systems on a flat roof. Modifications to the current system that normally lays flat on a pitched roof were needed, but were not very difficult. Changes to the system design included an insulated backing behind the PV and thermal arrays to create the air plenum and insulated rigid metal ducting from the thermal array to the house.

The tilted PVT installations at Garbett’s Solaris Collection were not monitored by BIRA; however, PVT Solar has shared its projected energy production data. The system description and estimated energy production data are in the table below:

PVT Array	Site 1840 B	Site 1380 B
Slope	30°	34°
Azimuth	South	South
PV Modules	8	6
Thermal Modules	4	3
Auxiliary		
Space Heating and Cooling	Furnace	Furnace

Water Heating	Electric Dual Element	Electric Dual Element
System Performance (kWh/yr)		
Basic PV	1,965	2,849
Echo Net Electricity	1,856	2,687
Water Heating	3,642	5,840
Home Heating	578	1,465
Home Cooling	338	752
Total	6,414	10,744

Table 87. Garbett Homes “Solaris Collection” Estimated PVT Production

“Must Meet” Gate Criteria - Performance-Based Code Approval

PVT modules are not explicitly described or mentioned in any code, but PVT systems, ranging from 2.6 kW to 4.6 kW, have been installed in seven U.S. locations and have been permitted by local jurisdictions. These seven locations include:

- Salem, OR
- Reno, NV
- San Francisco, CA
- Thousand Oaks, CA
- Fontana, CA
- Honolulu, HI
- Kennebunk, ME
- South Jordan, UT
- Gilbert, AZ

PVT is currently installed and being test monitored at two Kennecott Land Gold Medallion homes in South Jordan, Utah. Gold Medallion is offering PVT as an option to their homes. Currently, three out of the six homes at Gold Medallion have the PVT option. Garbett Homes has installed PVT as a standard feature on twenty (20) of their Solaris Collection homes at Kennecott Land’s Daybreak development.

PVT systems shall be installed per Chapter 23 of the 2006 International Residential Code. They must also meet the performance guidelines as described in the 2006 International Code Council Performance Code. PVT was approved by the Solar Rating and Certification Corporation (SRCC) for their OG-100 rating.

“Should Meet” Gate Criteria - Prescriptive-Based Code Approval

PVT must meet the existing prescriptive based codes for existing PV and Solar Thermal units. PVT must conform to local fire safety codes for proper roof access and emergency electrical PV disconnection. All systems shall be grounded and wiring weatherproofed. The City of Tempe,

Arizona has required that PVT Solar provide a potable water certification for their flat plate heat exchanger, which PVT Solar is trying to obtain from the manufacturer.

“Should Meet” Gate Criteria - Cost Advantage

The cost of mounting the Gold Medallion PVT system was \$14,500 before local, state, and federal incentives were taken with a net cost of \$8,225. The gross cost of the PVT system was about 25% more than installing a conventional PV-only system. The additional 25% increase in cost accounts for the racking system, thermal collector, duct work, air handler, heat exchanger, motorized dampers, and the PVT controller. The PVT system costs more than the conventional PV-only system. The PVT payback time varies depending on the array size, environmental conditions, and utility rates.

South Jordan’s electric utility provider is Rocky Mountain Power (RMP). Questar is the gas utility provider for South Jordan. Utility rates are shown in Table 88. South Jordan, Utah’s electrical and utility rates are considerably lower than the rest of the country (Pacific Gas & Electric: \$0.12/kWh, \$1.10/therm).

Rocky Mountain Power		
	May-September	October-April
0-400kWh	\$ 0.075292	\$0.078009
400-600kWh	\$ 0.092749	
>600kWh	\$ 0.115361	
Questar		
	April - October	November - March
0-45 therm	\$0.737344	\$0.832615
> 45 therm	\$0.621572	\$0.704763

Table 88: Gas and Electricity Rates for South Jordan, Utah

When using the projected and 2009 monitored savings data, RMP’s electricity rate, and Questar’s gas rate, the 2008 Gold Medallion’s PVT system has an estimated payback period of about 45 years. An equivalent PV-only system has an estimated payback time of 32 years. When using higher electricity and gas utility rates, (e.g., PG&E) the payback time drastically reduces. The PVT system would pay for itself in 29 years based on the Gold Medallion monitored savings data, 16 fewer years than with RMP and Questar’s rates. When eliminating the parasitic losses (\$53/year) from the PVT system, the payback time decreases by 10 years and 5 years using South Jordan’s utility rates and PG&E rates, respectively. Neither of the PVT BIRA annual savings include savings from space heating or cooling.

	Annual Savings

	RMP & Questar	PG&E
PV (estimated)	\$195	\$281
PVT Solar (est.)	\$324	\$424
PVT Solar (net)	\$187	\$283
PVT Solar (gross)	\$240	\$336
PVT BIRA (net)	\$177	\$279
PVT BIRA (gross)	\$230	\$332

Table 89. PVT Production Annual Savings

RMP & Questar				
	PV	PVT Solar	PVT BIRA	PVT Solar (est)
Cost (after incentives)	\$6,195	\$8,225	\$8,225	\$8,225
Payback Years	32	44	46	25
Payback Years w/o Parasitic Losses	32	34	36	25

Table 90: 2008 Gold Medallion PVT payback time comparison #1

Pacific Gas & Electric				
	PV	PVT Solar	PVT BIRA	PVT Solar (est)
Cost (after incentives)	\$6,195	\$8,225	\$8,225	\$8,225
Payback Years	22	29	29	19
Payback Years w/o Parasitic Losses	22	24	25	19

Table 91: 2008 Gold Medallion PVT payback time comparison #2

PVT utilizes a rack mounting system that eases contractor installation. Per Utah Solar, the approximate additional costs for a PVT system on a roof pitch 6:12 and greater is \$1 per Watt and \$0.50 per Watt on a roof pitch less than 6:12. More cost data will become available after future installations are completed.

According to the Department of Energy, homeowners can receive a 30% tax credit for SRCC approved solar electric systems that are placed in service from January 1, 2006 through December 31, 2016 under the Residential Renewable Energy Tax Credit. Another incentive available to PVT is a 30% tax credit (up to \$2,000) for a SRCC approved solar water heating system. They must show that half of the energy used for domestic water use comes from the sun.

The tax credits for the homeowner and homebuilder should be enough incentive to use the PVT

system. The homeowner will see a return in the money spent to install the system if the system is installed after January 1, 2009 (Consumer Tax Incentives, 2008). The tax credit for the homebuilder is quite substantial at \$2,000 for each home built. These are only federal tax credits. With the addition of federal and state tax credits or utility rebates, the reduction of installation cost for the PVT system will increase this product's marketability.

"Should Meet" Gate Criteria - Reliability Advantage

One advantage of using a PVT system with air is that the system does not fail if there is an air leak. PVT systems that use water as a heat transfer medium that runs to and from the exterior panels have the potential for water damage on the roof from leaks or freezing. PVT Solar's system utilizes a glycol-based heat transfer medium running from, which has a lower freezing temperature than water. Non-corrosive materials, such as aluminum, are used extensively for their durability.

PVT was initially designed to easily integrate with existing proven PV modules and off-the-shelf blowers & coils, which makes PVT easily integrated into the current building process. The original air handler was replaced with a newer, modulating air handler to optimize the transfer of thermal energy to the house. Currently, the PVT installation process can still be done in a segmented manner in which each trade installs their respective component of the PVT. Otherwise, a qualified solar contractor can perform the installation in its entirety, including installation of the controller and air handler. For the two Gold Medallion homes in Kennecott Land's Daybreak Development, Utah Solar & Alternative Energy has performed the installations.

David Herr from Utah Solar & Alternative Energy stated that the two Gold Medallion homes installations proved equally difficult. The mechanical air delivery of the solar heated air was the hardest part to incorporate into the homes, for both Gold Medallion and Garbett Homes. The added difficulty of the deck mounted Cleanline Racking system and galvalume was also a real time sink, and the steep 7:12 roof pitch almost doubles the cost of installation on the roof. Also, available space in these small homes is at a premium. Adding supplemental systems like PVT really complicates clearances and tolerances. Herr anticipates future installations going smoothly after a process has been established.

After installation, the PVT Solar controller had issues communicating with the third-party air handler due to compatibility issues. The previous air handler did not use a variable speed motor so it did not run when the controller sent a variable signal. The controller and air handler have since been changed to a production model PVT Solar controller and a new air handler that communicates properly with the controller.

Having a quality installation is one of the keys to maximizing the benefits of the PVT system. The inspection process will also help ensure that the system performs to the stated specifications. The inspection includes checking of panel temperatures, azimuth, pitch, and shading. Inspections can be performed by qualified representatives from the manufacturer or

from certified third party inspectors.

One disadvantage, like all other solar systems, is that the PVT efficiency is susceptible to degradation if shaded or covered. Other factors that might carry over from when PV systems were first being used were subpar installations or poor planning. Mostly, these poor installations were due to lack of experience. Simple education about PVT and their installation methods, either through the manufacturer or an organization like the North American Board of Certified Energy Practitioners (NABCEP) coupled with inspections would help ensure the quality of installation.

“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment

PV modules are highly reliable – and because PVT is an integrated system, it does not modify or void the third party PV manufacturer’s warranties in any way. Installing the PVT as an integrated system would eliminate the separate warranties that the homebuilder requires if installing PV-only and thermal-only systems. Installation also should be performed by a certified NABCEP contractor to help ensure a proper installation.

The PVT warranty covers the mounting system for 10 years and the finish for 5 years. The mechanical component warranties are not through PVT Solar, but through the respective manufacturers, which range from 18 months to 10 years. PVT Solar systems are ready for production and product shipping.

“Should Meet” Gate Criteria - Gaps Analysis

The three main market drivers for the PVT are available roof space, profitability, and building integration. The historical trend for American home production has been to build increasingly larger homes, thus providing larger roof areas. With the larger roof areas, PVT systems can easily be installed as opposed to the side-by-side PV and Thermal units, which require more space for the equivalent kWh production. However, as David Herr stated, smaller homes and homes with higher roof pitches, installations become difficult due to the space constraints and fatigue from walking the steeper grade roofs.

The Solaris Collection by Garbett Homes installations were tilted up PVT systems on a flat roof. Modifications to the current system that normally lays flat on a pitched roof were needed, but were not very difficult. Changes included a tilted racking system with a rigid-insulated metal pan behind the PV modules to create part of the air plenum. The gap between the bottom of the PV modules and the roof deck is typically 2.8”, but in this tilted system the gap is 1.8” between the bottom of the PV modules and the metal plenum pan. With this smaller air gap, the air moves at a higher velocity increasing the heat transfer rate. Since the PVT system at the Solaris Collection development is tilted, the air ducts that bring the heated air into the house are exposed to the natural elements. For this reason, the ducting from the thermal plenums at the top of the array is insulated rigid metal ducts that combine into a single duct; therefore,

making only one roof penetration into the attic space. Once inside the attic space of the house, the ducts change from metal rigid to flex duct. The new tilted racking system design provided very little difficulty to install the system.

Marketing to a currently unstable housing market could potentially hold back the PVT system. Builders are looking to build a cost-effective home and the additional cost of a PVT system could dissuade them from using it. However, the cost for PV systems has shown a steady decline in price with manufacturing processes become more efficient and increased supply from foreign PV modules. PV modules already have a foothold in the building industry. If PV manufacturers added PVT to their product line, PVTs would have a smoother introduction into the market. PVT would be marketed by established companies with credible reputations (Solar Electric Power, 2001). Another alternative for homebuilders is to build houses that are PVT-ready. Preparing the home by installing all the necessary components without the PVT system itself would reduce the cost to the homebuilder and give the homeowner the option for the future. The homeowner can then take utility rebates or subsidies for themselves. Rebates and incentives can be found at <http://www.dsireusa.org/>.

Rebate programs or subsidies from the government or utility company could help persuade homebuilders and homeowners to purchase and install PVT systems (Solar Electric Power, 2001). Builders do not have incentive to take the big step toward energy efficiency. Having federal or state government energy efficiency regulations and standards would push the homebuilder to explore emerging energy technologies, such as PVT. California has established a set of energy reduction standards with Assembly Bill (AB) 32, which requires all sectors, including the building sector, to reduce carbon emissions, another possible market driver

Creating a PVT system that can seamlessly integrate into the standard building systems would make PVT much more appealing to the homebuilder. As stated before, PVT Solar's product can either be installed by a certified solar contractor or by the individual trades themselves. Either party would have the knowledge to successfully integrate their portion of the PVT into the rest of the building systems; however, installation issues can arise. When the 2008 Gold Medallion PVT system was initially installed, half the array was sitting over a vaulted ceiling, which only allowed 1.5 of the arrays to be ducted. This installation allowed only 230 cfm to flow through the system. In June, it was discovered that one of the railings was covering part of a vent hole from the thermal array. This installation issue was corrected and the system flow rate increased to 350 cfm.

PVT systems that take a similar approach would also have building integration success; however, Utah Solar found both of the Gold Medallion installations equally difficult. Future installations should become easier with more experience and an established installation process.

Home Energy Management Systems (HEMs) - Verve Living Systems Budget Period 3 (2010)

As the Building America (BA) Program progresses towards its goal of cost-effective Zero Energy Homes by 2020, it faces several challenges. Two of these challenges are identified as the influence of occupant impact on energy consumption and the rising consumption from “plug loads”, otherwise known as miscellaneous electric loads (MELs). MELs introduces complications which are typically not addressed by building scientists, architects, and other such professionals. These professionals primarily focus on the more traditional loads such as hot water, lighting and space conditioning (heating and cooling) when designing energy efficient homes.

Engineers have made considerable progress throughout the years in reducing the energy consumption within residential homes. Improved envelopes, HVAC systems, water heating and lighting systems have enabled builders to create new homes that are substantially more energy efficient than those that incorporate standard building practices and conventional equipment. While these achievements in energy efficiency are impressive, they do not address how these homes are being operated by their occupants, nor does it address the rising importance of plug loads, as they can represent as much as half of an efficient home’s load in mild climates such as San Francisco or San Diego¹⁸.

This is an interim report for Home Energy Management Systems (HEMs) performance relative to the BA Stage Gate 1B Criteria. For this report, one HEMs is being evaluated to compare energy savings, cost-effectiveness, user impressions, consumer education, and occupant impact on energy consumption.

This research will build on NREL’s *System Research Plan for Reduction of Miscellaneous Electrical Loads in Zero Energy Homes* to identify viable control options and anticipated savings.

The impact that MELs has on the performance of a home is displayed in [Figure 52](#), and shows the load consumption for cooling, heating, MELs, and the amount of savings that can be achieved from HEMs for all climate zones. The home that was used to generate these results was designed to perform 40% more efficient than the BA Benchmark. The load breakdown demonstrates the value of understanding miscellaneous plug loads (‘Misc. Loads’ in the charts). While the consumption from plug loads between the high efficiency and benchmark homes is equal in absolute terms, plug loads jump from 15% of whole house consumption in the Benchmark to 25% in the as-built high efficiency home. Plug loads are the largest end-use category in high efficiency homes, and as seen in [Figure 52](#), was the only category that showed no improvement.

MELs are more difficult to address from a building science standpoint for the reason that many

¹⁸ Barley, Dennis; Haley, Christina; Anderson, Ren (2008). *System Research Plan for Reduction of Miscellaneous Electrical Loads in Zero Energy Homes*. Golden, CO; National Renewable Energy Laboratory.

of the loads cannot be controlled by the builder. Despite the enhanced energy efficient features that are installed in the highly efficient homes, MELs are an independent system, unaffected by weather or heating/cooling trends. As a result, home office, kitchen, entertainment equipment, lights and appliances run continuously throughout the entire year.

Key Results

The Verve Living System (herein referred to as Verve or Verve system), was installed in two Artistic Homes' prototypes, located in Albuquerque and Farmington, New Mexico, during the summer of 2009. Artistic Homes is a high performance residential builder, who has built over 5,300 energy efficient homes since 1998, and has committed to a partnership with BIRA and the BA Program. Utility bill data has been collected for one year, and has been analyzed to establish an energy consumption baseline for each prototype (See [Figure 54](#) and [Figure 55](#)). Since the Verve systems were only recently activated (October 2010), data is limited, and additional data is necessary to make any conclusions regarding energy reduction in lighting and plug loads.

Gate Status

Stage Gate 1B "Must Meet" criteria are incomplete at this time; although the Verve system passes the "Should Meet" criteria. The Verve system was activated in both prototype homes in October 2010, therefore not enough data has been accumulated for MELs reduction analysis. Research for HEMs will continue into 2011, expanding the test group and determining what other systems are available to be evaluated to help further reduce the MELs within residential construction. Actual results, with the Verve system on, will be analyzed once the data has been collected and received, which is expected around October 2011.

Conclusions

The Verve system was installed in two test homes where BIRA has established the energy consumption baseline. The HEMs have recently been activated and are currently capturing the lighting and plug load reductions for each prototype. BEopt software was used to help create a range of kWh that is consumed from MELs alone for the Albuquerque and Farmington prototypes. In addition to the simulations, the NREL MELs analysis tool was used, as well as manual calculations for the energy consumption based on assumptions for typical household appliances¹⁹ and hours of operation²⁰ for a typical family of four.

Project Overview and Background

This is an interim report for home energy management systems' (HEMs) performance relative to the BA Stage Gate 1B Criteria. Stage Gate 1B Criteria can be found in Appendix A of the

¹⁹ LBNL Standby Power Summary Table

²⁰ Roth et al., TIAX LLC, 2008

interim report. BIRA is investigating the electrical savings potential from the introduction of controls and consumer education into BA homes, aimed at small appliance and consumer electronics. Both manual and occupancy based controls will be evaluated.

Based on BEopt simulations, a 6% reduction in whole house energy use is possible with whole HEMs. Whole HEMs with smart metering, provide a means for addressing peak loads while minimizing disruptions to occupant comfort. Figure 52 summarizes an estimate of the average source energy savings relative to the BA performance goals for a whole house control system that captures savings from HEMs, lighting, and HVAC, showing an average 6% whole house source energy savings.

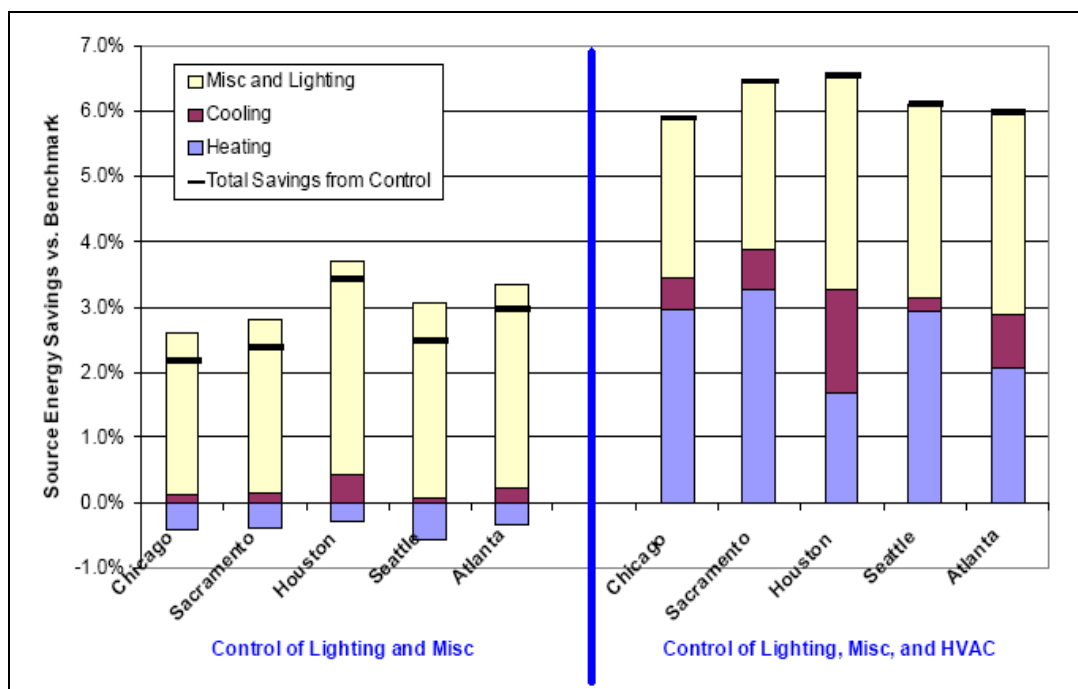


Figure 52. Estimated average source energy savings for whole house control systems in each of the major Climate zones

The primary focus of this research effort is on builder-implementable strategies for MELs reductions. As these strategies have the potential to also reduce non-MEL energy consumption, cost-benefit analyses will include the impact on whole house energy usage. Opportunities to reduce MELs fall into three general categories discussed below.

Individual Component Efficiency Improvements

Many improvements in the efficiency of individual products and components are expected to occur as a result of ongoing investments by product manufacturers, utilities, public interest organizations, and federal, state and local governments. Examples include recent progress by ENERGY STAR® such as an updated specification for ENERGY STAR® televisions that address standby

and active power consumption. There is also a new specification for ENERGY STAR® digital-to-analog converter boxes, which have been introduced to the market due to the recent transition from analog to digital broadcasting.

Recommended technical approaches with respect to this category include:

- Tracking product performance trends to ensure use of “best available” products in BA projects
- Providing recommendations for improvements in product performance based on experience in BA projects
- Acting as technical advisors on research efforts funded by other organizations
- Conducting targeted tests of new products when performance data is not otherwise available to verify benefits relative to BA performance goals

Home Energy Management Systems (HEMs)

Approaches in this category include programmable timers, occupancy detectors, whole house control switches, and adaptive controls. These systems may be implemented through a dedicated household wiring strategy, existing electrical wiring, wireless switching, and tie-ins with other control hardware in the home, such as insulating blinds, lighting systems, space conditioning systems, building security systems, and utility load-management/demand-response controls.

Recommended technical approaches with respect to this category include:

- Use of lighting systems, space conditioning systems, switchable power outlets, and other devices that allow for occupancy based control
- Use of control systems, receptacles, or other devices that control one or more outlets based on the power used by the main (master) outlet
- Use of manual whole house switches that provide occupants a tool to disable selected plug loads and lighting as well as customize thermostat settings indefinitely or for prescribed time periods (e.g., 2 hours, 4 hours, 8 hours, extended vacation, etc.)

The Verve system fits into the product category of developing standardized energy use modes for implementation in home automation and control system software and user displays.

Occupant Behavior Changes

Approaches in this category include occupant education in household energy usage and product selection, in addition to real-time feedback to occupants regarding energy usage. *(While it is important to provide consumers with the information required to reduce energy end-uses, occupant behavior changes are considered to be largely outside the scope of the system research and technology development tasks of the Building America Program.)*

Opportunities with respect to this category include:

- Information with reference to energy efficient home operation and product selection with home owners' manuals and operating guides
- Energy feedback displays in Building America homes
- Proposed research efforts consisting of six tasks and incorporating the Building America Stage Gates

System Description

Background

The Verve system is being evaluated to compare energy reduction in lighting and plug loads, cost-effectiveness, and user impressions. Information on consumer education and occupant impact on energy consumption will also be collected. This research will build on NREL's *System Research Plan for Reduction of Miscellaneous Electrical Loads in Zero Energy Homes* to identify viable control options and anticipated savings.

The Verve Living System (herein referred to as "Verve" or "Verve system") is produced by Verve, a subsidiary of the Masco Corporation. The system features a ten switch controller with accompanying switches, motion sensors and lumens sensors. Each channel can control up to 300 watts at ten amps, and channel one and two can be bridged to double the capacity.

Harvesting Technology

The Verve system relies on an extraordinary technology developed by EnOcean GmbH, a Siemens Corporation subsidiary. The technology is based on a simple discovery made by EnOcean scientists where enough energy is created by a simple act, such as turning a switch on and off to allow the transmission of radio signals across distances as great as 300 feet. It is this energy that is harvested and used to power the switches, therefore no hardwiring or batteries are required. Due to this technology, the system demands very little power to operate and consumes a minimal four Watts.

EnOcean created a small wireless sensor that can collect ("harvest") tiny amounts of energy. When Verve came across the technology, they immediately recognized its potential for radically changing the dynamics of home control. Verve has used this technology to create a wireless, energy-harvesting, whole-house lighting control system that can turn on and off both incandescent and compact fluorescent lights, as well as have the ability to incorporate dimmers. The switches were designed in a manner that does not call for wiring to the lighting sources, thereby making the switches completely movable.

Verve Controllers

Verve uses a trunk and branch type configuration (see Figure 53) from its central controller, where each controller consists of ten channels, which can be used to control either lighting, fans or plug loads. The unique dimmable controllers are wireless, and can be programmed and placed anywhere throughout the house, allowing for a whole house shutoff “green switch” when leaving or going to bed. The controller also utilizes occupancy or lumens sensors to shutoff various loads when a room has been left vacant for a specific amount of time. Verve also includes a programmable thermostat that can be combined with their controls to setback or shut off the HVAC system for maximum energy savings.

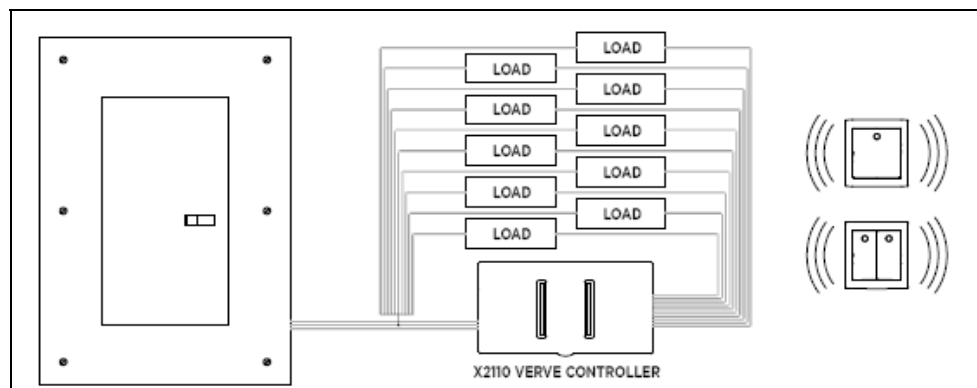


Figure 53. Verve System wiring schematic

Automated and Manual Control Systems

The Verve system allowed BIRA to focus on two MELs reduction strategies: automated and manual control systems. This represents the two predominant system types currently available on the market, and fortunately the Verve system is capable of using both control mechanisms. Automated systems represent solutions as simple as motion controlled light switches, and as complex as control systems for whole house lighting, security, outlets, thermostat, etc. Manual control systems have the ability to control a set of outlets from a centralized location. Power strips are the most simple manual control system, but are usually unreachable to consistently shut down. “Green switches” are more complex systems which use a master switch to control numerous objects in the house from one centralized location.

Additional Verve Information

Verve’s marketing materials and a Quick Start Guide are available in the interim report’s Appendix B and Appendix C.

Research Study Approach

In order to compare the actual data collected from the Artistic Homes’ prototypes, BIRA has performed three additional approaches to quantify MELs consumption. The three approaches include:

- Calculations based on assumptions concerning household appliance selection and hours of operation
- Simulation data obtained from BEopt modeling software using Artistic Homes as models
- NREL MELs Analysis Spreadsheet

MELs Energy Consumption

BIRA MELs research focuses on specific house load categories used to evaluate the performance benefits and specifications for specific mitigating solutions. These target categories were created for an average sized family (four members) and include:

- Home Entertainment – TV, DVD player, cable box top, stereo equipment, video game consoles
- Home Office – Desktop/laptop, monitor, printer, cable/dsl modem, router
- Kitchen – Microwave, toaster oven, coffee maker
- Hardwired – Ceiling fans, security system, garage door opener, doorbell, irrigation timer
- Other Household Appliances – cordless phone, answering machine, cell phone chargers, surge protector/power strip

The home entertainment center and home office categories were selected due to their large potential impact on centralized consumer electronics equipment. Both the home entertainment and home office centers have a national average daily usage greater than eight hours a day. [Table 94](#)–[Table 98](#) detail the specifications for each appliance that may contribute to MELs consumption in residential homes including the power drawn for each mode of operation (standby, idle and on), hourly usage for each mode of operation, as well as the unit electrical consumption (UEC) for the average miscellaneous household and hardwired appliances, and home entertainment, kitchen, and office centers¹¹. Using the average hourly usage and UEC data, the home entertainment center accounts for about 800-1,200 kWh/yr, the home office accounts for 500-900 kWh/yr, kitchen appliances use a total of 200-500 kWh/yr, whereas miscellaneous household appliances consume 100-200 kWh/yr, and hardwired appliances use as much as 1500 – 2000 kWh/yr. A total of 4,516 kWh/yr was calculated, based on the devices listed below in [Table 94](#)–[Table 98](#) as the estimated energy consumption due to MELs. [Table 99](#) shows the breakdown of energy consumption for each mode of operation. The amount of energy that is consumed in household appliances, during the mode in which most homeowners believe do not consume energy (otherwise known as standby mode), consume about 1,500 kWh/yr, whereas full operation mode can consume as much as 3,000 kWh/yr. The total amount of energy consumed for MELs accounts for 44.3% of the whole house energy consumption for the Albuquerque prototype, which satisfies the assumption made earlier, that the total MELs can account for about 50% of the energy loads used throughout residential homes.

It can be seen in [Table 99](#) that all target areas produce considerable loads, where these loads can fluctuate tremendously as they are largely impacted by occupant behavior. This

characteristic brought rise to the unique opportunity to evaluate HEMs as well as occupant impact for each target area defined throughout [Table 94](#) – [Table 98](#).

Interim Status

A preliminary background search was done to determine if MELs loads could accurately be modeled in any of the approved software simulation packages, and none were capable. This is presumed to be largely because MELs cannot be completely controlled since they are essentially based on occupant lifestyle.

Conversely, there was insufficient data available when comparing Verve users with a baseline test group. Instead, BIRA has allowed the system to be installed, but not fully utilized for a period of one year to accumulate baseline test information about occupant energy usage. BIRA has accumulated one year's worth of baseline data, where the system was recently activated to provide the most energy savings possible targeting MELs reduction.

The Verve system was installed in two Artistic homes in the summer of 2009, where BIRA has analyzed utility bill data for one year to establish the energy consumption baseline for each home. This baseline will be used to compare the energy consumption of both prototypes while the Verve system is activated. Prototype 1 is a 2,118 ft² 3 bed / two bath home in Albuquerque, NM and Prototype 2 is a 1,008 ft² two bed / two bath home located in Farmington, NM. The two Artistic homes will be evaluated based on the utility bills for the next year, with the Verve system activated, to quantify the energy savings from implementing the HEMs. This analysis will be used to determine the source energy savings provided by the system, as well as determine if the system meets the “Must Meet” and “Should Meet” criteria.

“Must Meet” Gate Criteria - Source Energy and Whole Buildings Benefits

Baseline Data

The prototype tests will be very valuable in learning about the capabilities of the Verve system and how it may reduce the electrical consumption from MELs, as well as impact occupancy behavior. *While the test is not large enough to determine statistical variances, the results will be a very good prototype none the less.*

BIRA has been collecting data for two prototype homes located in New Mexico, in order to establish a baseline before activating the Verve system. Benchmark data collection is complete, and can be seen below in [Figure 54](#) and [Figure 55](#). Utility bill data was used to determine the energy consumption for each prototype, where the bill summary is displayed for each prototype below in [Table 92](#) and [Table 93](#).

The Farmington prototype's energy consumption is inconsistent, where close to no energy was consumed between the months of July and September. The spike in energy usage during

December was primarily due to the holiday season, incorporating additional exterior lighting and increases in the number of occupants. The prototype located in Albuquerque, NM demonstrates a more consistent energy-use pattern, showing a range between 500-1,200 kWh per month. With reference to the percentage of MELs with respect to the whole house energy calculated in Table 99, the estimated MELs from the baseline data would be between 2,658-6,379 kWh/yr, satisfying the calculated range of MELs, with $\pm 5\%$ variance that can be reduced due to HEMs (see Table 100).

Billing Period	Year	Energy Used (kWh)	Energy Generated ²¹ (kWh)	Bill Total (\$)
July - Aug	2009	17	n/a	\$4.94
Aug- Sept	2009	4	n/a	\$3.62
Sept - Oct	2009	41	n/a	\$7.38
Oct - Nov	2009	302	n/a	33.52
Nov - Dec	2009	645	n/a	\$67.11
Dec - Jan	2009/2010	1193	n/a	\$114.37
Jan- Feb	2010	652	n/a	\$64.31
Feb - March	2010	735	n/a	\$71.99
March - April	2010	508	n/a	\$50.97
April - May	2010	307	n/a	\$32.38

Table 92. Baseline utility bill data for Farmington, NM prototype (w/o VERVE)

Billing Period	Year	Energy Used (kWh)	Energy Generated (kWh)	Bill Total (\$)
Oct	2009	501	442	-\$28.04
Nov	2009	936	750	-\$78.28
Dec	2009	1075	861	-\$90.15
Jan	2010	1075	861	-\$90.25
Feb	2010	1281	878	-\$72.84
March	2010	1027	849	-\$91.91
April	2010	738	937	-\$117.39
May	2010	693	1022	-\$128.44
June	2010	840	996	-\$125.06

Table 93. Baseline utility bill data for Albuquerque, NM prototype (w/o VERVE)

²¹ PV System malfunction for data collection period

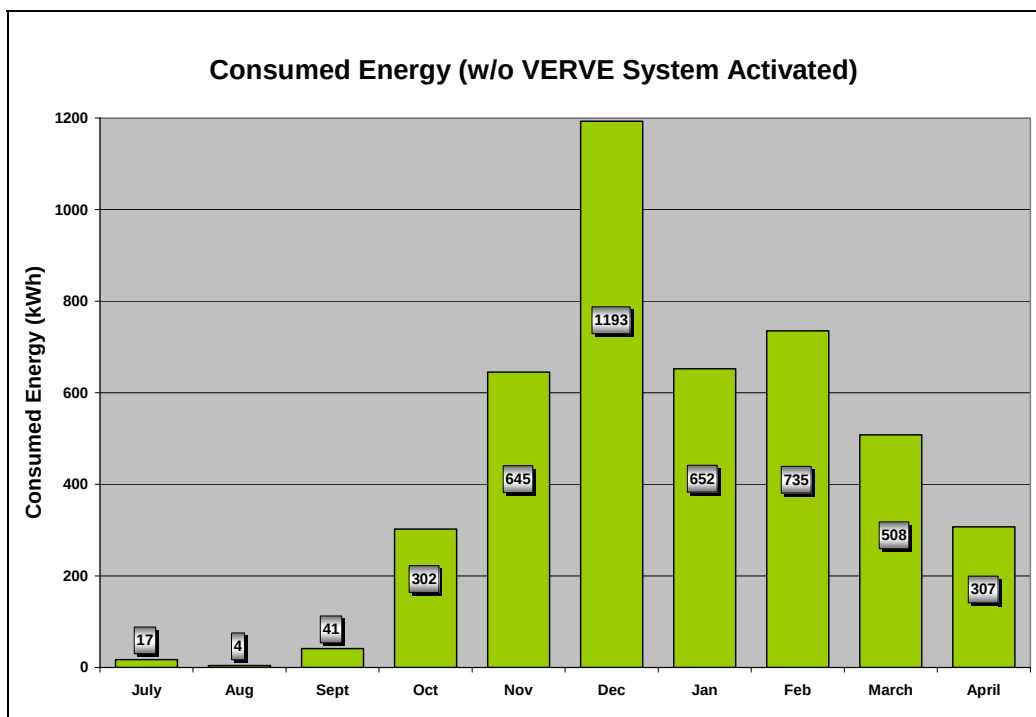


Figure 54. Baseline utility bill data for Farmington, NM prototype (w/o VERVE)

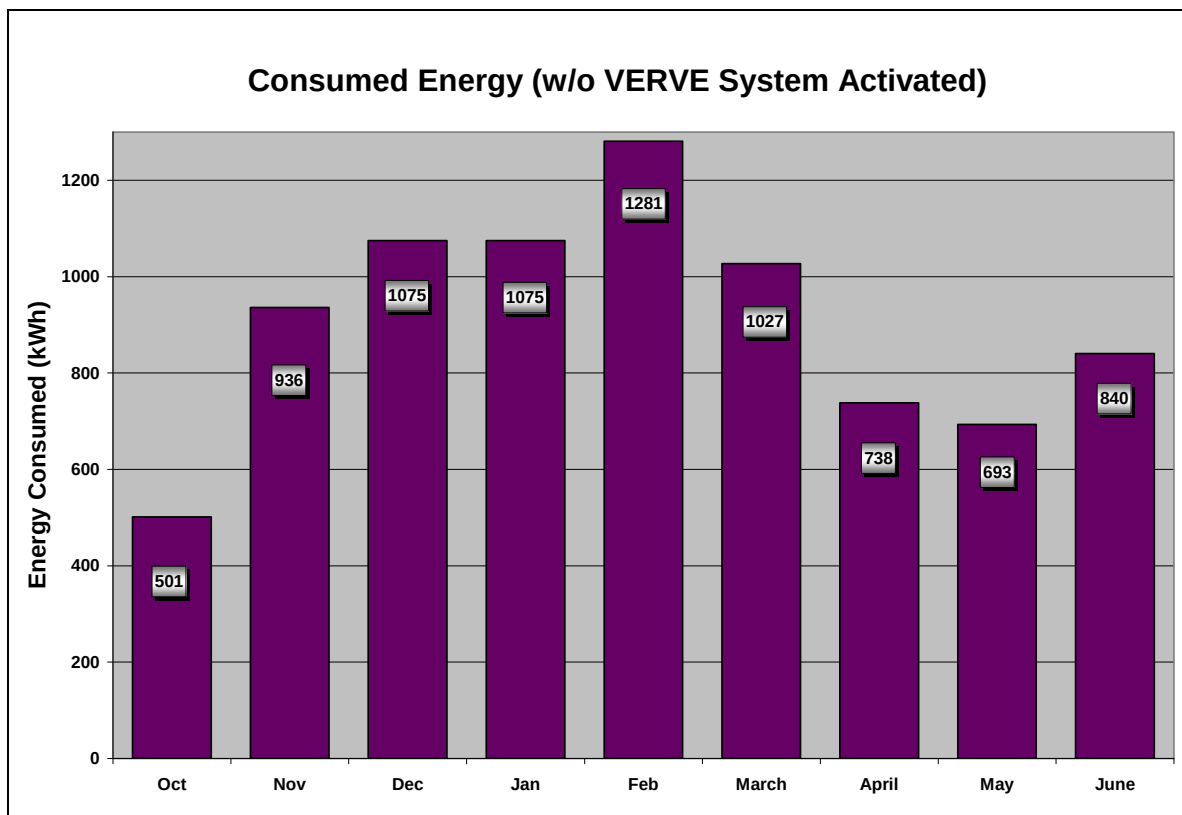


Figure 55. Baseline utility bill data for Albuquerque, NM prototype (w/o VERVE)

Simulated Data

An additional method to obtaining a range of energy (expressed in kWh) that can be reduced using HEMs was found by using BEopt modeling software. Each prototype was modeled in order to determine the whole house energy savings, as well as comparing the MELs consumption to the established range found in [Table 100](#). For each prototype, the MELs consumption accounts for an average of 30% of the whole house energy use, which is why it is understandable that MELs have such an important role when designing energy efficient homes.

The features and results for both prototypes can be found in Appendix G of the interim report.

Calculated Data

An alternative approach to quantifying the range of MELs to be reduced by HEMs was found by calculating the kWh/yr for typical household appliances (See [Table 94 –Table 98](#)). The estimated amount of MELs used annually ranges from 2,850 – 6,200 kWh as seen in [Table 100](#). Standby loads were calculated to account for about 15% of the whole house energy, where idle appliances draw about 3%, and when these appliances are fully functioning they can consume up to almost 30% of the energy the whole house uses. The overall consumption of MELs was found to be 4,516 kWh/yr, which accounts for 44.3% of the whole house energy.

	No. Units	Standby (W)	Idle (W)	On (W)	Usage ³ (hrs./yr)			UEC (kWh/yr)		
					Standby	Idle	On	Standby	Idle	On
27" Flat screen TV	2	1.2	n/a	120	6,860	n/a	1,900	8.2	n/a	228
DVD Player	2	1.6	7.5	9.9	7,590	900	270	11.8	6.8	2.7
Stereo	2	1.2	9.5	9.9	7,190	730	840	8.6	6.9	8.3
Cable Box	2	17.5	24.7	29.6	6,030	n/a	2,730	105.5	n/a	80.9
Nintendo Wii	1	1.8	13.5	18.4	7,795	560	405	14.0	7.6	7.5
Microsoft Xbox360	1	2.2	168	173	7,660	600	500	16.8	100.8	86.5

Table 94. Home entertainment – Unit electrical consumption (per unit)

	No. Units	Standby (W)	Idle (W)	On (W)	Usage ³ (hrs./yr)			UEC (kWh/yr)		
					Standby	Idle	On	Standby	Idle	On
Laptop	2	8.9	15.8	44.3	5,458	918	2,383	48.6	14.5	105.5
Desktop w/ PC Speakers	1	4.6	25.3	79.0	5,457	333	2,968	25.3	8.4	234.4
PC Monitor	1	1.1	1.4	27.6	6,029	869	1,861	6.8	1.2	51.4
Cable Modem	1	n/a	n/a	6.3	n/a	n/a	8,760	n/a	n/a	54.8
Wireless Router	1	n/a	n/a	12.0	0	0	8,760	n/a	n/a	105.1
Inkjet Printer (all-in-one)	1	0.4	3.0	9.6	8,672	n/a	88	3.5	n/a	0.85

Table 95. Home office – Unit electrical consumption (per unit)

	No. Units	Standby (W)	Idle (W)	On (W)	Usage ³ (hrs./yr)			UEC (kWh/yr)		
					Standby	Idle	On	Standby	Idle	On
Microwave	1	3.1	n/a	1,433	8,690	n/a	70	26.8	n/a	100.3
Coffee Maker	1	2.5	250	1,025	8,493	229	38	21.2	57.3	39.0
Toaster Oven	1	1.2	n/a	1,050	8,723	n/a	37	10.0	n/a	38.9

Table 96. Kitchen – Electrical consumption (per unit)

	No. Units	Standby (W)	Idle (W)	On (W)	Usage ³ (hrs./yr)			UEC (kWh/yr)		
					Standby	Idle	On	Standby	Idle	On
Cordless Phone	2	0.9	1.6	2.8	2,015	5,694	701	1.9	9.0	1.9
Answering Machine	1	n/a	2.3	3.0	n/a	8,640	120	n/a	19.4	0.4
Cell Phone Charger	4	0.3	2.2	3.7	7,446	175	436	1.9	0.4	1.6
Surge Protector / Power Strip	6	1.1	0.8	0.8	0	0	8,760	n/a	n/a	7.0

Table 97. Other household appliances – Electrical consumption (per unit)

	No. Units	Standby (W)	Idle (W)	On (W)	Usage ³ (hrs./yr)			UEC (kWh/yr)		
					Standby	Idle	On	Standby	Idle	On
Security System	1	2.7	n/a	5.0	3,770	n/a	4,990	10.2	n/a	24.9
Garage Door Opener	1	4.5	n/a	10.0	8,745	n/a	15	39.2	n/a	0.15
Timer (Irrigation)	1	2.8	2.84	2.8	8,480	180	100	23.3	.51	0.3
Ceiling Fans	4	40.0	n/a	87.0	5,548	n/a	3,212	222.0	n/a	279.4
Doorbell	1	2.0	n/a	6.3	8,750	n/a	10	17.9	n/a	0.06

Table 98. Hard wired - Electrical consumption (per unit)

	Total Energy Consumption (kW/yr)			
	Standby	Idle	Operating	MELs Total
Home Entertainment	298.9	135.8	733.8	1168.5
Home Office	132.8	38.6	657.5	828.9
Kitchen	58.1	57.3	178.1	293.4
Other Household Items	11.7	39.0	52.7	103.4
Hard Wired	978.6	0.51	1143.04	2122.1
MELs Total	1480.1	271.2	2765.1	4516.4
Percent of WHES	14.7%	2.7%	27.5%	44.3%

Table 99. Total estimated electrical consumption

	Min. (kWh/yr)	Mean (kWh/yr)	Max. (kWh/yr)
MELs Energy Consumption	2,850	4,516	6,182

Table 100. Potential range of MELs (kWh/yr)

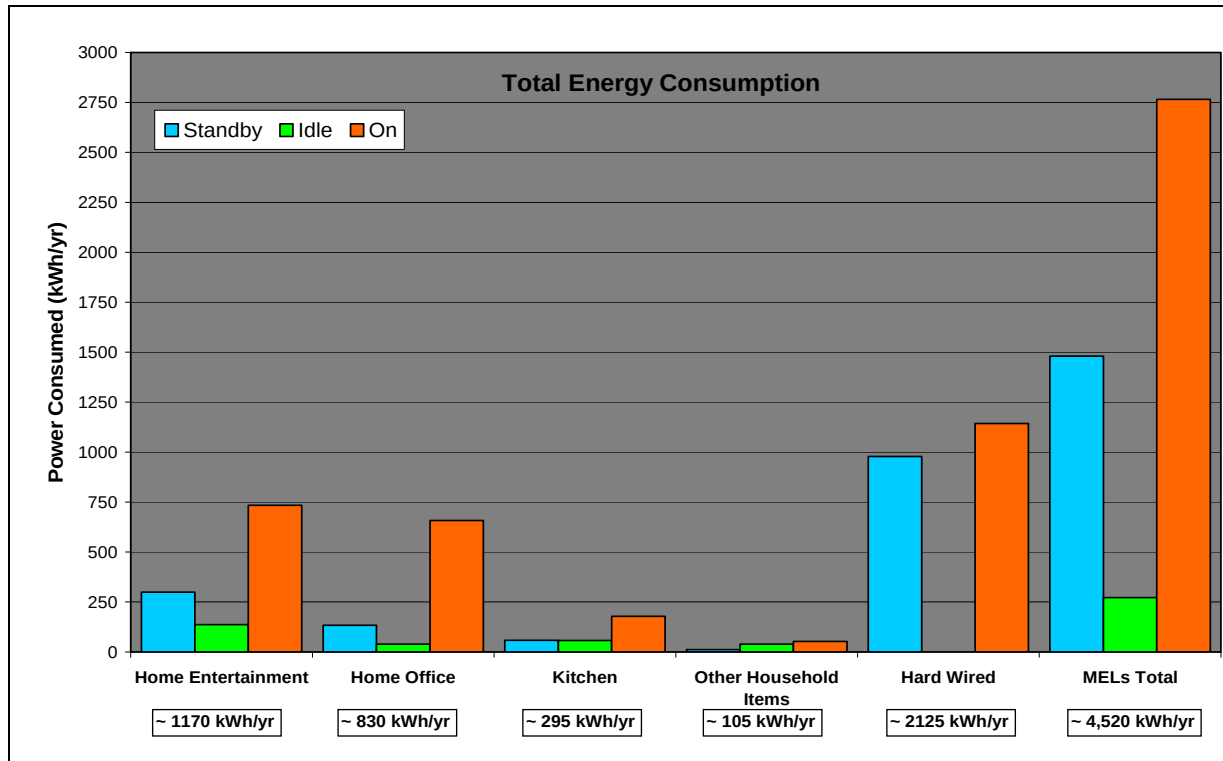


Figure 56. Total estimated MELs consumption

“Must Meet” Gate Criteria - Performance-Based Code Approval

The Verve system ten-channel controller is hardwired, and therefore requires the home to be inspected. However, since the central control panel actually reduces the number of connections and the amount of wire required to complete the electrical installation, it is considered easier to install compared to other HEMs. Through our interviews with local building officials and through Verve’s experience in other projects, building inspectors believe the system is revolutionary and find it is effortless to inspect compared to a standard HEMs installation.

“Should Meet” Gate Criteria - Prescriptive Code Based Approval

The Verve system has an UL rating, and meets all manufacturers’ health and safety requirements for use with electrical components. To date, BIRA has not experienced any problems with local building officials inspecting the Verve system, and neither has Verve in any of their installations.

“Should Meet” Gate Criteria - Cost Advantage

The system will be evaluated based on the total cost for the system, once the energy savings have been determined from using the Verve system. For now, the cost analysis has been conducted using the data from the baseline utility bills, where the savings from the Verve system was used as a variable, showing the return on investment (ROI) for different energy reduction percentages for each prototype.

Table 102 and Table 103 show the cost for the equipment that was installed in each home. The ROI was calculated assuming the Verve system would reduce MELs by 10% and by 85% of the calculated MELs usage from Table 100. The actual percentage is still unknown at this time, and will be defined more accurately next year.

According to Table 102 and Table 103, the cost of the Verve system ranges between \$2,980.00-\$5,285.00 (price dependent on design of home). The ROI has been calculated for each prototype depending on whether the Verve system reduces MELs by 10%, 50%, or 85%. If the Verve system were to reduce MELs by only 10%, the ROI is over 100 years, and we can conclude the system is not cost-effective at this level. If the Verve system were to reduce MELs by 50%, the ROI is roughly between 20-30 years, which is comparable to the duration of a mortgage loan. If MELs were considerably reduced by 85%, the system will pay for itself in about 10 - 20 years, therefore identifying the system as a cost effective system. (See Table 104 and Table 105)

	Amount (per kWh)	
	June, July August	Other Months
Customer Charge (per month)	\$4.00	
Tier 1 (first 200 kWh)	\$0.073254	
Tier 2 (next 500 kWh)	\$0.116918	\$0.100884
Tier 3 (additional kWh)	\$0.144404	\$0.103838

Table 101. PNM (New Mexico) utility rates

Equipment	Quantity	Cost per Unit (\$)	Total Cost (\$)
10-Channel Controller	3	\$700.00	\$2,100.00
Single Switch	12	\$95.00	\$1,140.00
Double Switch	11	\$95.00	\$1,045.00
Vacancy Sensor	4	\$250.00	\$1,000
Total Cost	\$5,285.00		

Table 102. Cost of Verve equipment for Albuquerque prototype

Equipment	Quantity	Cost per Unit (\$)	Total Cost (\$)
10-Channel Controller	2	\$700.00	\$1,400.00
Single Switch	6	\$95.00	\$570.00
Double Switch	8	\$95.00	\$760.00
Vacancy Sensor	1	\$250.00	\$250.00
Total Cost	\$2,980.00		

Table 103. Cost of Verve equipment for Farmington prototype

Milestone	Energy Consumed (kWh/yr)	Energy Reduction (kWh/yr)	Savings (\$/yr)	ROI (yrs.)
10% MELs Reduction	4,516	451.6	\$33.08	159.76
50% MELs Reduction	4,516	2258	\$165.41	31.95
85% MELs Reduction	4,516	3838.6	\$281.19	18.80

Table 104. ROI for Verve Living System in Albuquerque prototype

Milestone	Energy Consumed (kWh/yr)	Energy Reduction (kWh/yr)	Savings (\$/yr)	ROI (yrs.)
10% MELs Reduction	4,516	451.6	\$33.08	90.1
50% MELs Reduction	4,516	2258	\$165.41	18.0
85% MELs Reduction	4,516	3838.6	\$281.19	10.6

Table 105: ROI for Verve Living System in Farmington prototype

“Should Meet” Gate Criteria - Reliability Advantage

The Verve system has a lifetime warranty for both the controller and the switches, however due to their robust control system Verve representatives do not foresee any reliability issues.

“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment

The Verve system is readily available, and the manufacturer offers great support staff to train builders and electricians throughout the first install. Verve technical installation experts provide the preliminary electric schematics, then train builders and their electricians to generate their own schematics, program the controllers, and finally install the system per factory standards. The technical experts travel onsite to the installation location to maximize the training and answer any questions either party may have.

“Should Meet” Gate Criteria - Gaps Analysis

Through BIRA’s preliminary experience with the Verve system, the only perceived gap is the system’s limitation to new construction. The system can be used in retrofits, but due to the trunk and branch type installation, the system must ideally be pre-designed specific to each building layout, otherwise wall panels will need to be removed to successfully install the system.

A more thorough gaps analysis will be provided after the data collection period with the activated Verve system has been complete.

Conclusions

Home Energy Management systems are the technology that will reduce miscellaneous electric loads in the future. MELs are a significant consumer in residential homes, and their overall portion of end use is increasing as homes are engineered to be more efficient. BIRA divided MELs into more manageable segments including:

- Appliance Efficiency Regulations and Protocols
- Education and Ergonomics Research
- Automated and Whole House Controls
- Feedback Meters

Segmenting MELs into subcategories will help to develop customized strategies for mitigating their loads. For this period of research, BIRA selected Verve, an automated and whole house control system. BIRA chose the Verve system due to the diversity of the control system, the ease of its usage and installation, the low cost and the manufacturer’s commitment to the Building America program. This interim HEM study was beneficial in: quantifying the range of MELs that can be reduced; positively affecting the performance of more efficient homes; comparing more than one method to verify the obtained range of MELs; and establishing the baseline for each prototype that is monitored to measure the impact of the Verve system.

BIRA will continue to install and monitor prototype homes with the Verve system in 2011, and plans to verify energy savings, complete cost and gaps analysis for upcoming projects.

Ground Coupled Heat Pump (GeoX) Budget Period 3 (2010)

Snow Creek Cottages, an affordable housing project located adjacent to the city of Snow Creek, UT, consists of 13 energy-efficient buildings. The units will be heated using ground source heat pumps (GSHP) with ground heat coupling provided via U-tube boreholes. This Stage Gate 2 report documents the installation of the subsurface and above ground data acquisition systems, as well as modeling components of the study. The evaluation plans for completing a detailed evaluation of the performance of U-tube boreholes for heat recovery from an aquifer to the

heat pump, compared with ambient air coupling, a traditional gas furnace, and a passive thermosiphon are described

Key Results

All the field work required to evaluate the U-tube borehole performance has been completed and the GSHP installation to-date meets all design specifications. The data acquisition system is now operational and preliminary data are being verified for consistency and variability. Data will be collected for one calendar year, with a final evaluation report to be submitted in 2011. In addition to the energy data and modeling results, costs and construction schedule implications of using GSHP for heating are being analyzed. Data being gathered on the operation of the GSHP will allow for an accurate and calibrated evaluation of the heat pump energy use for comparison to installing and operating standard and high efficiency gas furnaces.

Gate Status

The GSHP remains at Stage Gate 1B status. The installation has met performance-based and prescriptive-based code approval. Detailed GSHP energy performance evaluations are in progress.

Conclusions

The U-tube boreholes and the horizontal piping to the houses were installed according to industry standards. The site geology created a higher than average installation cost. GSHP performance data from this installation are now being collected to provide both overall energy savings and cost data for “must meet” whole building benefit evaluations. Analyses will be completed once the buildings are occupied and the heating system has been functioning for a minimum of one year.

Project Overview

This Stage Gate 2 report documents the data acquisition system and describes the evaluation plans to complete the assessment of system performance of ground source heat pump system (GSHPs) relative to the Building America (BA) Stage Gate 1B criteria (see Appendix A of the evaluation report). This research will provide a detailed evaluation of the performance of U-tube boreholes for heat recovery from an aquifer to the heat pump, compared with ambient air coupling, a traditional gas furnace, and a passive thermosiphon.

To determine the schedule and cost impacts of installing GSHP systems, the overall installation cost of the GSHP systems was compared to a standard gas furnace, and the operational cost for each, will be identified. This requires a detailed analysis of the performance of the heat-pump/ground coupling systems, including measurements of the heat pump performance and transient energy transport in the soil. This report documents the installation of the subsurface

and above ground data acquisition systems, as well as modeling components of the study.

Snow Creek Cottages is an affordable housing project located adjacent to the city of Snow Creek, UT. It consists of thirteen energy-efficient buildings located at 2061 Park Avenue, Park City, UT 84068. This site is outside of the utility region that provides natural gas and the project will be serviced solely by electrical energy as its utility energy source. The units will be heated using GSHPs with ground heat coupling provided via U-tube boreholes. Two of the thirteen units will be monitored and evaluated, Fox A (#10) and Deer A (#11), where each prototype consists of the following unique features:

Test Home Details	
Fox A (#10) Unit Description	Deer A (#11) Unit Description
Two story, single family detached unit	Three story, single family detached units
2 bedrooms, 2 baths	3 bedrooms, 3 baths
Single car parking in garage	Single car parking in garage
26' x 30' footprint	26' x 30' footprint
Approximately 1,560 square feet of living and utility space	Approximately 2,340 square feet of living and utility space
3 U-Tube Boreholes to 100' + Thermosiphon Heat Pipe	4 U-Tube Boreholes to 100'

Table 106. Snow Creek Cottages unit description details (Fox and Deer Models)

To reduce the overall energy use by 50%, several energy saving/producing building technologies have been employed. These include:

- Structurally Insulated Panels (SIPs) exterior walls from foundation to roof bearing walls
- SIPs roof structure
- Photovoltaic (PV) cells
- GSHP Heating
- Solar hot water systems
- Clearstory roof windows
- Heat Recovery Ventilation (HRV)

Ground Source Heat Pump

A GSHP (also referred to as geexchange or ground-coupled heat pump) is a heating system that uses heat pumps to transfer energy between the conditioned space and the earth. Two flexible tubes, connected to a U-shape fitting, are inserted into vertically drilled boreholes (U-Tube borehole). The loop of tubing, typically filled with antifreeze mixture, is then connected in series to a standard fluid pump and a heat pump.

GSHPs utilize the fact that the ground can be treated as a reservoir that remains a relatively

constant temperature. GSHP systems use the subsurface soils as a heat sink during the summer when the ambient air temperature exceeds the ground temperature. During the winter when the ambient air temperature is lower than the ground temperature, GSHP systems use the ground as a heat source.

The antifreeze fluid exchanges thermal energy with the soil and groundwater near the borehole. The energy expenses are the work of pumping the fluid and the work input to the heat pump. For residential space heating, the energy transferred from the ground, plus the energy powering the pump and heat pump, replaces the energy from natural gas burned in a conventional gas fired furnace. If the antifreeze liquid returns from the U-tube borehole field, with a temperature near that of the groundwater, the overall efficiency of the heat pump will be maximized.

The test site homes are near Snow Creek, UT where the groundwater is relatively shallow (several feet depending on season). The groundwater gradient is high and the subsurface geology consists of a mixture of clay and gravel materials. The U-tube boreholes are grouted with a bentonite/silica sand mixture to provide sufficient heat transfer from the U-tubes to the surrounding soils and to prevent vertical flow of water along the U-tubes in the borehole. The supposed high convective groundwater fluxes at the site are expected to dissipate the cooling load placed through the U-tube boreholes. It is not known how these features factored into the final design.

Project Status

The installation of the GSHP boreholes, U-tubes, and horizontal tubing, was completed by Palace Geothermal. Mechanical contractors have connected the heat pumps to the ground coupled tubing inside the buildings. The research team from the University of Utah (UofU) assisted in the GSHP commissioning including flow rate measurements, pressure balancing, and inlet/outlet temperature measurements at the methanol inlet and outlet ports of the heat pump. A malfunction was identified and additional water/glycol fluid was added to the ground loops to remedy the problem.

The data acquisition system is now operational and preliminary data are being verified for consistency and variability. Data will be collected for one calendar year, with a final evaluation report to be submitted in 2011. In addition to the energy data and modeling results, costs and construction schedule implications of using GSHP for heating are being analyzed. Data being gathered on the operation of the GSHP will allow for an accurate and calibrated evaluation of the heat pump energy use for comparison to installing and operating standard and high efficiency gas furnaces.

“Must Meet” Gate Criteria - Source Energy Savings

Whole house source energy savings and whole building performance benefits will be calculated

based on BA performance analysis procedures and energy performance measurements. Specifically, the field tests, construction monitoring and energy simulations will address the following research questions:

- a. Can GSHP be used to reduce source energy consumption, decrease the carbon footprint, and lower the cost of heating residences compared to a low-efficiency and a 90%+ AFUE gas furnace? This question will be answered by measuring key parameters such as temperatures, power consumption and fluid flow rates to quantify actual energy uses. The performance will be compared to the performance of conventional HVAC systems based on example component specifications. (See evaluation report, Appendix B).
- b. Can the heat transfer coupling to the subsurface be improved in terms of cost effectiveness and performance if the U-tube boreholes are replaced with thermosiphon heat pipes? A U-tube borehole will be instrumented with temperature measuring devices to obtain detailed information on the heat transfer from the ground to the U-tube. A thermosiphon heat pipe, fitted with a condensing heat exchanger on its top to heat the methanol, has been installed near the instrumented U-tube boreholes and monitored to provide a comparison between conventional and emerging technologies.
- c. What modeling detail is necessary to define the dominant heat transfer interactions that control the overall heat transfer from U-tube boreholes and thermosiphon heat pipes? Our working hypothesis is that thermal interactions between the inlet and outlet sections of the tubing in the borehole limits the overall heat transfer effectiveness in installations relying on a high groundwater flux for energy dissipation. Detailed temperature data, combined with analytical and numerical modeling, will quantify those dominant interactions for both U-tube and thermosiphon heat transfer. (A full description of the available models and plan to expand on those models is presented in the evaluation report's Appendix C).

The evaluations will be based on the following assumptions:

- a. Ground source heat pump energy supply and cost are measured in relation to standard or high efficiency gas powered furnaces.
- b. The heating system in the residences is a condensing heat exchanger placed in the ducting of a central heating system. The condenser replaces a conventional furnace.
- c. Since the heat pump will be located in the conditioned space, the energy transfer to the house is the sum of the thermal energy from the ground to the methanol (measured at the inlet and outlet tubes inside the space), the electrical energy into the heat pump, and the electrical energy into the methanol pump.

Data from the temperatures and flow rates of the methanol to the heat pump, and the power to the heat pump, will be used to calculate the effective coefficient of performance (COP) of the heat pump system on nearly a continuous basis and compared to a gas furnace (See evaluation plan, Appendix B). The COP will be compared to the COP from the design study/documents and any discrepancies will be explained. The evaluation will consist of two steps:

- a. Evaluate the cost and performance variances of U-tube boreholes and thermosiphon heat pipes.
- b. Compare the measured performance and temperatures to the U-tube and heat pump models, including the interaction of the piping with the ground and the pipe-pipe interaction in the U-tube case.

“Must Meet” Gate Criteria - Performance-Based Code Approval

The critical design details have been defined and construction practices, training, quality assurance, and quality control practices required to successfully implement new systems with production builders and contractors have been observed.

Palace Geothermal appeared to be practicing industry standards, complying with all building codes and passing all inspections. The U-tube boreholes were carefully grouted and grout samples were collected and sent for testing as specified in the construction detail. Due to the difficult geology of the site, the drilling equipment was frequently undergoing repair, extending the drilling time beyond that expected. There is no evidence that the installation of the boreholes and horizontal trenching had a negative effect on the overall project.

“Should Meet” Gate Criteria - Prescriptive-Based Code Approval

Observations of the work the mechanical contractor performed while installing the heat pump system indicated that the installations met prescriptive safety, health and building code requirements for use in new construction homes.

Observations made during the installation of the U-tube boreholes and the horizontal trenching allowed this evaluation to identify whether the GSHP system was installed according to specifications. These observations included builder feedback in a practical setting. Through interviews, it was learned that the builder has a positive view of the design with respect to its feasibility, viability, and practicality. Personal interviews were performed with the following groups:

- Architect / Design teams
- Suppliers / Equipment vendors
- Builder
- Job Superintendent
- Installing contractor and individual crew members
- Coordinating trades, i.e. plumbers
- Building inspector
- Homeowner
- Post-installation service technician

Through post-construction evaluation, the conducted interviews included the following

questions:

- What problems, if any, were encountered during the installation?
- What solutions might exist for problems encountered throughout project implementation?
- What measures could be taken to streamline the implementation process in future installations?
- Were there problems with coordination between contractors?
- What criteria does the building inspector expect to be met?
- Is there homeowner satisfaction with the performance of the GSHP?

“Should Meet” Gate Criteria - Cost Advantage

It is expected that GSHPs provide strong potential for cost benefits relative to current systems within a whole building context. To evaluate this expectation, the incremental annual cost of GSHPs, when financed as part of a 30 year mortgage at 7% interest, will be used as the basis for cost evaluations. Those yearly “mortgage” costs should equate to less than or equal to the annual reduction in utility bill costs relative to the BA Benchmark. This basis will identify whether the initial capital investment in a GSHP system is worth the potential savings in operating costs.

To make this assessment, the costs of installing the GSHP system will be tracked and the total cost will be compared to “bids” for typical heating systems provided by partners. The plan will incorporate the following:

- Detailed bidding cost estimate from the builder, and all affected subcontractors, for ordering, shipping and handling, installation preparation, markup cost percentage, and actual installation and system startup.
- Detailed cost estimate from the installing and servicing contractor (or from the manufacturer's designated service organization) for warranty, service and replacement costs.
- Cost projections with actual expenditures during and after system implementation. Identify, note and quantify any additional cost items that were not originally anticipated.
- Quotes for the purchase and installation of standard efficiency and high efficiency furnaces.

The Project Manager (PM), Park City, is providing data regarding actual costs of the project. This data will be compared against the monitoring data for energy consumption to determine the ROI for the GSHP system. This comparison will also identify the energy benefit contributed by the GSHP to determine its contribution in reaching or exceeding zero-energy.

The final report will document all expenditures and projected future expenditures. Given the

experience of both Palace Geothermal and Colvin Engineering, and the number of U-tube boreholes being installed on the site, the actual design and installation expenditures at the Snow Creek site are likely to be near industry averages for the region.

“Should Meet” Gate Criteria - Reliability Advantage

The reliability, durability, ease of operation, and net added value requirements of GSHPs for use in new homes will be documented once the buildings are occupied and the heating systems have been functioning for a minimum of one year. Issues such as excessive soil cooling over the winter heating season, due to insufficient groundwater flow past the U-tube boreholes, will be explored in further detail.

“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment

Between the mechanical contractors, Colvin Associates, the heat pump manufacturer and Palace Geothermal, sufficient logistical support (warranty, supply, installation, and maintenance support) will likely exist for prototype homes.

“Should Meet” Gate Criteria - Gaps Analysis

GSHP gaps analyses, lessons learned, and evaluation of major technical and market barriers to achieving the targeted performance level are ongoing. Currently, it is believed that there exists sufficient duplicity in the subsurface temperature measure system to accurately assess the thermal performance of the ground coupling. Incomplete access to all cost data may be a potential gap. Preliminary research indicates that the initial installation cost and construction site disruption are market barriers to GSHP installations.

High R-Wall (SIPs) - Status Report Budget Period 3 (2010)

Snow Creek Cottages, an affordable housing project located adjacent to the city of Snow Creek, UT, consists of 13 energy-efficient buildings. To reduce the overall energy use, several energy saving/producing building technologies were employed including structurally insulated panels (SIPs) exterior walls from foundation to roof bearing. This Stage Gate 2 report documents the performance to-date of SIPs in two house configurations (Deer Unit, #11 and Fox Unit #10) relative to the Building America Must Meet and Should Meet Criteria (see Appendix A of the status report).

Key Results

Post construction interviews with key project players confirm the coordination challenges illustrating the impact of early design, and submittal integration led to schedule delays during construction.

The model showed a cost of \$109.76/sq. ft. without renewable technology, an additional increase of approximately \$5.60/sq. ft. without renewable technology. For detailed cost information, please refer to systems report, Appendix E.

Gate Status

The SIPs system remains at Stage Gate 1B. The system cost and preliminary modeling has been performed. Performance still needs to be evaluated since construction of the homes was completed in late summer 2010 and data has been received for no more than a few months.

Conclusions

Delays in the schedule were experienced due to difficulties with SIPs submittals and code review. Initial SIPs installation began at a slower rate than standard installation practice. As assembly techniques improved, the framing contractor moved more than if the standard framing construction techniques were implemented.

The SIPs thermocouple infrastructure is now in place and the units are complete with residents occupying each dwelling. Data has been gathered for the past two months and will be continually monitored throughout 2011 to determine the return on investment (ROI) and SIPs' contribution to whole house energy goals.

Introduction

Snow Creek Cottages, an affordable housing project located adjacent to the city of Snow Creek, UT, consists of 13 energy-efficient buildings. The Snow Creek Community is located at 2061 Park Avenue, Park City, UT 84068, outside of the utility region that provides natural gas, where the project will be serviced solely by electrical energy as its energy source.

To reduce the overall energy use, several energy saving/producing building technologies have been employed. These include SIPs exterior walls from foundation to roof bearing, SIPs roof structure, photovoltaic (PV) cells, ground coupled heat pump heating, solar hot water (SHW) systems, clearstory roof windows, and heat recovery ventilation (HRV). This report describes the evaluation of structurally insulated panels (SIPs) walls and roof system relative to the Building America Stage Gate 1B "Must Meet" and "Should Meet" Criteria (see Appendix A of the status report).

Structurally Insulated Panels (SIPs)

SIPs are engineered laminated panels for structure and exterior thermal envelope applications. SIPs are fabricated with solid polystyrene or polyurethane foam cores and structural wood panel sheathing on each side, typically with oriented strand board. The rigid OSB sheathing, bonded to the foam, provides structural support. Closed-cell foam is an excellent insulator and

SIPs walls far exceed traditional batt or cellulose cavity insulation values for similar wall and ceiling insulation thicknesses. They also offer an air-tight envelope, decreasing cold air infiltration.

Thermocouples have been installed on both inside and outside surfaces of the SIP panels at four different locations in both houses (refer to report, Addendum D).

Project/Builder Overview

Park City is the developer of the 13 unit affordable housing development in Snow Creek, UT. Park City has a Sustainability Team that connects the missions of various departments in order to achieve a balance between meeting the goals of economic development, community development and environmental impact reduction. A website was created which allows its citizens to download reports related to carbon emissions as a function of city operations. Residents of the city have access to the interactive tool provided on the website to calculate their own carbon footprint including energy consumption. Park City is committed to affordability and environmental sustainability in its operations and future developments. The Snow Creek development is in line with the mission of the city to reduce energy consumption in its operations and facilities.

Elliott WorkGroup is the architect responsible for this project and R&O Construction is the contractor. Roger Durst, of Elliott WorkGroup, is National Green Building Standard Certified and has implemented passive and active design strategies in the design of the houses. The architect did not, however, have experience in SIPs construction or ground coupled heat pump (GCHP) technologies. R&O Construction is primarily a commercial builder and was hired because of the volume of building that was being bid out. R&O did not have any experience to date with energy efficient building techniques, including SIPs construction and GCHP.

The SIPs supplier was Premier Building Systems located in Montana and the installer was AKI Framing. Premier is the largest polystyrene SIPs manufacturer in the U.S. with nine plants located in nine different states. AKI Framing did not have experience with SIPs construction. For this project, AKI has hired the installer of SIPs from the Gold Medallion Home in Daybreak, Utah, a Building America Home that was monitored previously. The SIPs panels have been installed by AKI and instrumented with. The University of Utah (UofU) team worked with Park City, R&O, Elliott WorkGroup, Premier, and AKI to gather information on delays, costs, schedules, and performance specifications.

“Must Meet” Gate Criteria - Source Energy Savings and Whole Building Benefits

Preliminary modeling has been performed for the two prototype houses in various modeling platforms including EQuest/DOE2 and E+/DOE 2 Blast in preparation for calibration to monitoring data in 2011.

Energy data provided by sensors installed in the Snow Creek Prototype units, energy simulation models against the BA benchmark, and collection of whole building performance data will provide targeted source energy savings estimates based on BA performance analysis procedures and energy performance measurements. This will be accomplished through calculations based on the following assumptions:

- a. The evaluations will be relative to a BA Benchmark house of identical size and configuration. The benchmark house will be modeled to provide a baseline for comparison to monitoring data from the case houses. The Benchmark is generally consistent with mid-1990s standard practice, as reflected in the Home Energy Rating System (HERS) Technical Guidelines (RESNET 2002). A reference guide is provided by the DOE Building America Program (BAP) that aids in defining the parameters of the BA Benchmark home for a given climate and design configuration.
- b. Space heating, water heating, and standard electrical energy needs (refrigerator, lights, electronic equipment) are the primary energy demands to be evaluated. The temperatures in Park City during most of the year are cold, where there are only a few weeks where cooling may be required. During those times, it is assumed that the homes will utilize passive natural ventilation systems to remain cool and not rely on any mechanical active cooling.
- c. The options and possibilities for various types and combinations of finishes are unlimited. In order to remain consistent in the comparison of the benchmark house to the houses at Snow Creek, the same finishes will be modeled in the simulation as occur at the Snow Creek Houses respectively.

Two methods will be used to better understand the energy use in the two prototypes. The first method is to conduct an overall energy balance for each unit. The second method is to model each unit and compare the model results with models of houses with the same configurations, but with conventional construction and energy systems (as controls). The conventional comparison will use the BIRA Benchmark House as the baseline. The overall energy balance will include data on the SIPs R-values, temperatures on exterior and interior surface of SIPs on each floor, and temperatures on interior and exterior of roof panels for both north and south slopes.

All temperature and electrical use data will be collected automatically using a data logger that can be accessed remotely via a dial-up modem. Units 10 and 11 have been fully fitted with thermocouple wires that include 12 points on each unit. Much effort was taken to route wires through precut chases in the SIPs exterior walls; however, the holes were not lined up from floor-to-floor and required drilling and fishing continually. See Addendum D, of the report, for points list and "as built" locations of sensors on the exterior and interior surfaces of the panels and other locations within the parameters of the building proper (excluding geothermal sensors).

In order to verify the performance of the prototype houses, R-values of the High Walls (SIPs panels) and the data from the performance monitoring of the two houses will be compared to

performance of simulated models of the BIRA Benchmark. The spatial data (3-D), from the architect as a Revit file or developed new in a 3D software platform, will be transferred to EnergyPlus software for energy simulation for Park City's climate scenario. Other software tools including BEopt, will be used as necessary in order capture as accurate an analysis of the benchmark house as possible. It is assumed that the orientation, location, and outdoor design conditions will be similar.

Preliminary modeling has occurred of the "as-built" condition of the units in DOE 2 and Energy Plus. However, these models remain to be calibrated with actual data from the monitoring process. Once the models are calibrated with actual energy data, the BA Benchmark house will be modeled to establish a baseline for comparative review with actual performance of the prototype houses. This task is scheduled for 2011. See report, Addendum H, for preliminary energy modeling results.

As part of the design process, Park City hired a consultant, Wasatch Engineering, to perform energy evaluations and produce a HERS ratings in connection with the National Green Building Standard guidelines. The HERS rating provides an additional baseline for energy performance which will be compared to data collected through monitoring during 2011. See systems report, Addendum G for the HERs report.

"Must Meet" Gate Criteria - Performance-Based Code Approval

Several issues were identified that impacted prescriptive or performance safety, health and building code requirements for new homes.

- a. Park City was unfamiliar with SIPs construction and, therefore, followed the code standard for Seismic Zone D, which was congruent with Premier Building System's submittals. BHB Structural Engineers wanted a slightly different system that consisted of additional hold downs and provisions for additional lumber and structure on the interior of the SIPs panels. These specifications were not standard and therefore led to delays in the submittal and permitting process.
- b. Foundations were only poured once submittal and permitting process was reviewed and accepted by all parties. If the panels had been designed and submittals had occurred during site preparation and excavation, there would not have been the month delay due to design, submission and code review miscommunications.
- c. AKI Framing came in late because R&O Construction could not find a framing contractor with SIPs experience. Contractors with experience in the installation of SIPs in Utah are still relatively few. The architect reports that the gap between supply and install is great from a code and submittal perspective.

"Should Meet" Gate Criteria - Prescriptive-Based Code Approval

In order to verify that SIPs will meet prescriptive safety, health and building code requirements

for use in new homes, critical design details, construction practices, training, quality assurance, and quality control practices are being documented. To accomplish this task, equipment is routinely inspected to determine whether each energy saving technology device is being installed according to design specifications. In addition, personal interviews have been conducted with the following individuals concerning the SIPs installation. These interviews are documented in the system report's Addendum F.

- Rob Dayton - R&O Construction (General Contractor)
- Roger Durst and Juliana Klein - Elliott Workgroup (Architect)
- Dave Gustafson - Park City (Owner)
- Tom Ryles - Premier (SIPs Supplier)
- Josh Singleton - Chipman Plumbing (Plumber)
- James Barnard - BHB Engineering (Structural Engineer)
- Snow Creek Residents (at Resident Meeting in August 2010)
- Brian Hicks - BNA Consulting (Electrical Engineer)

The following has been determined:

- a. Gaps exist between the sill plate and the concrete stem wall foundation. This can be attributed to the lack of quality control in the foundation pour. AKI, the install contractor for the SIPs panels, did not know how to mitigate this discrepancy and was prepared to grind the concrete. Shims have been used to make up the gap structurally, but foam was not used to mitigate air infiltration. It is suggested that mastic be placed between the sill plate and concrete as well as foam inserts to remove the thermal transfer and potential air infiltration gap. Air infiltration gaps are also gaping in many locations of fenestration (i.e. window and door openings). It is unclear whether those were sealed later.
- b. The plan for construction was inefficient. The contractor requested one crew per house. However, this led to great inefficiencies in the first two weeks of production until the crews became knowledgeable of the system. It is estimated that house 14 and 13 took two weeks to install as opposed to the anticipated five days to install. Roof panels were the most difficult due to geometrical challenges.

"Should Meet" Gate Criteria - Cost Advantage

It is expected that the use of SIPs has a strong potential for cost benefits relative to current systems. The incremental annual cost of energy improvements, when financed as part of a 30-year mortgage, will be compared to the annual reduction in utility bill costs relative to the BA Benchmark. It is expected that the incremental annual cost of energy improvements will be less than or equal to a reduction in energy bills.

Cost data was provided by Elliott Workgroup and Park City. Costs were then analyzed accordingly excluding site, infrastructure costs:

Residential Unit Construction Cost	\$115.39/sq. ft.
Renewable Technology Cost	\$16.49/sq. ft.
Total per Unit Cost	\$131.88/sq. ft.

Table 107. Cost data provided by Elliott Workgroup and Park City

This cost analysis was compared against a cost simulation based on R.S. Means 2009 data for BA Benchmark specifications. Gaps in this data include no existing information in data tables regarding renewable technologies. A “custom class” was selected because an architect designed the houses. A regional multiplier was assigned of 0.92 based on inquiry to local and regional builders of the cost comparisons of construction in Park City versus Salt Lake City, as well as on a chosen comparable location factor of Boulder, Colorado, a comparable resort town. This cost simulation resulted in a \$109.79/sq. ft. cost excluding renewable technology as compared to \$115.39/sq. ft. cost for construction at Snow Creek excluding renewable technologies. This reflects a \$5.60/sq. ft. difference. Given the added benefits of air tightness and increased R-value of SIPs construction, the High-R Wall construction compares fair with 2x6 standard construction.

A detailed analysis of the actual versus simulated cost correlation study can be read in systems report Addendum E. This data will be used in 2011 to compare to overall energy reductions for lifecycle cost and ROI evaluation of the SIPs enclosure. Each energy-saving technology has other impacts besides energy reductions, e.g., construction schedule modifications. The section titled ‘Quality Control Integration’ will report on the schedule impact of SIPs construction.

“Should Meet” Gate Criteria - Reliability Advantage

It is expected that SIPs will meet reliability, durability, ease of operation, and net added value requirements for use in new homes. SIPs should require no maintenance and are passive with respect to operation. One advantage of SIPs is that picture hanging is more convenient in e

“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment

Premier’s SIPs are available for continuing support and Park City has committed to cooperating with the research team to relay any issues identified in these homes. Thus, the SIPs installation has sufficient logistical support (warranty, supply, installation, and maintenance support) to be used in prototype homes.

“Should Meet” Gate Criteria - Gaps Analysis

One potential gap in cost and scheduling information has been identified. As issues regarding cost over runs and budget are frequently discussed in the weekly site meetings, the University team has been asked to not attend. Meeting notes and minutes are being collected, but there exists some uncertainty about what information might be missed by not attending the

meetings. Hopefully, this change will not affect the evaluation of major technical and market barriers to achieving the targeted performance level.

Interviews were conducted to gather information regarding the design and construction opportunities and challenges associated with SIPs construction. Interviews occurred after construction had been complete, providing a large time interval between initial construction and completion. Discrepancies in interviewee information revealed that this time difference has left project partners forgetful of information. These discrepancies were verified with respondents through follow up emails and phone calls.

“Should Meet” Gate Criteria – Quality Control Integration

Health, safety, durability, comfort, and energy related QA, QC, training, and commissioning requirements are being monitored. The data obtained will be integrated within construction documents, contracts and BA team scopes of work (SOW).

To evaluate construction methodology and to identify problems that can be documented and analyzed to learn from for future projects, Tuesday meetings in Park City have been attended. Notes were taken and photos collected for catalog in an archive available for later reference during analysis.

Attendance at weekly meetings occurred up through the middle of October 2009 when the research team was asked to not attend. The reasoning for the request was that in our presence, the contractor and architects were not able to talk as freely or candidly concerning budgetary concerns with the owner. Although the research team has not been able to attend weekly construction meetings, weekly site visits continue to occur with a walk around the site accompanied by the contractor and architect. Construction documentation has been thoroughly carried out to determine the challenges of the energy saving systems as compared with traditional construction.

Construction was stalled initially due to issues with de-watering the site and the submittal process surrounding the SIPs for a total of two months. Accordingly, the completion date has been moved back to May 2010 in order to avoid some winter months. The houses were completed in July of 2010.

The SIPs design, engineering, submittal, and installation difficulties contributed to schedule delays on the site of one month. The SIPs panels have been promising and problematic due to the following issues:

- DESIGN:
 - a. Houses were designed to maximize interior volume and minimize exterior surface area. The houses are 2 - 3 stories for heating efficiency.
 - b. Houses initially designed to incorporate stick frame with batt or foam insulation, but the bid for SIPs came in competitively and were attractive to the design team

- and owner because they were promoted as durable, prefabricated, recycled material content, which decreased labor on site.
- c. SIPs walls are 6.5" and roof is 12.25", with a 5.5" and 11.25" polystyrene core respectively.
 - d. Because it was not originally designed for SIPs construction, the house does not adopt efficiencies of SIPs module, and is over structured, meaning, much lumber exists within the SIPs envelope adding to thermal bridging problems.
 - e. Coordination between architect, engineer and the SIPs manufacturer is non-existent during design, leading to coordination problems throughout the design to install process.
- SUBMITTALS:
 - a. SIPs panels were designed for Seismic D Zone. Premier produced Seismic A, B & C, but not D. Also, the low bidder was not accustomed to doing larger residential or commercial work.
 - b. Submittals were not detailed enough for architect and structural engineers thus leaving out locations of post and beam embeds in walls in drawings. No connections to foundation or transitions at fenestrations. Specification submissions also were generic and not specific to the project.
 - c. BHB intended for a different design than Premier could accommodate to bring design up to D zone rating including location of hold downs. Submittal process back-and-forth was inefficient and fraught with error and argument.
 - d. The majority of the problem is in the lack of knowledge of the system from the architect and engineers perspective therefore demanding a higher level of shop submittals. The supplier was accustomed to one-off houses and not working directly with architects and engineers and, therefore, had difficulty delivering on their requests for detailed engineering information in submittals regarding the panels.

In addition, personal interviews have been conducted with the following individuals concerning SIPs quality control installation and can be read in detail in Addendum F in the final report.

- Rob Dayton - R&O Construction (General Contractor)
- Roger Durst and Juliana Klein - Elliott Workgroup (Architect)
- Dave Gustafson - Park City (Owner)
- Tom Ryles - Premier (SIPs Supplier)
- Josh Singleton - Chipman Plumbing (Plumber)
- James Barnard - BHB Engineering (Structural Engineer)
- Snow Creek Residents (at Resident Meeting in August 2010)
- Brian Hicks - BNA Consulting (Electrical Engineer)

The following additional information was discovered in 2010 through these interviews to augment the conclusion drawn in 2009. These are organized by trade:

- Rob Dayton – R&O Construction (General Contractor): Primary concerns of the General Contractor are cost and schedule.
 - The general contractor, architect, owner, electrical engineer and plumber's first experience with SIPs design and construction. Coordination was lacking in early stages of project development that affected construction site coordination. This affected change order costs and schedule delays during project delivery. On-site framing is estimated at 25% faster by General Contractor standards.
 - Design and engineering of SIPs was not completed until well into construction. Therefore, the initial cost of SIPs was not firm affecting overall budget of the project.
 - Shop drawing phase was not completed before SIPs were manufactured due to schedule constraints. Errors in chase locations and spline joints were mitigated on the construction site leading to decrease in quality of assembly, air infiltration rate increase, and change orders due to schedule increase.
 - Construction of SIPs was trial and error by onsite framer for the first two units. Schedule was expedited thereafter.
 - Building inspector was unfamiliar with SIP construction and onsite inspections were drawn out due to this fact.
 - Difficulty coordinating location of spline or 2x support in panel at roof and wall locations of PV and solar thermal technology.
 - Delays were in poor design and planning coordination, not in the design itself or the product of SIPs and other technologies.
 - With new technology including SIPs, a design build contract is preferred by the General Contractor
- Roger Durst and Juliana Klein - Elliott Workgroup (Architect): Primary concerns of the Architect are client service and design product.
- Dave Gustafson - Park City (Owner): Primary concerns over cost, schedule and final product performance.
 - The major delays in SIPs were attributed to lack of code capacity for advanced technologies including SIPs leaving the building department not engaged in process early on. Onsite framers and the SIPs manufacturer had virtually no coordination. The learning curve was very steep on the first couple of units.
 - Building department required engineering from both the SIPs manufacturer and the structural engineer. Where one responsibility began and another stopped was unclear. Therefore, there was work duplication and gaps.
 - Project would have been more efficient delivered under a design build contract.
- Tom Ryles – Premier (SIP manufacturer): Primary concerns of the SIPs product delivery.
 - Was involved after design development phase leading to a lack of alignment of design with product.
 - The submittal process included 5 plus parties making decisions regarding SIPs difficult to implement in a timely manner.
 - Submittal included five months of communications, whereas traditionally Premier

experiences a one to one-and-a-half month submittal phase.

- o Lack of coordination between structural engineer and engineer of manufacturer. Onsite framer declined support onsite for SIPs and basic assembly instructions.
- o Preferred integration for Premier includes: coordinate directly with Elliott and Park City (architect and client) beginning early at schematic design phase; three phases of integration:
 1. Material efficiency use in design phases;
 2. Detailing for energy efficiency;
 3. Installation support for proper construction and efficiency of construction.
- Josh Singleton – Chipman Plumbing (Plumber)
 - o Challenges with SIPs included thermal panel connections. This led to a unistrut bracketing system developed by the plumber for panel installation to distribute the load of the solar thermal across the SIPs panel. 2X spline support were provided at the roof, but the thermal panels had to be installed in slightly a different location for optimized performance.
- James Barnard – BHB Engineering (Structural Engineer)
 - o Coordination difficulty with Premier engineers:
 - Snow loads not available on manufacturer span ratings requiring unique engineering on the roof panel splines. This was performed collaboratively between BHB and Premier Engineers.
 - Load generation was led by BHB and sizing was led by Premier. Lack of communication primarily occurred at hold down locations due to seismic rating of region and shear wall location changes late in design development of location of fenestration. The manufacturer did not supply spline locations on the roof and other calculations needed by code officials for review.
 - Difficulties would have been mitigated under an integrated contract that parties get involved early and SIPs manufacturer is selected on performance, not cost.
- Brian Hicks – BNA Consulting (Electrical Engineer)
 - o SIP considerations included: reduced plenum space for routing electrical and mechanical cause unsightly protrusions into the finished space; canned lights had to be carefully coordinated with architect for location, lumens, heat loads and aesthetics.

Solar Thermal Budget Period 3 (2010)

The purpose of this report is to summarize the lessons learned over the past three years' solar thermal experience in the Northern Marine Climate. The results of four case studies are presented. Monitoring of these solar thermal systems, as well as "lessons learned", is presented. Systems comparisons to a 30 year old solar thermal domestic hot water (DHW) "closed loop" system installed by Washington State University (WSU) are also included.

Key Results

In spite of over 30 years of solar domestic hot water (SDHW) system installations, questions remain today regarding the energy savings and first costs associated with a number of unresolved issues related to Marine Climate design.

Gate Status

Despite the variability of system designs and the inconsistency in installation practices, SDHW systems achieve Stage Gate 1B criteria (Appendix A of the final report). Systems that serve a higher annual hot water use save more energy than lower annual hot water use systems. The return on investment (ROI) is higher in households with larger families and/or number of bedrooms.

Conclusion

Issues related to installation and maintenance of SDHW systems remain due to the variability in level of experience. Some code related issues remain unresolved which is directly related to product variability and market maturity.

Introduction

This report outlines the lessons learned over the past three years resulting from working with Oregon and Washington solar domestic hot water (SDHW) installers who installed systems for builders of Building America prototype home research projects. Project included Shirey Contracting, the Cohen Residence and Martha Rose Construction. These WSU/BIRA case studies and the BIRA Experts' Meeting in 2009 (see final report Appendix B) provide lessons learned, findings and issues for further investigation.

Market Background

Since the late 1970s, solar thermal collectors have been utilized to convert the sun's radiation to heat for residential domestic hot water (DHW) in the Marine Climate states of Washington and Oregon. While a number of these 1970-80s vintage systems continue to operate reliably today, many systems have been removed as a result of poor installations, maintenance problems, or simply a lack of interest or understanding by new homeowners. Attempts to design solar thermal systems including both DHW and hydronic space heating remain questionable in the Marine Climate where very little solar radiation is collected during much of the heating season. Active solar thermal systems have had a history of poor design, as well as being too complicated to install, commission, operate and maintain. As a result, many veteran installers install SDHW without space heating systems in the Marine Climate that provided a greater cost benefit; they lend themselves to system standardization and less custom "Rube

Goldberg designs” that were very common in the late 1970s. Active solar hot water systems installed in the late 1980s cost \$2,000. By the 1990s the price had doubled to roughly \$4,000.

Current Market

Today, typical two-panel 64 square-foot drain-back or antifreeze, one-tank systems are installed for roughly \$7,500 in simple new construction. The cost for more complex existing home retrofits, typical two-tank systems, is roughly \$8,800 to \$10,000 for systems involving government procurement. Some have estimated a cost savings on retrofit projects of as much as \$500-\$1000 for installation on “solar ready” homes when mounting hardware and insulated piping chases have already been pre-installed by the builder and included in the home mortgage. These savings result from less complex installation. Insulated piping runs are estimated to be roughly \$4.00 per linear foot from panels to the solar storage tank. Systems installed on well-designed “solar ready” homes add value to the home. Solar-ready designs may help facilitate the installation of more drain-back systems, where all piping must slope back to the drain-back tank location. The concept of solar-ready has not gained significant market acceptance in the building community— BIRA continues to encourage builders to consider it in the design of a new home in cases where solar access exists, and the local market supports incentives that reduce SDHW costs.

Oregon has a fairly mature solar thermal residential market as a result of years of state-supported tax credits, a strong grassroots solar industry and clear installer qualifications and installation requirements. Roughly, 20,000 Oregon-approved SDHW systems have been installed since the 1980s by certified contractors. The Oregon Office of Energy has very useful consumer information regarding the purchase of SDHW and other renewable systems. As of October 2010, Oregon has 122 approved solar contractors, of which 17 companies install solar thermal and 43 companies indicate they install both photovoltaic (PV) and solar thermal. In 2009, 291 state approved SDHW systems were installed in Oregon. ([refer to final report, Appendix C](#))

Oregon offers state income tax credits for energy efficiency and renewable energy home features. Additionally, the Energy Trust of Oregon also provides utility-based incentives for SDHW systems. In order to qualify, the systems must be SRCC OG-300 certified and approved by the Oregon Energy Office approved systems. The credits are based on performance savings of \$0.60/kWh (DHW) and \$0.40/kWh (electric). These incentives, combined with a federal \$2,000 tax credit, reduce the cost of an \$8,000 solar DHW system to typically under \$4,000.

Oregon residents must obtain documentation completed by a certified technician that verifies solar equipment in order to qualify for the state’s Residential Energy Tax credit. Technicians are required to complete the Department of Energy Tax Credit Training, as well as an application verified by the Oregon Department of Energy. To maintain certification status, the technician must participate in conference call updates, complete an agreement form, complete four hours of continuing education and verify a minimum of two tax credit certified installations each year.

Technicians will assist the homeowner with the paperwork necessary to apply for the tax credit. The list of tax credit certified solar technicians can be found at:

http://www.oregon.gov/ENERGY/CONS/RES/tax/docs/solar_techs.pdf

Unlike Oregon, Washington has few, if any, state SDHW incentives, limited utility rebates, limited or no installer certification and infrastructure, and less building department code guidance on installation and licensing requirements.

With combined utility incentives and state and federal tax credits, a typical \$8,000 SDHW system installed in Oregon is estimated to save 2,200 kWh per year or roughly \$220 per year at \$0.10 per kWh. Assuming no maintenance costs, the simple system payback, after tax credits in Oregon, results in 36 years without tax credits and 18 years with tax credits and incentives.

It should be noted that well-designed, installed, and maintained SDHW systems have been operating in the Pacific Northwest since the late 1970s when federal solar tax credits were first introduced. A significant amount of this longevity is believed to be a result of educated occupants who understand how to maintain their systems, in addition to system designs that limit temperature stagnation in hot summer months and freezing of panel and/or piping systems in cold winter months. (refer to final report Appendix A)

As a result of the solar thermal and PV market penetration and incentive programs in Oregon, installation of systems must meet state and/or local structural, electrical and mechanical codes and be installed by a “state tax credit approved” contractor. Code requirements related to the installation of solar thermal systems have been addressed fairly extensively in the City of Portland’s code: *Solar Water Heating and Photovoltaic Electric Generators Installed on One or Two Family Dwellings*. Portland’s code has a prescriptive path option for panel mounting, allowing for panels with a 4.5 pound per square foot load and rear leg tilt not to exceed 18°. If the prescriptive path is not followed, a structural engineering analysis is required which can increase the cost of a system by as much as \$1,000 and delay the permitting process (see final report’s Appendix C).

Some utility supported organizations, such as the Energy Trust of Oregon, have funded engineering testing to determine the structural limitations of a specific metal roof panel (e.g. S5) mounting systems. This study indicated the importance of fastening the metal roof to the roof decking, and provides guidance on mounting system structural limitations.

Study Summary

The case studies and the BIRA Experts’ Meeting held in 2009 (see final report Appendix B) provide lessons learned, findings, and issues for further investigation.

In spite of over 30 years of SDHW system installations, questions remain today regarding the energy savings and first costs associated with a number of unresolved issues related to Marine Climate design. These were identified during the BIRA expert meeting held in 2009 and include:

- One vs. two-tank pre-heat systems
- Closed loop vs. drain-back systems
- PV pumping systems vs. AC pumping systems with differential thermostats
- Flat plate vs. evacuated tube solar panels
- Impacts of panel stagnation temperature in closed loop anti-freeze on long-term performance and maintenance costs

Maintenance and Operation

Once a well-designed solar DHW system is installed and commissioned, it is essential that proper maintenance and operation (M&O) be conducted to ensure performance over the system's potential useful expected operating life of 30+ years. Typical system drain-back SDHW requires very little service or maintenance compared with closed loop anti-freeze, where panel temperature stagnation can result in solar fluid acidity which may lead to system leakage at corroded fittings.

A good quality solar thermal DHW system installation, operation and maintenance manual is needed to help ensure long-term performance. *A&R Solar Owner's Manual and Reference Book for Your A&R Solar Hot Water System* was used throughout the Fish Singer Place project as an example of best practice (see final report Appendix D).

Installation of Btu meters may provide homeowners more reliable and quantifiable information to ensure long-term system performance. Lower cost monitoring technologies (currently available \$600 Btu meters) are needed. Integrating Btu meters into differential thermostats provides a lower cost solution to measuring solar energy collected. The meters can provide valuable homeowner usage information if the installer inputs data to the device regarding the measured collector flow rate and specific heat of transfer fluid. This avoids the need for the Btu meter to include an integrating flow meter (the most expensive component part of the meter). The Btu meter only has to measure solar supply and return temperature differences and pump operation. This idea is applicable to non-PV pumping constant flow systems. The European Btu meters available in the market such as the Metrima-F2 and Resol-iSolarBX cost roughly \$500-\$600 and provide utility billing quality monitoring. One lower cost Btu meter made in the U.S. is the USDT series, available from Thermo Technologies (www.thermotechs.com) for \$200-\$300, however this meter has no battery backup to save data during power outages.



Figure 57. Btu meter

Installation

Solar PV has fewer moving parts and M&O requirements and is believed to be less prone to installer error than solar thermal. However PV is still more expensive to install and produces less energy savings per square foot of roof area. Solar thermal may have higher maintenance costs (especially closed loop antifreeze systems) than PV systems, assuming that PV panels perform beyond their warranty period (typically 20-30 years) and inverter life (typically estimated at 15-20 years and which cost roughly \$0.70-\$0.75 per watt). A two-kW PV system (10-200W panels or roughly 130 ft² of roof area) is estimated to save 2,200 kWh per year (\$220/year at \$.10 per kilowatt hour) at a cost of roughly \$10,000 (\$5/watt installed) or more. PV solar may be a more attractive investment than SDHW systems if the price of PV continues to fall and if the costs of solar thermal increases.

Solar PV and SDHW installers have a great variability in their “level of experience.” PV systems tend to be less problematic in terms of installation and maintenance issues than SDHW systems.

Solar-ready may save on installation costs, especially if more generic mounting rails are used (such as 1-5/8” UniStrut™ rail and mounting clip) for most manufacturers’ products (with some exceptions).

Code Related Issues

A number of code-related questions were identified during the BIRA Solar Thermal Experts’ Meeting including:

- Use of plastic (PEX) piping in the solar loop
- The need for firefighter access around panels on the roof

- Steep roof pitches requiring additional safety considerations for installation, servicing, and the configuration of panels
- On-going structural analysis of panel mounting is encouraged to reduce the need for expensive custom engineering on each system. Examples of this include the City of Portland (which allows for lower-cost prescriptive approaches for parallel mounted panels) and The Energy Trust of Oregon's engineering analysis on S5 mounting brackets for standing-seam metal roofs (final report Appendix C)
- The State of Oregon Building Codes division is currently working to complete a solar code for the installation of solar electric systems. The code is expected to be completed by 2011 and may help to provide information related to solar thermal structural issues

Return on Investment

In the solar thermal business the motto has been “the more hot water you use, the quicker the payback.” This means that systems with higher annual hot water use will save more energy than lower annual hot water use systems; hence the return on investment (ROI) is higher in households with larger families and/or number of bedrooms. Investigation into solar in multi-family centralized systems may provide greater ROI than single-family systems with low hot water use.

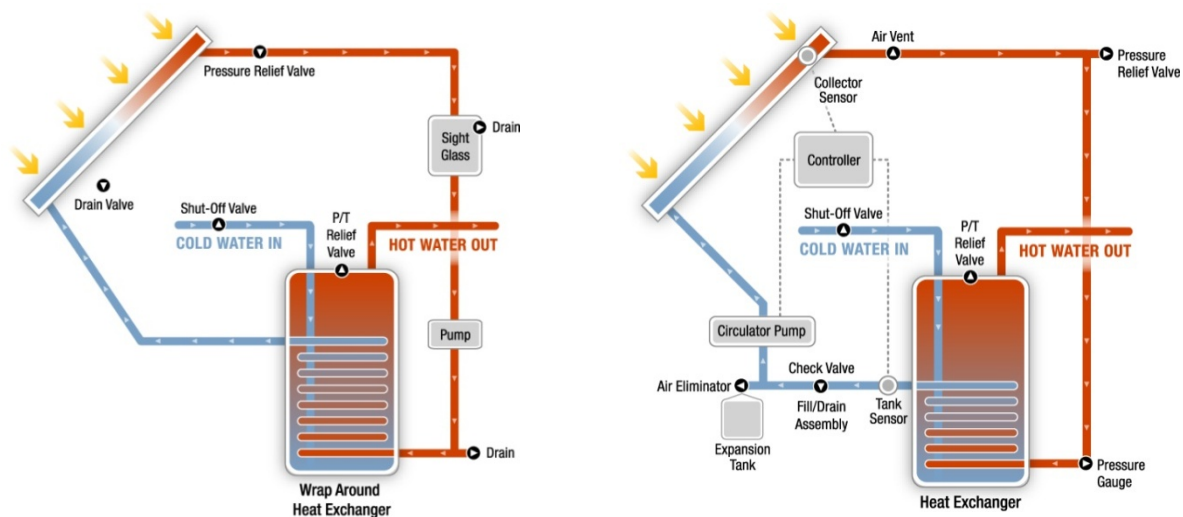


Figure 58. Drain-back and propylene glycol active indirect

Case Studies

This report includes anecdotal “lessons learned” and performance information on four solar thermal systems installed in BA high performance BIRA partners’ homes.

- Martha Rose Construction – two communities in Shoreline, WA (Homestead & Fish Singer)
- Cohan Residence – one custom home in Portland, OR
- Shirey Zero Energy Ideas House – one custom home in Bellevue, WA

In addition to these case studies, BIRA/WSU investigated a 30+ year-old solar thermal DHW “closed loop” system installed by the author in the late 1970s to highlight the point that well-designed, installed and maintained systems can provide energy savings for many years to ensure reasonable economic return on investments. These are discussed in the Solar Thermal Experts’ Meeting (see final report Appendix B).

- Romero Residence – one Grumman closed loop SDHW system installed in 1978
- Columbia Valley Elementary School – 96-panel closed loop system installed in 1981

Martha Rose Construction’s and Cohan Residence’s installed systems included the use of the Metrima F2 Btu meters to help provide energy performance data for homeowners and to identify poor performance of the systems sooner rather than later. The F2 system cost over \$600 (plus installation labor).

Martha Rose Construction



Figure 59. Martha Rose Construction SDHW systems

Homestead

A solar DHW/space heating system was installed and monitored at Martha Rose Construction in 2007 at Homestead. The BA team found numerous design and installation problems that have limited the system’s performance. The original system cost \$8,000, before repairs, made in 2008. Repairs cost an additional \$3,800 for the three solar, mechanical, and plumbing contractors that assisted in repairing the original system.

The solar “expert” touted his belief that considerable solar space heating was achievable with

the evacuated tube system that he designed and was unwilling to listen to the design suggestions made by the BIRA team. As a result, this 16-tube evacuated tube system provided 1,406 kWh in 2009 and 1,106 kWh in 2010. This does not include system losses in heated storage tank or pumping energy. The system should be providing at least 2,000 kWh per year. [Figure 60](#) shows a comparison of measured energy produced by solar panels vs. typical estimated savings using F-chart simulation software.

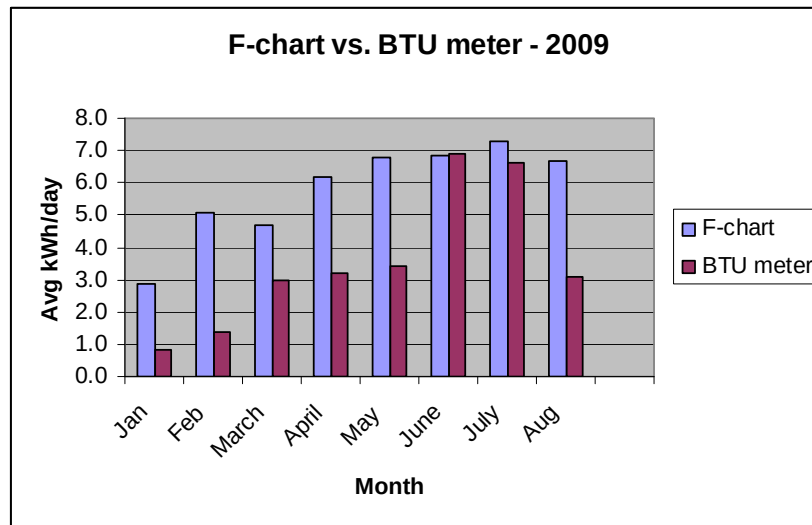


Figure 60. Homestead's Btu metered performance compared to F-chart simulation

A schematic of this poorly designed system is provided in [Figure 61](#). The attempt to integrate the solar space heating and one pass DHW coil were both reasons for lack of system performance. [Figure 62](#) shows heat loss from the solar space heating storage tank. [Figure 63](#) shows the complex piping system in the mechanical room. [Figure 64](#) shows pump cycling problems that resulted from installation mistakes that were identified and repaired.

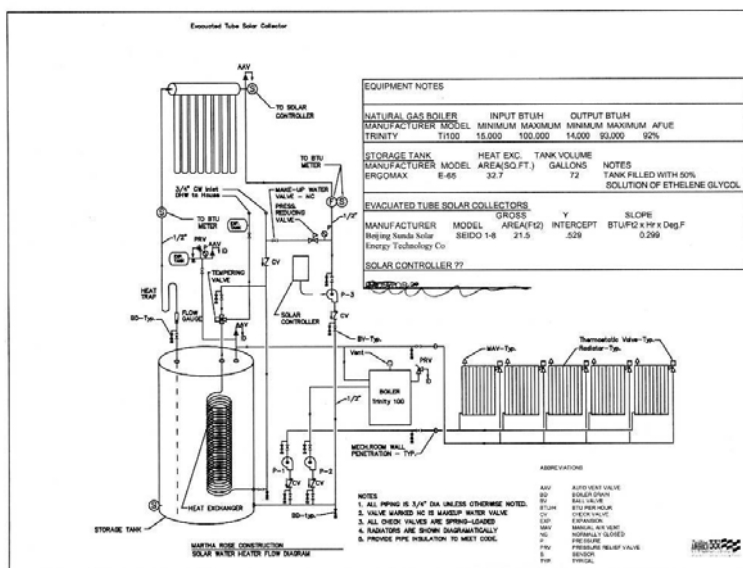


Figure 61. Redesign of Martha Rose's solar thermal system - Homestead

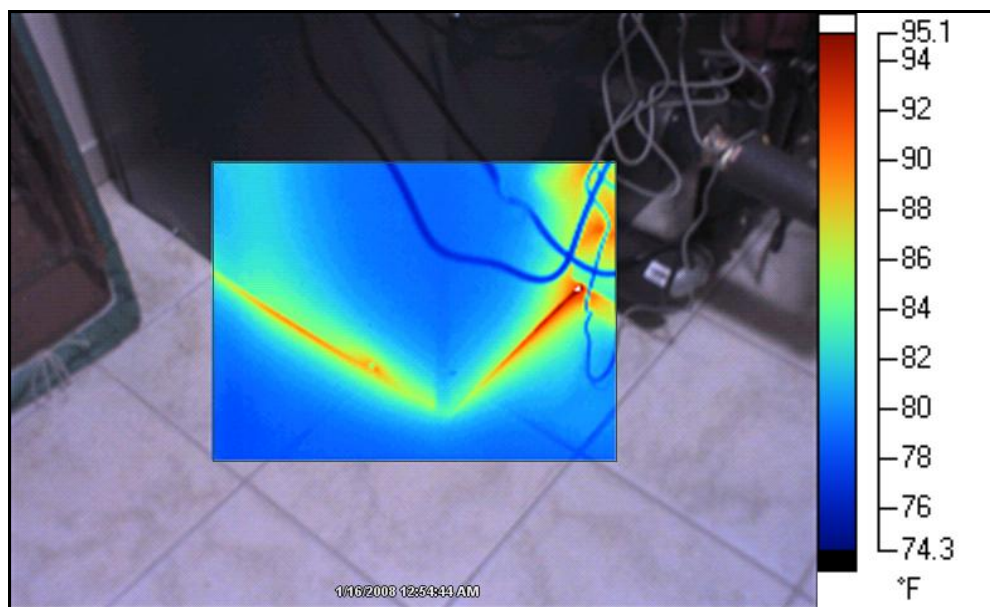


Figure 62. IR photo of heat loss from gas heated 120°F solar tank at Homestead



Figure 63. Solar thermal piping installation at Homestead

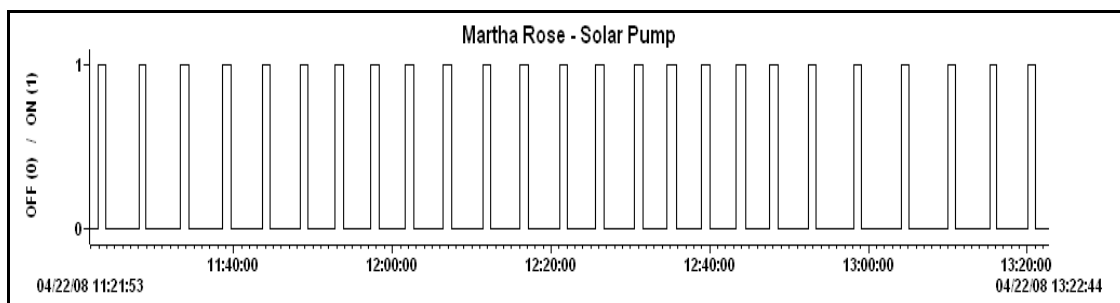


Figure 64. Solar pump cycling in April 2008 for Homestead

Design and Installation Issues

Overall design and installation issues identified in the system at Homestead were discussed at BIRA/WSU Experts' Meeting in 2009. The following items were identified:

Design Issues:

- Solar tank must be kept at @115°-120°F with 96% tankless gas “combo”
- One-time pass DHW tank heat-exchanger coil exceeds maximum DHW demand
- Circulating hot water to panels for freeze protection reduces performance
- No anti-freeze in solar loop may freeze pipes during power outages
- Solar loop auto-fill could cause water damage issues if the loop leaks
- System to be re-designed to provide DHW only when most sun exists
- 16 evacuated tubes may stagnate in summer during low water usages

Installation Issues:

- Pumps oriented incorrectly
- Temperature sensors to control ΔT were reversed, causing short cycling
- Piping to tank was reversed, causing short cycling
- PEX pipe used on solar loop may leak during high stagnation temperatures

Fish Singer Place

As a result of the poor experience at Homestead, Martha Rose Construction hired a more competent solar contractor, A&R Solar. A&R Solar installed a more conventional, two-tank SDHW system with two (4x8) flat plate panels and an 80-gallon storage tank with internal heat exchanger at a cost of \$10,195 (\$7,814 after federal tax credit). Assuming the system saves 2,200 kWh/year and with the after-tax credit, the simple payback is 35 years at \$0.10 per kWh. Typical current electricity costs are \$0.08-0.09 per kWh.

No performance data is available for this system since the home is unsold and unoccupied. This system also includes an innovative heat dump using a fin tube radiator with three-way auto diverting valve to help avoid stagnation temperature and ensure long-term operation. The heat dump costs an additional \$800 and A&R Solar has standardized the heat dump as part of all systems they install. [Figure 65](#) shows a diagram of the solar DHW system. A&R Solar provided an extensive *Owner's Manual and Reference Book for Your A&R Solar Hot Water System* for the Fish Singer Place, which is a great example of best practice (see final report Appendix D). The reference book also includes documentation of the system commissioning including system pressure, flow rate, percent glycol, temperature sensor resistance check, and panel and tank temperature on sunny days.

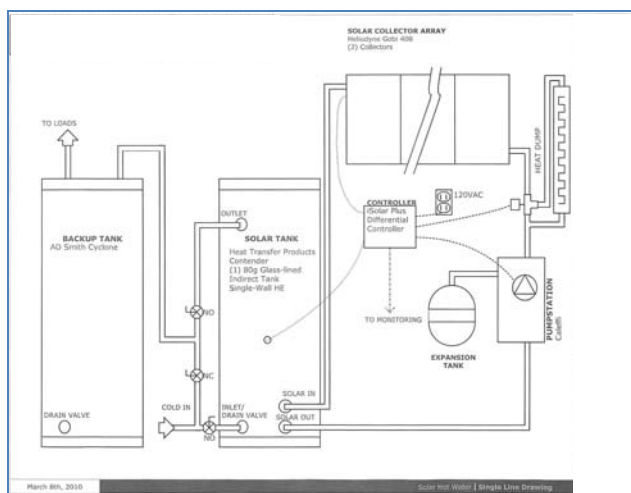


Figure 65. Diagram of Fish Singer Place solar two-tank DHW system

Cohan Residence

The Cohan residence has a flat plate drain-back single-tank DHW system with F2 Btu meters installed in August 2009. This system was completely operational in June 2010. The one-tank system was selected due to the limited size of the mechanical room. The system was installed for \$7,700 (\$3,500 after the \$1,320 Oregon tax credit, \$2,000 federal tax credit and \$880 utility rebates). Occupancy of the home and monitoring began in January 2010. Estimated energy savings for this system are assumed to be 2,200 kWh per year or \$220 at \$0.10 per kWh, yielding roughly a 16-year simple payback excluding maintenance costs. Energy savings are assumed based on information provided by the Oregon Office of Energy. Figure 70 shows how these savings vary from climate to climate. A typical two-tank drain back system approved in Oregon is shown in Figure 66. The Cohan system is similar to the schematic of a two-tank system provided in Figure 65, with the exception of the conventional tank.

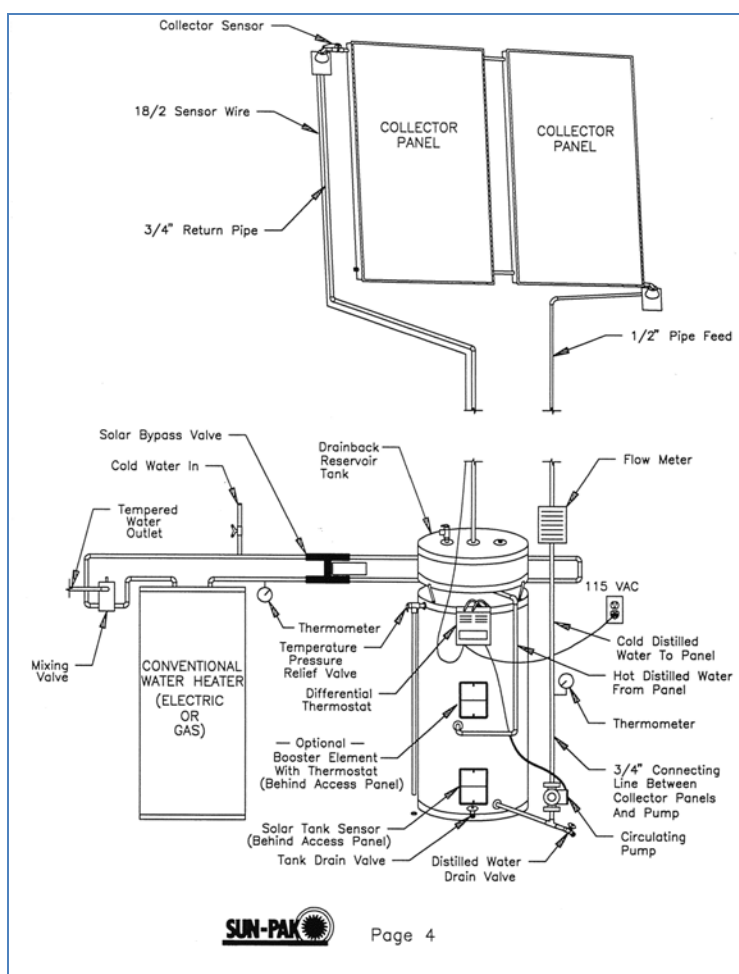


Figure 66. Typical two-tank SDHW drain-back SDHW approved in Oregon



Figure 67. Drain-back and solar tanks



Figure 68. Solar panel tilted on flat roof

Because of the flat roof and required tilt, the solar system was not approved under the Oregon prescriptive code and required an engineering approval to address wind uplift. To avoid the additional \$1,000 cost of engineering required for permitting, the system was originally flat-mounted, but was tilted to a 45% angle in April 2009 after occupancy. During that time, a leak in the collector loop caused staining of the ceiling and ceiling fan housing where fluid leaked into the home. This leak was determined to be a result of a roofing nail penetrating the solar piping. It was repaired at the expense of the solar contractor with no cost to the homeowner. The system has been operating as intended since June 2010.

The total energy collected as shown by the Btu meter from mid-June to mid-October was 786 kWh; however no back-up DHW electricity was used (excluding solar pump) for this period. In effect the system provided 100% of the DHW load for that “highest solar summer to early fall period.” The 786 kWh measured solar energy produced is significantly less energy savings than assumed in the Oregon Solar tax credit program (2,200 kWh/year) for this type of system. During the sunniest time of year (e.g. June to October), when the system is “fully operational”, one would expect the system to produce significantly more than one third of the estimated annual production. Although, the assumed savings was not achieved and is likely a result of the lower water usage of the Cohan household (e.g. family of two with no laundry use) compared to the tax credit program family of four who uses 75 gallons per day at 120°F. This case study suggests that the solar thermal business motto, “the more hot water you use, the quicker the payback”, rings true.

Drain-back systems tend to have a slightly larger solar pump (1/20 hp vs. 1/12 hp) compared to a closed-loop, antifreeze systems in order to overcome the vertical head requirements. The

monitored pump energy (e.g. pump parasitics) was 68 kWh over this period or 5.6% of the total solar production. Roughly 50% of the pumping electrical energy is transferred to the solar fluid so as to reduce the parasitic losses. Since the solar storage tank was also the back-up electric resistance tank, the system efficiency is reduced, due to warmer tank temperatures than in a two- tank system. Solar panels operate more efficiently when the solar fluid temperature is lower. Figure 69 shows the impact of inlet temperature on flat plate, evacuated tube and pool panel efficiency. Assuming a typical sunny day at ambient temperature of 75°F and an inlet temperature (e.g. bottom of solar tank) of 50° F, then roughly 70% of the flat plate solar energy is transferred to solar fluid, whereas the efficiency drops to 65% when the bottom of the solar tank is at 100°F (100-75= 25). While evacuated tube panels tend to perform at higher efficiencies at higher collector inlet and/or lower ambient temperatures (delta of 125°F), they may not perform as well in the Marine Climate for DHW during the sunnier and warmer months when solar production is greatest. It should be noted that while two-tank systems may provide lower inlet water temperatures than single tank systems, hence higher panel efficiencies, they also have twice the tank standby losses, which can reduce actual system performance.

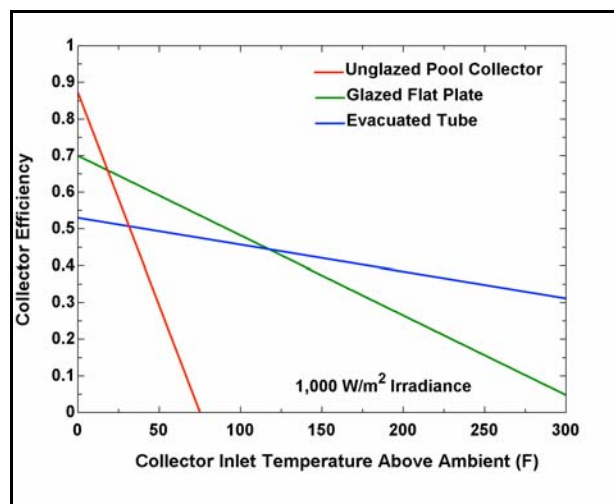


Figure 69. Impact of inlet temperature of flat plate, evacuated tube and pool panel efficiency

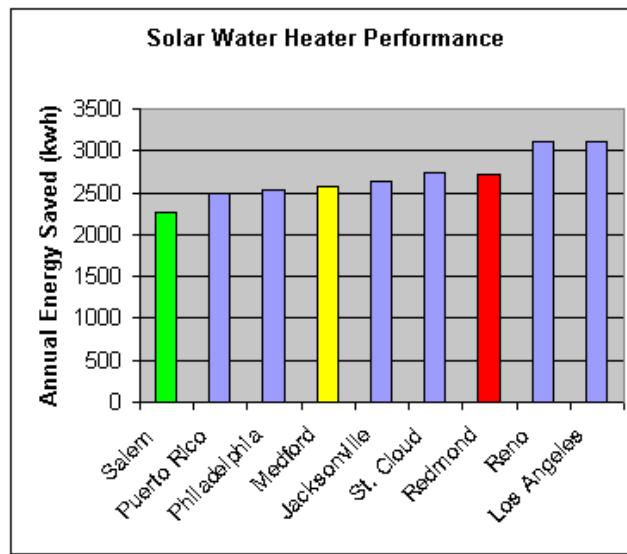


Figure 70. Estimated solar heating performance in Oregon vs. other climates

Shirey Residence – Ideas House

The Zero Energy Idea House is located on West Lake Sammamish Parkway in Bellevue, WA. The home was designed to show that smart choices can result in a home that minimizes energy use while maximizing comfort and style. The goal of the 1,630-square-foot home was to combine energy generation and conservation techniques that would result in estimated total energy bill of less than \$40/month. WSU/BIRA supported this effort by providing technical assistance during the design, installation and testing/commissioning phases of the project. More information on this project is available at: <http://www.zeroenergyideahouse.com/>

Installation of the evacuated tube solar DHW system at the Shirey Residence was completed in October 2009 with occupancy to begin winter 2010, and reported to BIRA at the end of 2010. The installed system cost was \$8,000. The solar installer never installed the Btu meter as intended so there is little monitored data on the SDHW system performance. The occupants report that they believe the system to be operational and is reducing energy use in this home, especially during summer.

The SDHW consists of a 20-tube solar collector manufactured by ThermoMax. There is a SSC-50 gallon heat transfer tank with internal heat exchanger manufactured by Heat Transfer products. A heat rejection device designed into this closed-loop system prevents stagnation of solar panels, similar to the one employed and described in Martha Rose Construction's Fish Singer Place system case study.

Assuming a first cost of roughly \$8,000 and \$2,000 federal tax credit, the overall system cost was approximately \$6,000. Assuming an estimated energy savings of 2,200 kWh/year or \$220/year at \$0.10 per kWh, the simple payback excluding maintenance costs is about 27 years

at current electricity rates.



Figure 71: Shirey Zero Energy Idea House with evacuated tube panels on left

OASys - Final Report Budget Period 3 (2010)

OASYS is a two-stage indirect-direct evaporative cooler developed by Speakman CRS, LLC in conjunction with Speakman Company. The California Energy Commission (CEC) is supporting its development.

Traditional evaporative coolers work by using the natural phenomenon of water evaporation to cool air. When water evaporates, it requires energy to transition phases from liquid to gas. This energy is usually in the form of heat. Evaporative coolers take advantage of this phenomenon by absorbing heat from the air. Perspiration is an example of natural evaporative cooling; when the water evaporates from your skin, it absorbs heat from your skin, cooling your body in the process. The evaporative cooler then circulates this cooler air into the house. Thus, evaporative cooler technology is best suited for areas where temperatures are high and the relative humidity is low. Using only a pump and a fan, the overall power consumption of this process is typically less than that of traditional air conditioners using compressor technology.

OASys is one of several varieties of evaporative coolers currently available. The OASys distinguishes itself in its two-stage indirect-direct evaporative cooling. Air is initially cooled without adding moisture in the indirect stage via a heat exchanger. In the direct stage, this cooled air is then cleansed and its humidity is optimized before being introduced into the house. Because the unit does not re-circulate indoor air, OASys constantly brings in fresh air while in operation. OASys system advocates claim that its low energy usage (less than 600 watts) results in an energy efficiency equivalent of more than 40-SEER.

BIRA has been extensively monitoring the performance of the OASys at Gold Medallion's

Newport House since September of 2008. The Newport House is 1,832 square feet above-grade finished floor area (not including the conditioned basement) and is also a 40% BIRA prototype located in South Jordan, Utah (Figure 72). Its energy efficient features include the OASys, SIP walls, SIP roof, R13 basement insulation, and a 2.0 kW photovoltaic thermal (PVT) system. The high desert climate of South Jordan is hot, generally has low humidity, and is located at a high elevation, creating ideal conditions for the operation of the OASys unit. BIRA has been in communication with the Newport homeowners, several builders, and other industry partners to obtain feedback about the performance, acceptance, installation, and maintenance of the OASys unit.



Figure 72. Gold Medallion's Newport House

BIRA also worked with partners for the Community Development Corporation of Utah's Webster Cottages project as a consultant for the HVAC design with OASys. The Webster Cottages project is a 1,185 square foot, three bedroom two bathroom house located in Salt Lake City, Utah. Its features include R-50 blown in attic insulation, R-16.5 walls plus 1-inch of foam, and 90% AFUE furnace (Figure 73).



Figure 73. Community Development Corporation's Webster Cottages house

Key Results

The actual amount of electricity that the OASys uses is less than the projected energy usage of most other compressor air conditioners. Water usage might be an issue in counties and states where water is scarcer as OASys can use more than 6,400 gallons in a summer. There are no known code issues when installing OASys. It has passed through jurisdictions including California and South Jordan, Utah several times without any incidents for code compliance and installation issues. Inspectors may need education on the product, as some are unfamiliar with OASys. The cost is less than other air conditioners, and rebates will bring costs down further. OASys is also projected to use less electricity than most other common air conditioners. The cost of water used to operate OASys thus far in 2010 is \$223. Speakman CRS and its suppliers are ready to fulfill any number of OASys units, and Speakman is also working on introducing two new evaporative coolers into the market. The homeowner of the Newport House where the OASys is being monitored is happy with the product, its performance, and its energy savings. However, OASys' ability to provide comfort may be limited due to high outdoor relative humidity and during extended periods where temperatures are high during both day and night. Gold Medallion Homes has expressed frustration with evaporative coolers, claiming that

homeowners need more education and hand holding with the newer technology than they care to learn, as a homeowner's primary concern of any air conditioning system is to keep the house at cool temperatures during hot periods.

Gate Status

BIRA has collected data over the past two years for electricity consumption, temperatures, and relative humidity and interviewed various partners to obtain feedback from different perspectives of OASys. The OASys has been proven to: be capable of comfortably conditioning the living space of a 1,800 square foot above grade area; use less electricity than most other common air conditioners; be cost-effective; and have manufacturer and distributor support. However, its reliability remains a hurdle that has yet to be overcome. While OASys has seen success in the Newport House, Gold Medallion's experience when installing OASys into other houses has not been favorable. Homeowners complained of comfort issues and required a lot of education and hand holding to understand that the comfort performance of an evaporative cooler is not the same as compressor air conditioners. Another factor that may have played a role is that since the Newport House is a Building America prototype house with a 40% whole house energy savings level, its cooling load may have been lower than that of the other houses in which Gold Medallion installed OASys. Despite this, BIRA will recommend OASys to proceed onto Stage Gate 2. The OASys' performance in the Newport House has shown that it is capable of meeting all of the stage gate criteria in a prototype house. In addition, Speakman CRS' upcoming products, one utilizing water cooler technology and the other with compressor cooling, have promise and the potential to improve the shortcomings of its first generation product, the OASys. BIRA would recommend evaluating either of these systems when they become available.

Conclusion

The amount of electricity OASys used during the monitoring period in the Newport House has been less than the projected electricity usage of most other compressor air conditioners. In 2009, OASys used 723 kWh of electricity and 613 kWh in 2010. Other compressor air conditioners are simulated to use between 950 to 1125 kWh annually. OASys has also consumed at least 6,400 gallons of water during summers. The 6,400 gallons translates to the electricity equivalent of 1,076 kWh, which is near the same amount of electricity used by a 13 SEER compressor air conditioner.

Plans that have OASys specified as the primary piece of cooling equipment have met little to no resistance when applying for permits. It is usually during inspections when delays occur. This is mainly due to the inspector not being familiar with the OASys system. Once the inspector is given an explanation of OASys and educated on the principles of how it works, installations have proceeded without incident. As the units are installed in more jurisdictions, it will be less likely that any delays in inspections will occur.

OASys' manufacturer, Speakman CRS, LLC, is able to fulfill any size order for OASys, with distributors in California, Colorado, Nevada, New Mexico, and Utah. Malfunctioning OASys units are rare and have been said to occur less than 0.5% of the time. On top of this, OASys units are supported by a 5-year limited warranty. Speakman CRS, LLC, is backed by Speakman Company, a billion dollar company that has been providing products and services to the plumbing industry since 1869. They are looking to expand their current line of evaporative coolers, introducing a unit with cooling tower technology in November, and an additional one in the near future that has compressor cooling.

The homeowner of the Newport House did not have any major issues with humidity and temperatures and is happy with the performance of the system; however, there are a number of caveats to point out. He is considered tech savvy and knowledgeable of evaporative coolers and their limitations. He's from Illinois, where they experience warm humid summers, so he is more tolerant of higher humidity levels. The house also has advanced features to help reduce cooling load, including SIP walls and roofs, and ducts in conditioned space, which decreased the demand of OASys.

Gold Medallion Homes also installed an OASys and other evaporative coolers into other homes, but with less success than the Newport House. They mentioned that despite the technology having lots of promise, they do not have the resources to trouble shoot the systems. The homeowners required a lot of education and hand holding for the technology. The bottom line was that they wanted the house to be cool when it was hot outside; electricity savings and understanding technical details of how an evaporative cooler's cooling capacity would be limited by wet bulb temperature was secondary. Gold Medallion Homes is currently switching out seven of their homes where evaporative coolers were installed, substituting the systems for conventional air conditioners.

"Must Meet" Gate Criteria - Source Energy and Whole Building Benefits

One of the biggest benefits that OASys claims is its energy savings compared to other air conditioner systems. OASys essentially operates with just a fan and water pump, and because of this, does not require as much energy as other systems that require a compressor. BIRA energy simulations show that the cooling source savings will vary by climate when comparing a 13 SEER compressor air conditioner and an OASys to the BA benchmark. In Salt Lake City, Utah, source space cooling savings increased from 66.9% to 91.3%, resulting in an overall increase of 2.8% in whole house energy savings. In Sacramento, California, source space cooling savings increased from 75.7% to 90.3%, resulting in an overall increase of 2.4%.

BIRA energy simulations show that OASys has a clear advantage over most other alternative and traditional cooling systems. The closest competitor is the 15 SEER compressor air conditioner. Refer to the final report's Appendix B for energy simulation figures. It should be noted that BIRA is not confident that the software used (BEopt, EnergyGauge® and TRNSYS) can accurately predict whole house energy savings. From the final report's Appendix B, BIRA energy

simulations underestimated the actual energy usage. In the TRNSYS simulation, BIRA used an indirect evaporative cooler module to simulate the indirect cooling module of the OASys system. However, the indirect evaporative cooler module assumed an open water media source, which increased the relative humidity of the secondary air flow. This is inconsistent with the indirect cooling module of OASys, as little to no relative humidity is added when air passes through. Adding relative humidity to the secondary airflow will decrease the amount of heat transfer in evaporative coolers.

Through the two years of data collection, BIRA has a better idea of how much electricity OASys uses. During 2009, OASys used 723 kWh of electricity, and thus far in 2010, used 613 kWh. The results are higher than the original projected amount from EnergyGauge®, but still lower than most other air conditioning options. Only the 15 SEER is estimated to use less electricity than OASys. The data also reveals that on average, OASys will operate on an average high of 403 watts, although 0.4% of the hours in 2009 it used more than the 600 watts.

Month/Year	Water Usage (gallons)	Energy Equivalent (kWh)
Jun-09	1291	215
Jul-09	1929	322
Aug-09	1891	315
Sep-09	1343	224
Oct-09	3	0.5
Apr-10	87	15
May-10	240	40
Jun-10	1361	227
Jul-10	1976	329
Aug-10	1658	276
Sep-10	501	84

Table 108. Monthly water usage and energy equivalency

Water usage was also monitored beginning in June 2009. Starting from that point, OASys used nearly 6,500 gallons of water in 2009, and more than 5,800 in 2010 thus far. Its energy equivalents, using 2.0 gallons per kWh at the point of end use and then converting to source to have 0.167 kWh per gallons, are 1,076 kWh in 2009 and 971 kWh in 2010 (Table 108). These energy equivalent figures approach the amount of electricity used by a 13 SEER air conditioner. Water usage will vary depending on the dump sump intervals; the intervals are based on the hardness of the water. For a point of reference, the Newport House's interval was once every six hours. Also worth noting is that the flow meter was not installed until June of 2009, so the actual water consumption in 2009 is higher.

OASys has a lower cost than all other equipment, and besides a 15 SEER, it uses less electricity.

OASys will have a decremented cost of \$1,000 under 13 SEER. However, the cost of water will also have a significant role in operation costs. The final OASys system report's Appendix F shows the incremental costs of energy improvement from a 13 SEER to an OASys unit to annual reduction in utility bills when financed as part of a 30 year mortgage. Making such an improvement will increase annual mortgage costs by \$27.03 per year, making it not a cost-effective alternative.

"Must Meet" Gate Criteria - Performance Code Based Approval

The 2009 IECC states that the minimum efficiency for an evaporative cooler that has a capacity of less than 65,000 Btu/hr. is 12.1 EER. OASys' technical sheet states that it operates at 54 EER at the high speed setting and at a 91 degrees dry bulb and 69 degrees wet bulb.

Evaporative coolers are not specifically mentioned in the 2009 International Mechanical Code (IMC). However, since OASys provides fresh air ventilation, it would need to comply with the requirements of 2009 IMC's Chapter 4 – Ventilation.

Unlike the 2009 IMC, evaporative coolers have their own section in the 2008 California Mechanical Code (CMC). Section 405 of the CMC details the requirements of installing evaporative coolers, including location, accessibility for inspection and repair, and installation.

BIRA Builder Partners have installed numerous OASys units within Salt Lake County and Utah County. In both jurisdictions there were no issues for jurisdictional and installation requirements for OASys that went above and beyond a traditional 13 SEER compressor air conditioner.

Other jurisdictions have been reported to have little problems with approval of plans. However, there was a need to educate inspectors during the construction phase about how OASys works. Troy Harvey, president of Heliocentric and designer of Newport's HVAC system, said that there was some reluctance from the inspectors to give approval, as they had not had any previous experience with OASys. However, Harvey explained the benefits of OASys to them and gained their confidence and approval in its cooling performance.

"Should Meet" Gate Criteria - Prescriptive Based Code Approval

An OASys unit brings in fresh outside air during operation and therefore can be used to meet the minimum ventilation air requirements as specified by ASHRAE 62.2-2010. However, since the OASys will not be used when the outdoor ambient becomes cooler (e.g., during winter), an additional means of providing fresh outside air may be needed.

Table 4.1a (I-P) Ventilation Air Requirements, cfm

Floor Area (ft ²)	Bedrooms

Table 4.1a (I-P) Ventilation Air Requirements, cfm					
Floor Area (ft ²)	Bedrooms				
	0-1	2-3	4-5	6-7	>7
<1500	30	45	60	75	90
1501-3000	45	60	75	90	105
3001-4500	60	75	90	105	120
4501-6000	75	90	105	120	135
6001-7500	90	105	120	135	150
>7500	105	120	135	150	165

Table 109. Table 4.1a, ASHRAE 62.2

One of the possible locations that the OASys can be installed is on the roof. If this location is taken, certain jurisdictions will require structural calculations to ensure that the structural integrity will not be compromised due to the additional weight. Structural calculations typically cost about \$500.

“Should Meet” Gate Criteria - Cost Advantage

Estimated contracted costs of various cooling equipment was obtained (Table 110). OASys’ contracted price is the eventual price point once its new evaporative cooler product, Air-2-0, becomes readily available.

Unit	Cost
OASys	\$1,500
3 ton 13 SEER	\$2,500
3 ton 14 SEER	\$4,400
3 ton 15 SEER	\$6,500

Table 110. Estimated contracted cost of various cooling equipment

Unit	Total annual kWh used	Total annual bill	kWh Saved	Annual bill saved
OASys	723.0	\$55.80	-	-
3 ton 13 SEER	1084.7	\$74.13	361.7	\$18.33
3 ton 14 SEER	1008.2	\$73.73	285.2	\$17.93
3 ton 15 SEER	597.5	\$45.00	-125.5	-(\$10.80)
3 ton 13 SEER ASHP	1123.3	\$74.13	400.3	\$18.35
3 ton 14 SEER ASHP	1066.1	\$73.87	343.1	\$18.07

3 ton 15 SEER ASHP	945.0	\$71.17	222.0	\$15.37

Table 111. Electricity usage and savings of OASys and various SEER units

The predicted electricity usage and savings between various cooling equipment was then determined (Table 111). Only the 15 SEER compressor air conditioner is predicted to use a smaller amount of electricity than the OASys system, while the rest of the equipment will save between 222 to 400 kWh per year. South Jordan's electric utility provider is Rocky Mountain Power. Their Utah utility rates for the months of May through September is \$0.075292 for the first 400 kWh, \$0.092749 for the next 600 kWh, and \$ 0.115361 per kWh above that, and \$0.078009 from October through April. Using these rates, OASys will save between 15 and 18 dollars per year.

Observing the water usage of OASys gives further insight to its operating costs (Table 108). Using a base rate of \$34.88 and \$1.55 per 1000 gallons, OASys' water consumption cost was at least \$188 in 2009 and \$223 thus far in 2010. The flow meter was not installed until June and thus the water usage was not observed in May. 2010 will have higher water costs despite not completing a full year of observation. Combining electricity consumption and water use together will yield an annual operation cost of at least \$243.80.

There are multiple tax credits available for purchasing an advanced evaporative cooler like OASys. The American Recovery and Reinvestment Act (ARRA) offers a 30% tax credit if the OASys unit will be installed in either the Marine or Dry regions designated by the 2006 IECC Climate Zone map (see final report Appendix D). Local utilities also have rebates to encourage purchases of energy efficient equipment. Some examples of local rebates currently offered have been researched (Table 112).

State	Provider	Amount	Comments
California	Southern California Edison	\$600	two-stage ducted evaporative coolers with pressure relief dampers
	Southern California Edison	\$500	without pressure relief dampers
	Redding Electric Utility	\$1,000	
Colorado	Xcel Energy	\$500	
New Mexico	Xcel Energy	\$1,000	
Utah	Rocky Mountain Power	\$1,000	Ducted System
	Rocky Mountain Power	\$500	Unducted System
	PNM	\$500	

Table 112. Sample of rebates currently being offered

Even though an OASys costs less than 13, 14, and 15 SEER units, its operation costs are higher when both electricity consumption and water usage are taken into account, yielding a payback

period for choosing the other systems (Table 113). Factoring in the ARRA tax credit as well as local rebates will make OASys delay the payback periods of the other systems.

Unit	Cost	Simple Payback (years)
OASys	\$1,500	-
3 ton 13 SEER	\$2,500	-(5.9)
3 ton 14 SEER	\$3,500	-(11.7)
3 ton 15 SEER	\$4,400	-(14.6)

Table 113. Estimated payback periods

BIRA is working with local utilities and local government to help them understand the value of compressorless cooling in this region. BIRA is working with these entities to provide the information necessary to show conclusively if compressor-less cooling is a viable, cost-effective, energy efficient alternative to traditional air conditioning systems. BIRA research will provide the necessary information to officials within the utilities and state government in order to determine if an increase in incentives for this technology is warranted.

“Should Meet” Gate Criteria - Reliability Advantage

To gauge a sense of ease of operation, reliability, and net added value of the OASys unit, BIRA turned to the homeowner of the Newport house for his first-hand opinions. He said that for the most part, the system is easy to operate. The aesthetics of the thermostat that comes with the unit seems a little dated, but operation of the unit is simple.

As far as reliability, changing the filter was the only maintenance needed during the two years he has had the system, and no major problems were encountered. The OASys is able to keep his house at a comfortable temperature and relative humidity under normal conditions. The OASys had trouble keeping the main living area cool when he had ten guests over for dinner and when the outdoor relative humidity was high, the OASys unit made the indoor relative humidity level higher than his preferred comfort level.

The homeowner also mentioned that during periods where the night time temperatures are higher than the thermostat set point, OASys will operate with both fan and pump, continuously adding humidity into the living area. The amount of humidity added into the living area will become an issue during heat waves.

He has chosen to leave OASys running all the time as opposed to allowing the house to warm up and then turning the unit on. He believes that the time to cool a house down from the mid-80s to 75 degrees was a little longer than he would have like. However, even though he has not turned off the OASys, his electricity bills have been around 20 to 30 dollars per month. He definitely notices the energy savings’ benefit through his relatively low electricity bills. While

there are other aspects that can contribute to his low electricity bills, he feels relieved that he can leave the OASys continuously on without having to worry about high energy bills. His main concern as far as operating costs was with water consumption, as the price of water in Salt Lake County has resulted in 80-90 dollar monthly water bills.

The Newport homeowner would be considered someone who is tech savvy and knowledgeable and understands of the limitations of evaporative coolers. His family was also from a part of Illinois where they were exposed to warm but humid summers, so they are familiar and more tolerable of higher humidity levels. Despite the homeowner of the Newport House not having any issues with OASys, there were others that did. Kristen Nilssen, co-President of Gold Medallion Homes, stated that their company has decided to not install OASys and other evaporative coolers in the future. When using evaporative cooling technology, they said that there has been a lot of education and hand holding with the homeowners. Ultimately, homeowners want the house to be cool during hot temperatures; they do not want to worry about wet bulb temperature and saving a few dollars. This issue is not only with OASys, but with other evaporative coolers as well. Currently, Gold Medallion is in the process of switching out seven of their houses with evaporative coolers and replacing them with conventional air conditioning.

“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment

When investigating the sufficient logistical support of OASys, Moe Salem, the technical sales engineer for the Speakman CRS, LLC, provided answers. He said that at this point, they could fulfill any number of OASys unit orders. There is no typical problem associated with the units; there were some malfunctioning units reported in the past, such as a blower motor not working, but these problems are rare and have been said to occur less than 0.5% of the time. If a problem should arise, Salem will be the point of contact. The typical turnaround time for any maintenance, malfunction, or service requests is usually less than 24 hours, based on the response time of the contractor.

Each OASys unit is backed by a full warranty in the first year and a limited warranty on the cabinet and indirect heat exchanger during the second through fifth years. A similar product (Coolerado) also has a five year limited warranty on all of its units. It should also be noted that OASys is not warranted outside the continental US.

Speakman CRS is also expanding its product line of evaporative coolers to further penetrate into markets in which the OASys may not be as effective. The Air-2-0 product will be introduced into the market in November and utilizes cooling tower technology to pre-cool water before entering the aluminum fins. It has increased its fan capacity to 2,500 cfm and 125% coefficient of performance (versus OASys' 111%). It will not require a special thermostat or humidistat, but an additional outdoor thermostat will be needed. When the outdoor temperature is lower than the indoor thermostat set point, the outdoor thermostat will communicate with the OASys unit to operate its fan only, offering a potential way to save electricity. Stainless steel construction

will reduce the possibility of mold and corrosion.

Speakman CRS is also developing a 5-ton, 2-compressor, 5-stage unit. The five stages include fan only, indirect evaporative cooling, direct evaporative cooling, 2.5-ton compressor cooling, and then the second 2.5-ton compressor. Its motherboard will take into account relative humidity and temperatures to determine which stage will provide the necessary level of cooling. This unit will also have heating capabilities. The availability date is to be determined.

Marlin Alvis, one of the OASys distributors in California, has experience with both selling and installing the systems. He states that the installation takes no longer than a traditional compressor cooled air conditioning unit in new construction projects. They have only received positive feedback from homeowners about OASys. They committed to Speakman CRS' product line by stocking and selling Air-2-0 units. Besides California, OASys distributors are also located in Colorado, Nevada, New Mexico, and Utah.

The Speakman CRS, LLC is backed by the Speakman Company, a billion dollar company that has been providing products and services to the plumbing industry since 1869. Speakman CRS, LLC is also expanding their business into commercial construction, such as hospitals.

"Should Meet" Gate Criteria - Gap Analysis

One of the questions that needs to be answered before contractors and builders adopt OASys is how well the unit can meet cooling loads. Below is a graph of data collected from the Newport House on the hottest day recorded during the two-year monitoring period.

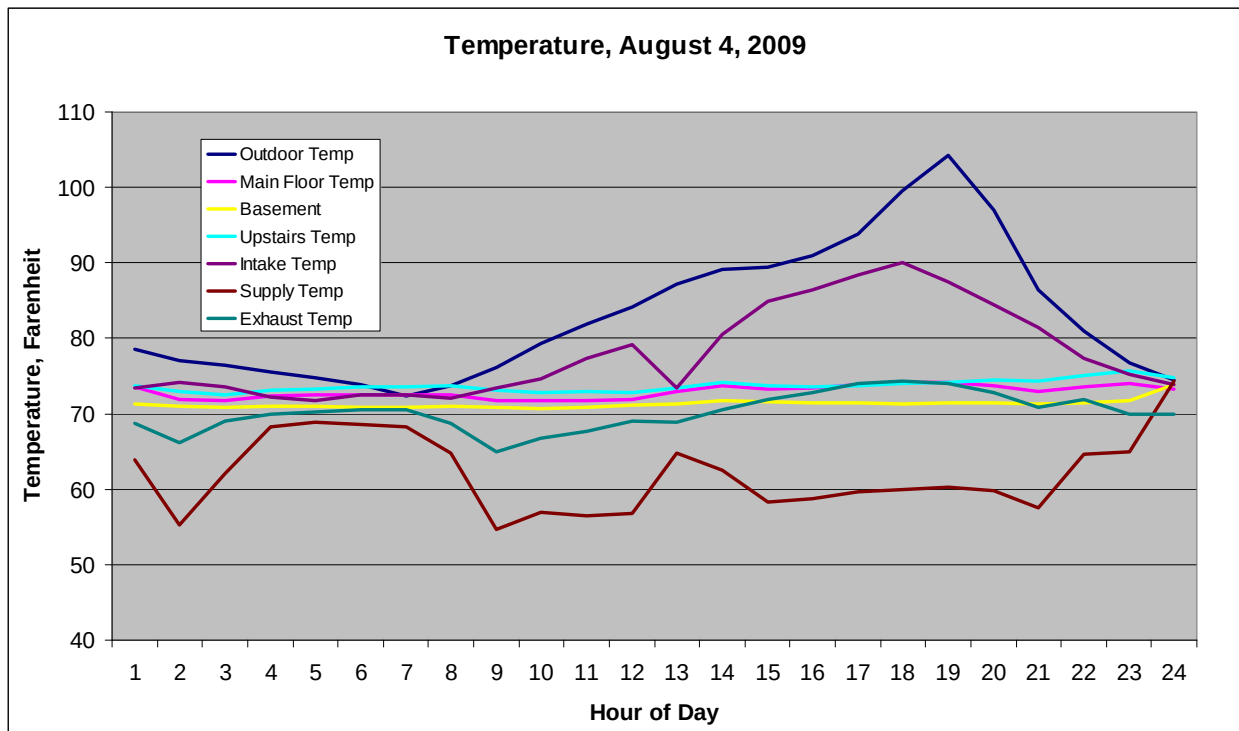


Figure 74. Cooling performance of OASys during a 104.2 degree day in Gold Medallion's Newport House

Figure 74 indicates various temperatures recorded at the Newport House. The high temperature for August 4th, 2009 was 104.2 degrees F. The thermostat is kept around 73-74 degrees, just below ASHRAE's recommended indoor temperature of 75 degrees. Supply air temperature is recorded to be no higher than 60 degrees F during peak temperatures. The data collected shows that despite the high recorded temperature to be in the triple digits, OASys has the ability to meet the cooling loads. There are contractors and inspectors who are unfamiliar and skeptical about evaporative coolers so no matter how much marketing OASys does, there are those who will still be hesitant to adopt the system. This data will help alleviate doubts and potentially overcome this marketing barrier.

Another concern contractors, inspectors, and other potential adopters might have is how much humidity OASys adds into a house. Per 2008 ASHRAE HVAC Systems and Equipment, the recommended relative humidity percentage should be 50%. At this percentage, the mortality rate of certain organisms is at its highest, and the mortality rate will decrease if the relative humidity goes above or below this number. For example, if the environment is too humid, you have issues with condensation, which could lead to mold. Low relative humidity will increase the rate of evaporation of sweat glands and mucous membranes, thus leading to an increased rate of respiratory related illnesses and dry skin.

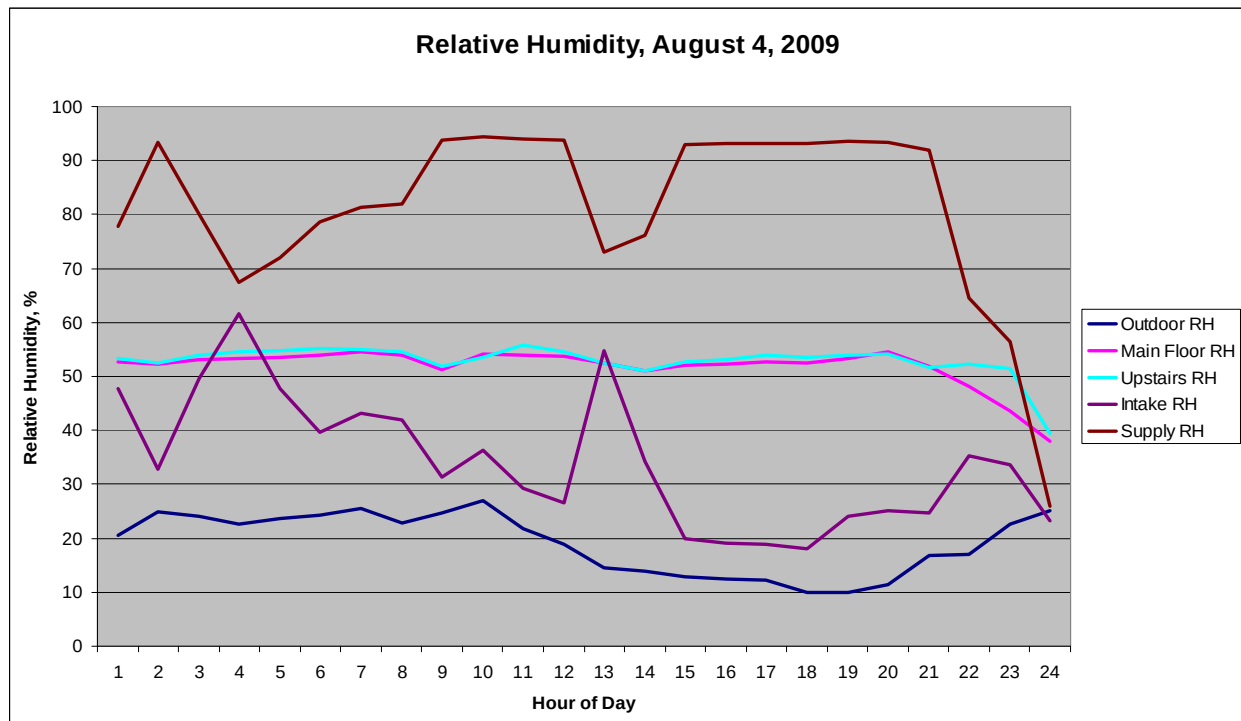


Figure 75. Relative humidity levels during a 104.2 degree day in the Gold Medallion Newport House

In the data collected from Newport House, BIRA found indoor relative humidity levels near the 50% level. This is the ideal relative humidity level as recommended by ASHRAE. As stated above, the homeowners did not mind this higher level despite Utah having a relatively dry climate.

However, OASys, as well as other evaporative coolers, have an inherent limitation. They work by taking advantage of the phenomenon of water evaporation to absorb heat out of the air. Therefore, the ideal location where OASys will operate optimally is in hot dry climates with high elevation. OASys and other evaporative coolers will not be as effective in humid climates and climates subject to monsoon seasons and thus are not recommended for use there. As mentioned previously, Speakman CRS, LLC is currently developing two products, one with cooling tower technology and the other with direct expansion cooling. This will help increase the maximum cooling capacity of the unit, and will potentially increase the climates in which an OASys can be effective.

Taking a look at OASys' effectiveness during the most humid days of the summer reveals additional information into its performance. Below, BIRA looked at the most humid day during the monitoring period.

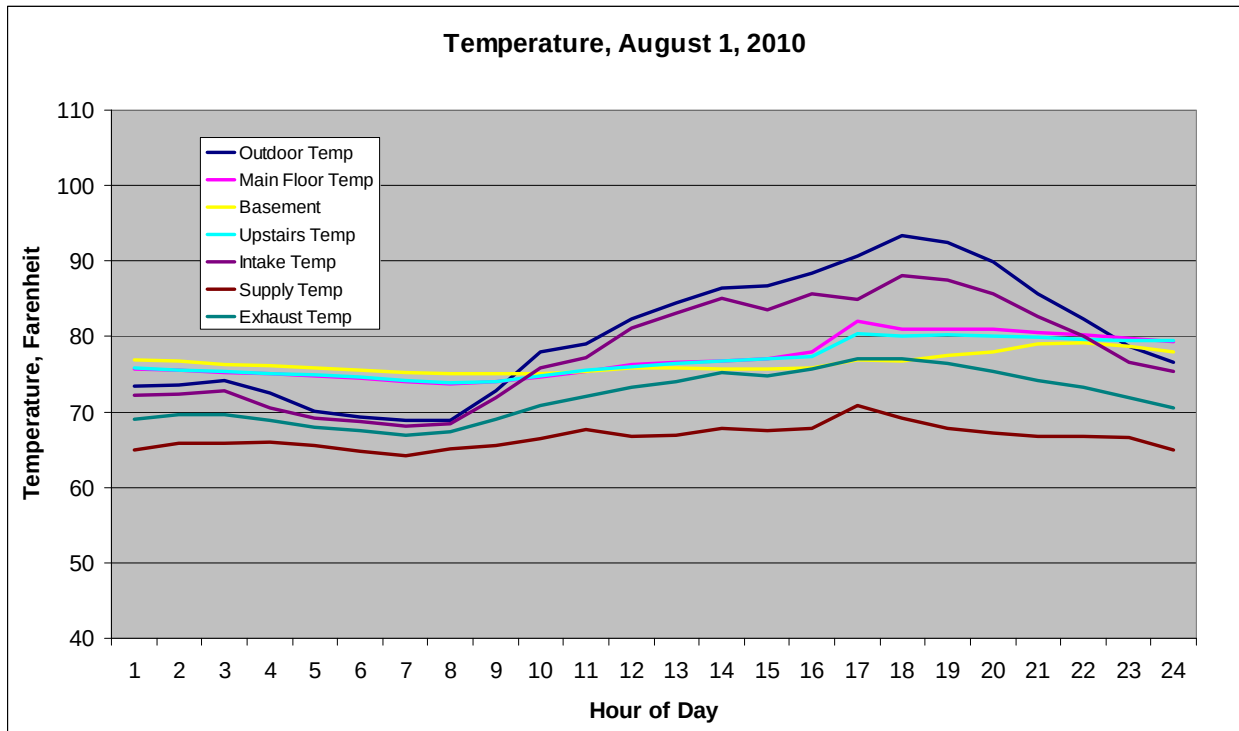


Figure 76. Cooling performance of OASys during a 36.95% outdoor relative humidity day in the Gold Medallion’s Newport House

Figure 76 shows the recorded temperatures during a 93.4 degree, 36.95% relative humidity day in the Newport House. The recorded temperatures in the main floor were around the mid- to high-70s, while the upstairs reached a high temperature of 82 degrees.

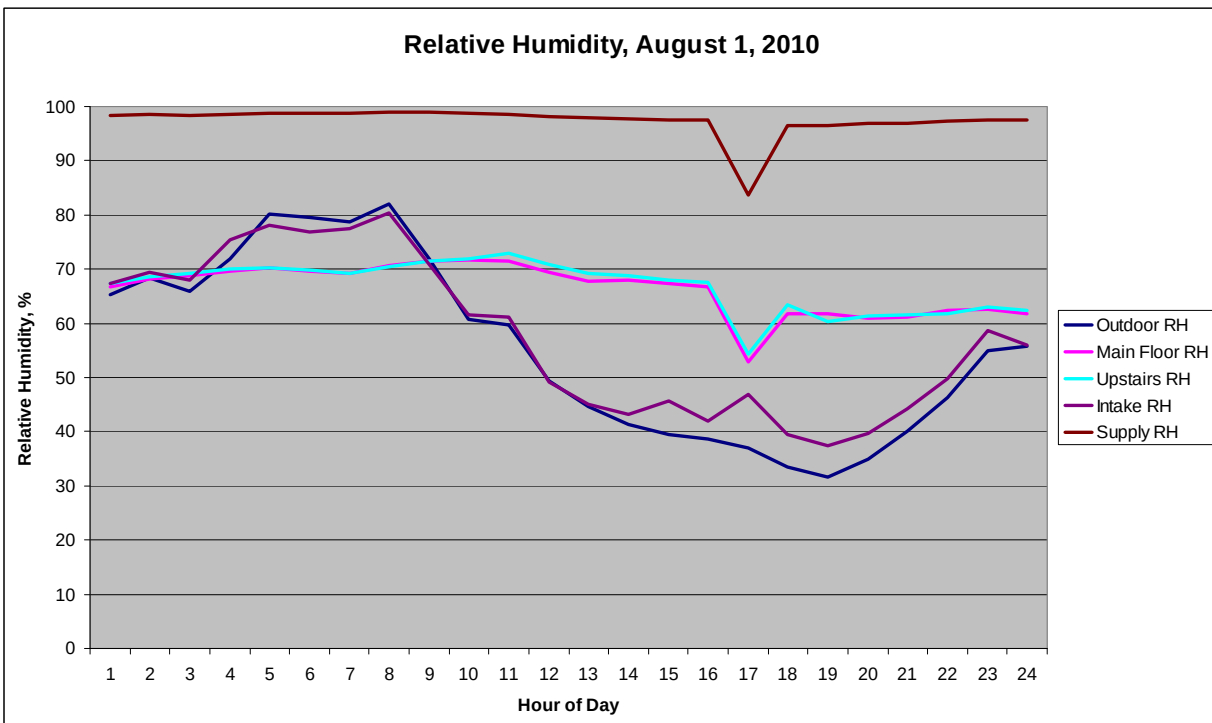


Figure 77. Cooling performance of OASys during a 36.95% outdoor relative humidity day in the Gold Medallion’s Newport House

Figure 77 maps out the relative humidity levels during the same 36.95% relative humidity day. The majority of the indoor relative humidity levels are between 60% and 70%, higher than the recommended 50% relative humidity range.

The recommended clearances to install OASys are one-foot at the sides and top, and two-feet in front of the water pump. This may become an issue in the scenario where OASys will have to be installed in the side yard, as space there can sometimes be limited. OASys can also be installed indoors, but to do so, a means to draw in outside air, usually requiring a large 18-20 inch duct from OASys to the outside, and a method to drain the water would be needed.

Because OASys uses a lot of water, counties and states where there is a water shortage might be hesitant to adopt evaporative coolers. OASys can use at least 6,400 gallons of water in a single summer.

Another gap that is present is the modeling of OASys in energy software. Energy software used were BEopt, EnergyGauge®, and TRNSYS. BEopt and EnergyGauge® both have trouble accurately modeling indirect/direct evaporative coolers such as OASys. Energy usage estimates were lower than the actual data collected. TRNSYS was able to provide a more accurate energy usage simulation.

TRNSYS was also able to simulate temperatures and relative humidity levels, as shown in final

report Appendix B. With outdoor ambient temperatures as high as 100 degrees, indoor temperatures oscillated between 68 and 77 degrees. The actual indoor temperatures maintained, as shown in [Figure 74](#), were around 70-77 degrees. Relative humidity levels were not as accurate. Living space relative humidity fluctuated between 50-60%, and in some cases, spiked as high as 75%. The estimates in the basement were even higher, as the simulations were between 60-80% and on some occasions peaked at 100%.

Heat Pump Water Heater (HPWH) Budget Period 3 (2010)

It is estimated that water heating accounts for 11% of the total energy consumption in the residential sector and accounts for approximately 12.4% of carbon dioxide emissions (U.S. Department of Energy, 2009 Buildings Energy Data Book [Figure 78](#) and [Figure 79](#)).

2.1.6 2010 Residential Energy End-Use Splits, by Fuel Type (Quadrillion Btu)											
	Natural Gas		Fuel Oil		Other Fuel (1)		Renw. En. (2)	Site Electric	Site		Primary Electric (3)
	Gas	Oil	LPG	Fuel(1)	En.(2)	Electric			Total	Percent	Primary Total
Space Heating (4)	3.57	0.66	0.24	0.09	0.44	0.37			5.37	46.0%	6.16
Space Cooling	0.00					0.79			0.79	6.8%	2.48
Water Heating	1.08	0.09	0.05		0.02	0.38			1.63	13.9%	2.45
Lighting						0.72			0.72	6.2%	2.26
Refrigeration (5)						0.45			0.45	3.8%	1.41
Wet Clean (6)	0.07					0.38			0.45	3.9%	1.19
Electronics (7)						0.39			0.39	3.4%	1.23
Cooking	0.22		0.03			0.11			0.36	3.1%	0.34
Computers						0.10			0.10	0.8%	0.30
Other (8)	0.00		0.16		0.00	1.26			1.42	12.2%	3.97
Total	4.95	0.75	0.48	0.09	0.46	4.95			11.68	100%	22.27

Note(s): 1) Kerosene (0.08 quad) and coal (0.01 quad) are assumed attributable to space heating. 2) Comprised of wood space heating (0.44 quad), solar water heating (0.02 quad), geothermal space heating (less than 0.01 quad), and solar PV (less than 0.01 quad). 3) Site -to-source electricity conversion (due to generation and transmission losses) = 3.14. 4) Includes furnace fans (0.19 quad). 5) Includes refrigerators (1.16 quad) and freezers (0.25 quad). 6) Includes clothes washers (0.10 quad), natural gas clothes dryers (0.07 quad), electric clothes dryers (0.80 quad), and dishwashers (0.29 quad). Does not include water heating energy. 7) Includes color television (1.23 quad). 8) Includes small electric devices, heating elements, motors, swimming pool heaters, hot tub heaters, outdoor grills, and natural gas outdoor lighting.

Source(s): EIA, Annual Energy Outlook 2008, Mar. 2008, Tables A2, p. 117-119, Table A4, p. 122-123 and Table A17, p. 143-144.

Figure 78. DOE Buildings Energy Data Book Table 2.1.6

2.4.3 2006 Residential Buildings Energy End-Use Carbon Dioxide Emissions Splits, by Fuel Type (Million Metric Tons) (1)									
	Natural Gas	Petroleum							
		Distil.	Resid.	LPG	Oth(2)	Total	Coal	Electricity (3)	Total Percent
Space Heating (4)	166.0	43.9		14.4	5.4	63.7	0.8	62.3	292.8 24.6%
Space Cooling	0.0							159.7	159.7 13.4%
Water Heating	57.3	7.7		3.5		11.2		79.2	147.6 12.4%
Lighting								142.5	142.5 12.0%
Electronics (5)								100.0	100.0 8.4%
Refrigeration (6)								88.6	88.6 7.4%
Wet Clean (7)	3.9							72.2	76.1 6.4%
Cooking	11.6			2.0		2.0		42.8	56.4 4.7%
Computers								12.5	12.5 1.0%
Other (8)				9.6		9.6		35.8	45.3 3.8%
Adjust to SEDS (9)								70.1	70.1 5.9%
Total	238.7	51.5		29.5	5.4	86.4	0.8	865.6	1,191.5 100%

Note(s): 1) Emissions assume complete combustion from energy consumption, excluding gas flaring, coal mining, and cement production. Emissions exclude wood since it is assumed that the carbon released from combustion is reabsorbed in a future carbon cycle. Carbon emissions calculated from EIA, Assumptions to the AEO 2008 and differs from AEO 2008, Table A18. Buildings sector total varies by 0.7% from AEO 2008. 2) Includes kerosene space heating (5.4 MMT). 3) Excludes electric imports by utilities. 4) Includes residential furnace fans (10.1 MMT). 5) Includes color television (62.2 MMT) and other office equipment(11.9 MMT). 6) Includes refrigerators (73.1 MMT) and freezers (15.6 MMT). 7) Includes clothes washers (6.7 MMT), natural gas clothes dryers (3.9 MMT), electric clothes dryers (47.7 MMT), and dishwashers (17.9 MMT). Does not include water heating energy. 8) Includes residential small electric devices, heating elements, motors, swimming pool heaters, hot tub heaters, outdoor grills, and natural gas outdoor lighting. 9) Emissions related to a discrepancy between data sources. Energy attributable to the residential sector, but not directly to specific end-uses.

Source(s): EIA, Annual Energy Outlook 2008, Mar. 2008, Table A2, p. 117-119, Table A4, p. 122-123 and Table A5, p. 124-125 for energy consumption, and Table A18, p. 144 for emissions; EIA, Assumptions to the AEO 2008, June 2008, Table 2, p. 10 for emission coefficients; BTS/A.D. Little, Electricity Consumption by Small End-Uses in Residential Buildings, Aug. 1998, Appendix A for residential electric end-uses; EIA, AEO 1999, Dec. 1998, Table A4, p. 118-119

Figure 79. DOE Buildings Energy Data Book Table 2.4.3

One technology that may prove beneficial in reducing both overall energy consumption and carbon emissions in the U.S. is the heat pump water heater (HPWH). Although the technology has been available for over twenty years and been widely used in Europe and Asia, the HPWH has been slow to develop in the U.S. market.

A number of factors may be accountable for this, including the reputation for unreliability, high costs, and a lack of widespread marketing for early units.

General Electric Company (GE) has released the GeoSpring™ hybrid HPWH in the U.S. market in the fall of 2009. With an increased ability to provide greater logistics and marketing than has been historically available for HPWH's, GE may be able to create a demand in the U.S. market that has not existed in the past.

Most conventional water heaters for the residential market today use either gas burners or electric heating elements to heat water for use in the home. The HPWH works similarly to a conventional heat pump by taking heat from the surrounding air and using it to heat low-pressure liquid refrigerant in the heat pump's evaporative coil, changing the liquid to a low pressure gas. The refrigerant then passes through a compressor which raises the pressure, and thus the temperature as well. The heated high pressure gas passes through the heat pump condenser where it gives off its heat and condenses back to a liquid state. The cooled liquid refrigerant then passes through an expansion valve where the pressure is reduced and the cycle is repeated.

The GeoSpring™ hybrid water heater unit uses a compressor to extract heat from the surrounding air and sends this heat through condenser coils which are wrapped around the water tank to transfer the heat into the tank and heat the water. The system relies on two 4,500 watt back-up heating elements, one upper and one lower, to heat water when ambient temperatures are inadequate to provide heat energy to the heat pump.

The GeoSpring™ has a controller that easily allows the end-user to switch between operating modes as well as a vacation mode to save energy when there is no hot water demand. It is Demand Response (DR) compatible which, when utilized may reduce energy consumption during peak periods.

The BIRA team is investigating hot water production using G.E.'s GeoSpring™ model # GEH50DNSRSA to determine energy savings. The test procedure is being carried out at a single-family residence in California Climate Zone 12. The home is a 3,500 square-foot, two-story, owner occupied home with four bedrooms and 3 ½ baths with two full time occupants.

The overall objective of this study is to evaluate the GeoSpring™, relative to the Stage Gate 1B criteria.

BIRA will also explore the possibility that the use of HPWH's can be as cost-effective as natural gas and open the possibility of using site generated renewable energy (PV) to generate hot water.

Key Results

Data collection began in September 2010. Monitoring equipment is in place and calibrated. Although there is not yet enough data to accurately gauge annual performance, results look promising as the homeowner has reported adequate hot water delivery. Preliminary data analysis suggests the water heater is operating close to the manufacturer's stated EF rating of 3.0 in EMode. The unit has been run only in EMode using the heat pump exclusively. Code approval, both prescriptive and performance would appear to be easily achieved. Installation of the unit was reported as being no more difficult than a typical electric water heater. The water heater has not been installed long enough to gauge reliability.

Gate Status

GeoSpring™ is currently in Gate 1B. Further monitoring is being done to obtain complete performance data.

Conclusions

Preliminary results look promising. The water heater has delivered adequate hot water in EMode since its installation. Installation was straightforward with no complications. No

apparent code restrictions would prevent the unit's installation in this jurisdiction.

"Must Meet" Gate Criteria - Source Energy and Whole Building Benefits

At the time of this report, BIRA installed the system, instrumented the HPWH to address research questions, calibrated all monitoring equipment and has begun to gather and analyze data.

Analysis of the data from the GeoSpring™ is focused on showing if the unit can provide reliable and adequate hot water for this residence on a year-round basis with proven energy savings over conventional tank type electric resistive and gas powered water heaters.

The operating environment of the system is also being measured by collecting temperatures of the ambient air and relative humidity near the hot water tank, cold water going into the water tank, and hot water coming from the tank. In addition, the gallons of hot water used will also be measured.

Performance of the system during the all seasons is also important and 12 months of monitoring are planned. Performance of the GeoSpring™ during the winter months is of particular importance.

BIRA received the GeoSpring™ early in 2010. The installation was scheduled for later in the year in order to continue data collection for the AirTap™ previously installed. The installation of sensors and dataloggers took place on Friday September 3rd, 2010. Tests to confirm that accurate data was being collected took place on September 24th. Preliminary results have shown that the sensors are gathering accurate data. At this time the unit is performing according to manufacturer's specifications. Preliminary data analysis consists of:

- Looking at total electrical energy consumed converted to MBtus
- Total flow in gallons
- Average daily Delta T between incoming cold water
- Hot water output for the month of October

The data shows an average ratio between input electrical energy converted to Btus and equivalent Btus stored in the hot water flow for the month at approximately 3.6 to 1 ([Table 114](#) and [Figure 80](#)). The manufacturer has informed BIRA that the unit performed at an EF of 3.0 when in EMode. The reason for the unusually high ratio is that there is a low average Delta T due to the ground water coming in at high temperatures. The water is supplied from a well and the storage tank is outside the garage. Given that the water spends a good deal of time exposed to ambient air conditions before going into the hot water tank, it seems reasonable that the cold water will normalize to ambient air temperature before being used.

Date	Electrical Energy Input converted to MBtus	Water Flow. Gallons	Delta T	Equivalent Energy Output In Flow (MBtus)	Ratio of Energy Input to Output
October 1, 2010	0.035	38	24.188	0.153	4.434
October 2, 2010	0.025	24	25.661	0.097	3.941
October 3, 2010	0.022	30	26.410	0.122	5.573
October 4, 2010	0.042	39	29.811	0.159	3.809
October 5, 2010	0.050	36	27.004	0.146	2.943
October 6, 2010	0.046	58	32.310	0.238	5.130
October 7, 2010	0.029	11	21.498	0.044	1.515
October 8, 2010	0.035	37	31.645	0.152	4.320
October 9, 2010	0.037	44	29.962	0.180	4.909
October 10, 2010	0.038	39	28.016	0.159	4.191
October 11, 2010	0.034	26	25.553	0.105	3.066
October 12, 2010	0.030	27	24.350	0.109	3.668
October 13, 2010	0.032	37	26.098	0.150	4.748
October 14, 2010	0.032	28	23.005	0.113	3.547
October 15, 2010	0.029	33	23.889	0.133	4.593
October 16, 2010	0.038	41	30.866	0.168	4.398
October 17, 2010	0.070	58	33.643	0.239	3.400
October 18, 2010	0.068	67	33.490	0.276	4.072
October 19, 2010	0.051	56	33.153	0.230	4.508
October 20, 2010	0.030	19	26.651	0.077	2.572
October 21, 2010	0.034	34	28.793	0.139	4.048
October 22, 2010	0.069	57	32.175	0.234	3.396
October 23, 2010	0.032	27	31.658	0.111	3.505
October 24, 2010	0.060	48	32.252	0.197	3.283
October 25, 2010	0.020	11	28.900	0.045	2.206
October 26, 2010	0.030	15	28.741	0.061	2.020
October 27, 2010	0.080	42	35.455	0.174	2.169
October 28, 2010	0.061	48	31.653	0.197	3.249
October 29, 2010	0.034	33	31.146	0.135	3.919
October 30, 2010	0.039	25	32.154	0.103	2.602
October 31, 2010	0.063	54	35.750	0.223	3.543
Month Total:	1.294	1142	905.882	4.668	3.607

Table 114. Ratio of energy input to equivalent energy output

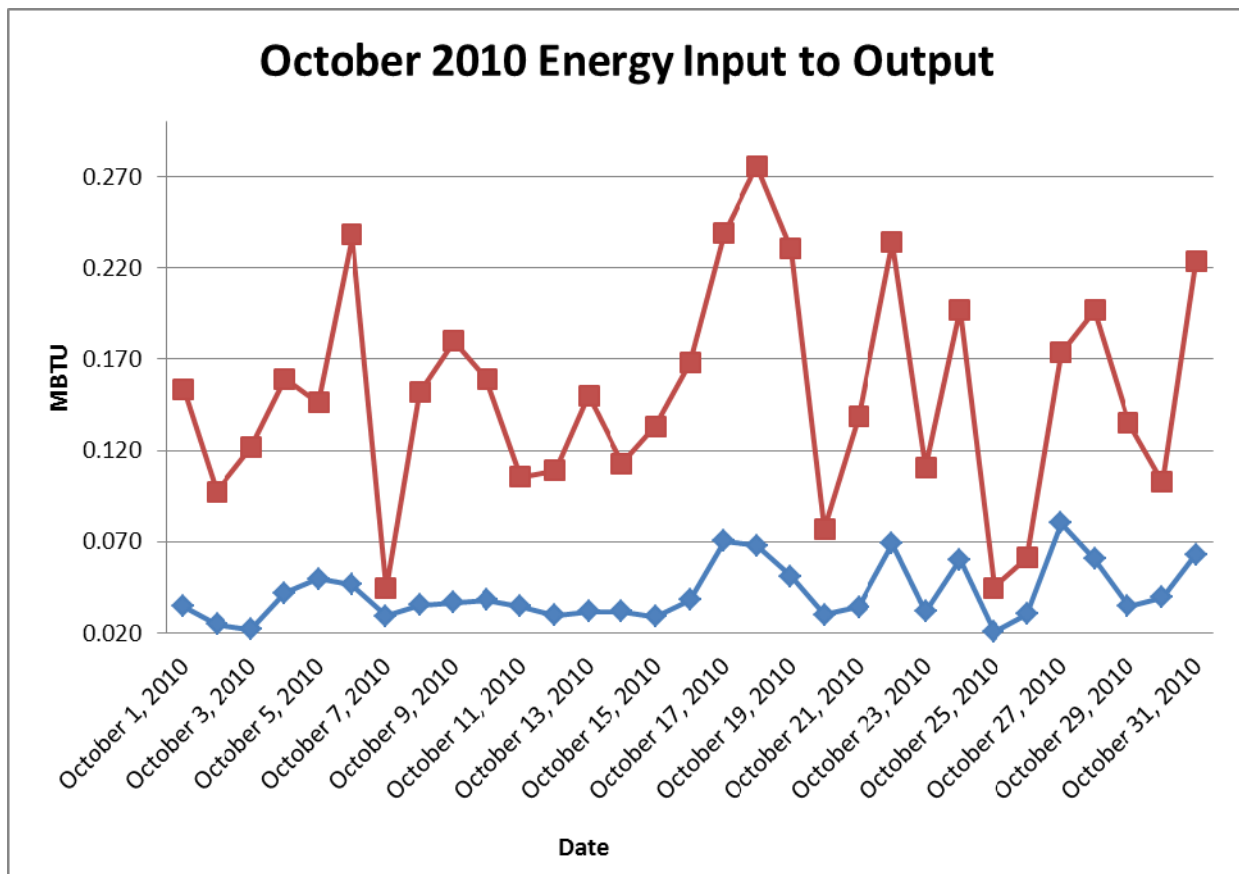


Figure 80. Graph showing energy input to output in MBtus

It is not BIRA's intentions to duplicate DOE's EF testing but to determine if there is a reasonable source energy savings under these specific test conditions. At this time the BIRA team is reviewing its data collection and analysis criteria.

BIRA will continue to test the overall energy efficiency, ability to consistently meet domestic hot water demands and cost advantage in a long term study.

"Must Meet" Gate Criteria - Performance-Based Code Approval

The 2006 IECC code, Chapter 4 Residential Energy Efficiency, Section 404 Simulated Performance Alternative establishes criteria for compliance using simulated energy performance analysis. The BIRA team will provide the results of a simulation using compliance software tools with the final report.

Table 404.5.2(1) Specifications for the Standard Reference and Proposed Designs states that the standard reference for efficiency for Service Water Heating when complying under section 404 be "in accordance with the prevailing Federal minimum standards."

The GeoSpring™ has an Energy Factor rating of 2.35 which exceeds both the minimum Federal

standards for resistive electric water heaters and the minimum ENERGY STAR® EF rating of 2.00 for heat pump water heaters.

“Should Meet” Gate Criteria - Prescriptive Based Code Approval

Concerning water heaters, prescriptive based code approval in the Uniform Plumbing Code (UPC) deals mostly in installation and venting issues. The two areas that relate directly to this unit would be UPC (Figure 81) First Hour Rating and sections 505.4 and 505.5, Pressure-Limiting Devices and Temperature-Limiting Devices.

The GeoSpring™ has a First Hour Rating of 63 gallons. Using UPC Table 5-1 (Figure 81 below), this First Hour Rating would be approved for use in a residential dwelling with up to two bedrooms and two and one half baths.

TABLE 5-1 ¹ FIRST HOUR RATING											
Number of Bathrooms	1 to 1.5			2 to 2.5				3 to 3.5			
Number of Bedrooms	1	2	3	2	3	4	5	3	4	5	6
First Hour Rating, ² Gallons	42	54	54	54	67	67	80	67	80	80	80

Note:
 1 The first hour rating is found on the “Energy Guide” label.
 2 Non-storage and solar water heaters shall be sized to meet the appropriate first hour rating as shown in the table.

Figure 81. UPC Table 5-1

Based on GeoSpring’s™ Underwriters Laboratory (UL) listing, file # SA32593 it will be assumed that the product meets UPC requirements for sections 505.4 and 505.5.

BIRA believes that all other prescriptive code requirements concerning installation can be met with minimal efforts and expense, are not outside widely accepted building practices and will not be addressed in this study.

“Should Meet” Gate Criteria - Cost Advantage

BIRA will obtain estimates from qualified contractors for installation of the GeoSpring™. Complete installation costs will be addressed in the final report.

The GeoSpring™ has a Manufactures Suggested Retail Price (MSRP) of \$1699.00. In the area the study is being conducted, the unit can be purchased from Sears or Lowes for \$1439.00.

Rebates and incentives for water heater replacement in this area include a 30% Federal Tax Credit (up to \$1,500.00) for ENERGY STAR® qualified appliances, California’s Cash for Appliances program offers a \$300.00 rebate for a contractor installed and permitted replacement of an old water heater with a HPWH, and Pacific Gas and Electric, the local investor-owned utility offers a \$30.00 rebate for electric water heaters that meet or exceed .93EF.

Assuming all current rebates can be taken, based on the price points above, the cost would be between \$677.30 and \$859.30 not including installation, permit or applicable recycling fees.

For comparison, some 50 gallon replacement electric water heaters that do not meet the requirements of the above rebate programs retail between \$283.00 with an EF of .90 (Whirlpool model #E1F50RD045V) to \$397.00 with an EF of .92 (U.S. Craftmaster #EE2H50HD045V) according to www.Lowes.com.

Since data collection and analysis has just begun. BIRA will report on overall cost advantage after more data is obtained.

“Should Meet” Gate Criteria - Reliability Advantage

The unit has been installed since early September of this year and data has been collected since mid-September. After long term testing BIRA will be able to respond long term reliability. It’s interesting to note that the only mode the unit has been run in to this point has been the “E-heat Mode” which operates using only the heat pump. Ambient temperatures have been mild, averaging in the mid 70 degrees Fahrenheit. So far the homeowner has reported adequate hot water and has not seen a reason to change operating modes.

The warranty is a ten year transferable, which meets or exceeds most water heater warranties on the market today.

“Should Meet” Gate Criteria - Manufacturer/Supplier/Builder Commitment

Based on the manufacturer’s current marketing, extended warranty for the product, and historical strategies when introducing new products, it’s anticipated that the manufacturer will devote sufficient resources to support its penetration into the market. BIRA will compile available evidence to substantiate the manufacturer’s commitment with the final report.

“Should Meet” Gate Criteria - Gaps Analysis

At present there have been not significant gaps in codes, installation, and performance. BIRA research in the winter and summer months may identify gaps in performance.

Subtask 2B.3 Expert Meetings (1 Minimum)

On Tuesday, Aug 19, 2008, the BIRA team hosted a Miscellaneous Electrical Loads (MELs) Experts' Meeting at the ACEEE Summer Study for Energy Efficiency in Buildings in Asilomar, CA.

The Building America Program aims to reach cost-effective Zero Energy Homes by 2020. As we progress toward this goal, we are facing several challenges. Two of these challenges are the influence of occupant on energy consumption and the rising consumption from "plug loads", such as consumer electronics. These challenges are typically not addressed by building scientists, architects and other such design professionals as they work to reduce the more traditional loads of water heating, lighting and space conditioning (heating and cooling). Figure 1 demonstrates the relative impact of MELs on whole house consumption. In a base case home, MELs represents 15% of the home's total consumption, while it jumps up to 25% in a Building America home that is 40% more efficient than the Benchmark.

The Building America Program is on a collision course with MELs in that they are the fastest growing load in the home and they are primarily due to consumer behaviors. Furthermore, simply installing PV systems on homes is not an appropriate mitigation measure for MELs. For reference, a typical 2 kW system installed on new homes in California produces 2,500-3,000 kWh a year matches *current* typical yearly MELs use, and MELs are on the rise. Building America teams are working to coordinate future work with the industry, as well as with each other, to collaborate on different approaches to reduce MELs.

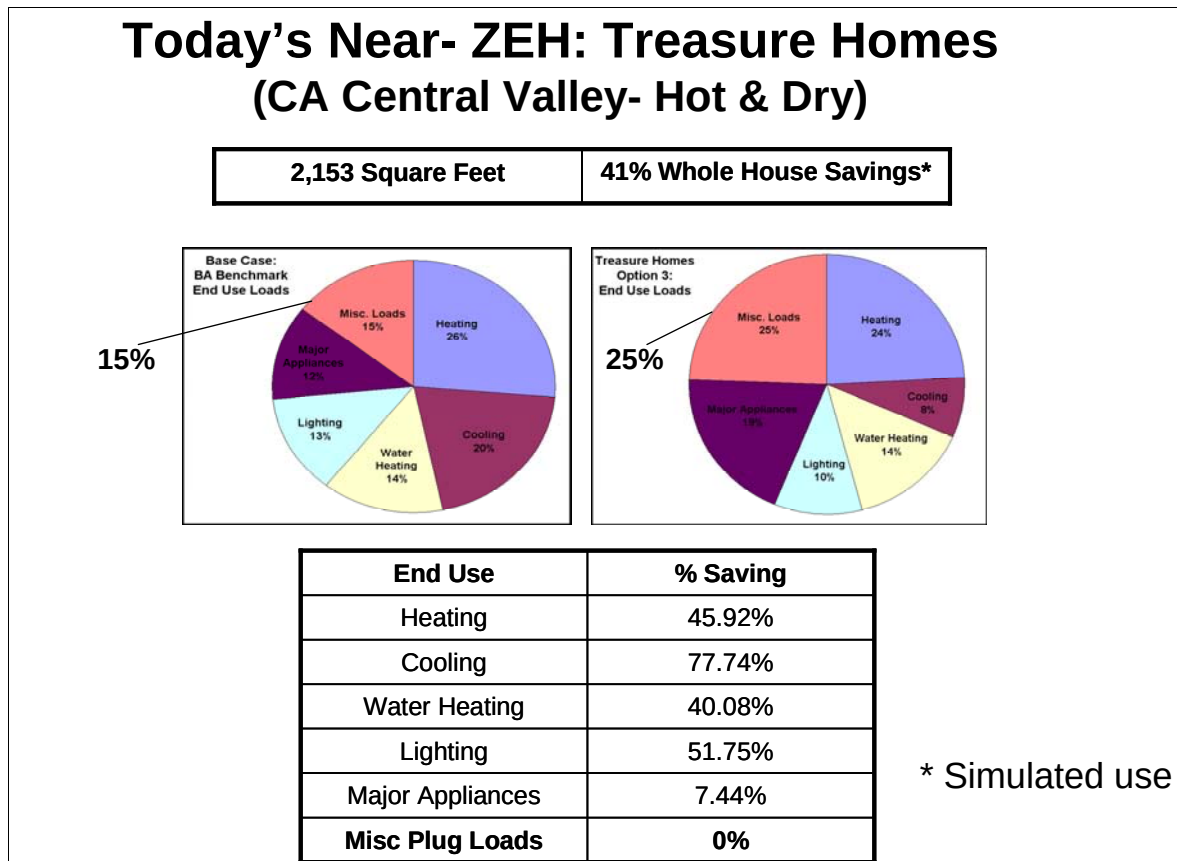


**Figure 82: Comparison of MELs Use
BA Benchmark Home vs. 40% Energy Efficient Home**

Objectives

The primary purpose of the BIRA MELs Experts Meeting was to assemble experts from different industries affecting plug loads, and to facilitate an open forum regarding systems, policies and strategies to mitigate MELs. The scope of the experts meeting included identifying:

existing research and practice aimed at MELs reductions
short (<5 yrs.) and long (>10 yrs.) term solutions
opportunities and synergies between industries & technologies
barriers, challenges and necessary research toward consumer friendly solutions

The meeting was moderated by BIRA Associate Program Manager Ryan Kerr and led by a group of panelists that directed the open discussion. Participants represented a wide range of interests and expertise in various areas of the industry. Attendees included:

1. Building America Teams
 - a. BIRA
 - i. ConSol

- ii. Washington State University (WSU)
 - b. Florida Solar Energy Center (FSEC)
 - c. Integrated Building and Construction Solutions (IBACOS)
 - d. Oak Ridge National Laboratory (ORNL)
- 2. National Labs/ BA Leadership
 - a. National Renewable Energy Laboratory (NREL)
 - b. Pacific Northwest National Laboratory (PNNL)
 - c. Lawrence Berkeley National Laboratory (LBNL)
 - d. United States Department of Energy (US DOE)
- 3. Energy Consultants
 - a. Ecos Consulting
 - b. Energy Solutions
 - c. Energy Trust of Oregon
 - d. Consortium for Energy Efficiency
 - e. Portland Energy Conservation, Inc. (PECI)
- 4. Energy Star
 - a. United States Environmental Protection Agency (US EPA) Energy Star
- 5. Utilities
 - a. Nevada Power Co
 - b. Ontario Power Authority
 - c. Southern California Edison
 - d. Bonneville Power Administration
- 6. Energy Efficiency Programs and State Energy Offices
 - a. Idaho Office of Energy Resources
 - b. Energy Center of Wisconsin
 - c. Colorado Public Utilities Commission
- 7. Local and State Officials
 - a. City of Lompoc, CA
 - b. Idaho Fish and Game

A full attendees list is available in the BIRA Task 2B.3 Expert Meeting Report.

Overview

The expert's meeting was to focus on past and current research done on MELs, as well as on systems used to control/mitigate MELs in homes. It was made clear that even though behavior is an important aspect to reducing MELs, it is not a part of the Building America scope. It was also expressed that while lighting, HVAC and large appliances were not to be included, plug load management and appliance communicating protocols might include controls of these features. Building America defines MELs as:

- Small appliances, e.g. electric razors, coffee makers and toasters
- Large "extra" appliances, e.g. freezers and 2nd/garage refrigerators

- Consumer electronics, e.g. TVs, stereos and home offices
- Hard wired features, e.g. security and alarm systems

Expert Panel

The panelists led the discussion with an overview of current work projects in the field of MELs. The panelists included: Rob Hammon, ConSol; Sarah Darby, Environmental Change Institute – Oxford University Centre for the Environment; Danny Parker, Florida Solar Energy Center; and Ren Anderson, National Renewable Energy Laboratory. (More detailed biographical information on the panelist is available in the full meeting report)

Rob Hammon began the discussion by categorizing the control systems for the various plug loads into three categories:

- 4) Home automation systems
- 5) Consumer electronics
- 6) Consumer behavior

Home automation and control systems may be a feasible solution to mitigating the impact of MELs. These systems will be interconnected with everything in a home, facilitating control of lighting, appliances, heating, cooling and even plug loads from a central location. This centralized monitoring of a home will help reduce unnecessary loads from, for example, a light left on in an unoccupied room. In addition, these home control systems can tie into demand responsive technologies and smart grids to further coordinate home energy usage with utility signals. This will relieve the burden to the consumer through reduced power infrastructure, and prevent future power shortages.

Consumer electronics must be addressed from the “top down”. Coordination between consumer electronic designers, manufacturers and the energy efficient industry must be conducted to reduce standby and phantom loads, as well as improve the overall efficiency of their products. Research has shown that using best-in-class appliances can already save 10-20% in miscellaneous electric loads, creating more efficient TV’s, set top boxes and computers will further improve that figure.

Changing consumer behavior to be more conscientious of energy consumption is another strategy for reducing MELs. Changes can be elicited from education material and feedback devices, helping home owners make informed choices towards living more energy efficiently. This can be achieved through educational material, like a Home Owner’s User Guide, explaining the energy efficient components included in Building America homes, and how to get the most out of them.

Ren Anderson wanted to empower occupants to become zero energy occupants. There are a lot of products coming out to target this area, and all of them are beneficial to improving occupant behavior. However, with all the products coming out, a protocol should be created to test the equipment and determine its practicality. In addition, the industry (research labs, Building America teams, builders, manufacturers and utilities) must coordinate their research efforts so that everyone is playing their part, ensuring common protocols, and preventing the repetition of tasks, as well as better transferring of information.

Danny Parker expressed that the “current BA program on a collision course with MELs” and that a 2 kW PV system really only reduces the MELs portion of energy consumption. Some pieces are hard to get at since an energy audit can only tell you so much like insulation, heating and cooling etc., but it neglects the minutia items like wall warts. He also expressed that feedback will be an essential piece to the puzzle.

Sarah Darby talked about the research currently being done in the U.K. She questioned whether a 60% carbon reduction is just pretty words from an ambitious government, or is it really possible? It is possible, but we must make allowance for consumer electronics. We’re not necessarily talking about zero energy homes, but rather zero non-renewable energy homes that are “organisms” that don’t use renewable fuels. What kind of difference would it make if they had feedback to see how their home is working as an organism? She gave a great example of historic “feedback” devices, in the “old days, people would look at their wood piles to take stalk on their reserves”. This simple feedback system required the proper budgeting of limited resources, or else freeze.

Sarah was skeptical about home automation, claiming that reducing loads from a high baseline is not creating a low energy consuming home. Feedback, on the other hand, will be very important as it satisfies the short term objective of immediate savings as well as longer term objectives of fostering more critical thinking as it relates to buying and energy use decisions and ultimately creating householders that are more aware of their energy use.

Sarah’s final idea was to think about starting choice editing, a nice way of saying some things should never leave the drawing board. An “environmental health check” prior to production if you will, for electronics that use way more resources than an item of that class should e.g. many plasma TV’s). Her rationale was that by preventing energy hogging appliances/consumer electronics from entering the marketplace, they wouldn’t become a future MELs load.

Open Discussion

Consumer Electronics

As the discussion was opened up to the floor, consumer electronics became a large target for discussion. Consumer electronics have come a long way in reducing standby loads and improving their efficiencies; however, they are still a major contributor to MELs. Many ideas

were thrown around to reducing consumer electronics loads. Redundant items like clocks and displays that are always on could be removed; more “all-in-one” appliances could be developed to increase conveniences, and use less energy. For instance an all-in-one cable box, DVD player and stereo receiver would reduce 3 loads into one, making it easier to manage.

Antagonizing consumer electronics slowly turned into a debate as Douglas Johnson, a representative from the Consumer Electronics Association, defended consumer electronics. Douglas has been working with the consumer electronics industry, and expressed how the industry has been working hard to reduce the loads of their electronics and to install minimal load standby modes. Energy Star is working with designers throughout the industry to create protocols and standards for future hardware developments. He also cautioned the villainization of the items that people most prize in their homes. Finally, he expressed how it was more useful if the consumer electronics loads were broken out into distinct categories. This would allow for much better targeting of specific loads, rather than painting all MELs with a broad brush. This would result in a much better understanding of the trends from specific groupings to make better judgments and controls. This sentiment was shared by others in the room.

Feedback

Feedback was a topic that received a lot of attention during the experts meeting as well. Feedback is a very simple technology that would provide a more immediate usage information as compared to the monthly home energy bill. Feedback devices allow the occupants to see the immediate energy impact from large appliances as well as MELs. An analogy was made with feedback devices, comparing them to a scale: if you can see the total “weight” of your consumption (especially if in monetary terms), the more you will want to cut down on consumption.

Manufacturers of feedback devices have two main audiences, utilities (feedback programs) and builders who want to put these in their new homes to help their clients control devices in their homes, and, secondarily, manage their energy usage. Perhaps feedback devices as simple as an outlet cover with LED indicator to display relative usage (red yellow green) would be sufficient in fulfilling both Gate 1B “must meet, should meet” criteria while being user friendly. Unfortunately not much research has been done in the area of feedback, and the participants all agreed that more should be done soon.

Education was another important category discussed in conjunction with feedback. As occupants and home owners became more aware of their energy usage, education becomes more and more important to help them identify what’s consuming so much energy, and what can be done to reduce their consumption. Education could come in the form of pamphlets or newsletters, or even a home owner’s user manual. In a new Building America home, the user manual would identify the energy efficient components in the home, how to maintain them and how to get the most savings out of the house. In a retrofit application, the user manual

could identify areas where the home could be upgraded for the most cost effective energy saving solutions.

Controls

Whole home automation did not receive as much optimism as other, simpler methods to mitigate MELs. Home automation can have a large sensor electrical draw, reducing its effectiveness at reducing MELs. In addition, home automation can be difficult to program and maintain, reducing home owners to shutting off the entire system (i.e. programmable thermostats). The participants agreed that home automation should allow full control of all systems, but have “modes” to optimize energy usage. Sarah Darby’s research study in the UK will help uncover the impacts of whole house controls, and whether the technology can be successful in reducing MELs.

Conclusions and Next Steps

The expert’s meeting went very well and garnished a lot of support from all parties of the industry. Two key partnerships were fostered as a result of the meeting, Douglas Johnson from the Consumer Electronics Association, and Sarah Darby from the Environmental Change Institute - Oxford University Centre for the Environment. Working with Douglas will be instrumental in accessing the consumer electronics industry, and determining a solution from the conceptual stages to reducing MELs. Sarah Darby will provide invaluable information from case studies being performed throughout Europe, which has been progressive in its response to energy efficiency and conservation.

The expert’s meeting exposed many gaps in the MELs area, but it also exposed the numerous possible solutions to combating the problem. Electronics are the biggest problem to MELs, but systems like smart power strip and house automation controls, feedback devices, and education for behavior change can all be used to mitigate their MELs impact. Much needs to be done in the area of MELs, so everyone is eager to begin coordinating research efforts to make an impact in this area. As the Building America Program progresses through its milestones, it will be increasingly important to find a way to mitigate MELs loads.

Expert’s Meeting Action Items

As the expert’s meeting drew to an end, next steps were developed to initiate collaboration and cohesion in research goals:

Get the word out to builders: tell them how to make MEL areas as efficient as possible.
Keep up with consumer electronic and controls trends and knowledge
Perform end-load use research (more up to date than the TIAX report)
Assess the different feedback and control mechanisms - Study “ergonomics”, what’s too much information vs. what’s just right

Develop an owner's manual for homes

Implement a rating system to compare energy bills among community residences. Since monthly energy bills are not usually a conversation piece, this will help homeowners compare their bills with the community average and encourage them to reduce their monthly consumption.

Implement a standard with the appliances and consumer electronics industries to allow for greater customization of individual components. The result of this effort will be electronics with zero phantom loads.

Increase dialog with Sarah Darby and her UK projects. Follow up with the project's results and coordinate future research efforts.

BIRA Next Steps

Many gaps were identified during the Expert's meeting, and it was very encouraging to see the industry come together to explore different solutions to the growing problem of MELs. BIRA will begin working on two areas that received a lot of discussion during the experts meeting: feedback systems and an energy efficient home "user manual".

Introducing easy to install and simple to use feedback systems into Building America homes has the potential to combat the MELs problem, as well as create more conscientious home owners. The "user manual" will educate home owners on how to efficiently run their home in a comfortable manor. The two areas work very cohesively as the feedback system provides immediate results from behavioral changes, and together they will help reach the Zero Energy Home milestone.

Subtask 2B.5 WSU Heat Pumps

BIRA supported the State Technology Advancement Collaborative (STAC) heat pump research through partner WSU, and other regional partners. BIRA has a strong presence in the Pacific Northwest (PNW) offering many opportunities for marine and cold climate Stage Gate research. This region offers a progressive policy of incentives and regulation that promotes community level BA projects and informs work in other parts of the country.

Acknowledgements for the STAC project can be found beginning on Pg. i of the STAC report.

Scope of Report

This Gate 1B Report will focus on the findings of the State Technology Advancement Collaborative (STAC) Residential Heat Pump and Air Conditioner Research and Commissioning Training Development Project²² and how the results and conclusions of this project should be

²² As summarized in the STAC report titled "Residential Heat Pump and Air Conditioner Research, Demonstration, and Deployment Improving Pacific Northwest Utility and State HVAC Programs".

incorporated into the Building America Program. This work is accomplished with BIRA's many Pacific Northwest partners, led by WSU Energy Extension Office.

Background and Summary of STAC Project

Background

In 2001, Pacific Northwest utilities began promoting the installation of heat pumps as efficiency measures. Evaluations of the heat pump programs found that most systems were not performing to specifications, primarily due to duct leakage, premature compressor shut-off and unnecessary auxiliary heat usage.

Based on this analysis, the Regional Technical Forum (RTF) - a standing committee established by the Northwest Power and Conservation Council - adopted prescriptive standard that required minimum heat pump efficiencies and duct sealing and recommended, but did not require, performance testing and control changes. At the same time, a separate performance standard for heat pumps, called Performance Tested Comfort Systems (PTCS), was developed through the Northwest Energy Efficiency Alliance; the PTCS standard included requirements for duct sealing and testing along with requirements on setpoints for auxiliary heat and compressor lockouts.

These two standards were adopted between 2001 and 2004 as the requirements for various regional incentive programs; in some cases, separate incentives were offered for each of the two standards. Two separate studies were performed in 2004 and 2005 that continued to show underperformance of heat pump systems in the region. As a result of these findings, the PTCS standard was revised to include, amongst other changes, requirements for proper sizing, auxiliary lockout to 35°F, airflow testing and refrigerant charge verification.

The new PTCS standard was adopted by the Bonneville Power Administration (BPA) in 2006. Additionally, BPA began increased training, feedback and QA practices. Barriers identified by BPA included complexity of requirements and difficulty of mandatory field tests. Inspections revealed major issues with duct sealing, airflow, control settings (including those for defrost and auxiliary heating) and CO alarm installation.

Description of STAC Project

In March 2006 the STAC Residential Heat Pump and Air Conditioner Research and Commissioning Training Development Project was launched. The project was developed to (1) evaluate "out of specification" performance of air-source heat pumps, (2) perform field inspections and monitoring on existing systems in the heating-dominated Pacific Northwest, which includes both cold and marine climate zones and (3) determine how to improve the sizing, installation and commissioning standards for heat pumps in the region.

The project was launched under a contract with the National Association of State Energy Officials. The Idaho Office of Energy Resources managed the project. State collaborators were the Oregon Department of Energy and the Washington State University Energy Program. The main technical contractor was Ecotope, Inc. of Seattle, Washington and Portland, Oregon. Subcontracting to Ecotope was Purdue University's Herrick Laboratory for bench testing of heat pumps and Stellar Processes for monitoring assistance and development of short term testing equipment and software.

The project began with laboratory testing and software modeling to evaluate off spec (e.g. charge and air flow variation) performance of heat pumps because manufacturers are not required to report such information. Field testing and long-term monitoring was conducted to evaluate the performance of installed systems and identify any sizing, installation and commissioning problems. Lessons learned were used to develop improved heat pump standards, based on the PTCS standards, and additional training and reference materials. Finally, a cost study was performed on heat pumps installations and commissioning.

Findings and Conclusions

The laboratory testing and software modeling revealed that while heat pumps were generally tolerant to moderately reduced airflow or minor variations in refrigerant charge, further deviations can cause significant problems. These impacts are also not uniform between heating and cooling mode or when using different types of refrigerant. For example, in cooling mode at high temperatures, systems can suffer from complete compressor shut-down; when using the generally less tolerant R410a refrigerant, however, this failure tended to occur at temperatures well below those seen in typical cooling climates.

Field inspections and monitoring revealed significant installation issues that impaired the effectiveness of the heat pumps. Some issues were readily identified, though others were discovered through analysis of the monitoring data. These issues included poor duct installation, malfunctioning TXVs and improperly configured controls for system defrost and auxiliary heat system start-up. The malfunctioning TXV had to be replaced in order provide any effective cooling. The control systems needed to be set to properly limit defrost power and switch over to auxiliary heating at the correct temperature; otherwise the system was calling for electric resistance heat when the compressor still had useful capacity. These findings alone emphasized the need for proper commissioning. The project determined that, had these heat pump systems been sized, installed and controlled properly, they were capable of average annual heating COP of 2.5 in climates ranging from 4,000 to 5,400 heating degree days.

The STAC study identified short-comings in the current training for and execution of heat pump sizing, installation and commissioning. The regional PTCS standards were amended to include the findings of the STAC study. The primary additions were TXV diagnosis and proper defrost settings and troubleshooting. A Heat Pump and AC Commissioning Form was developed, based on the existing PTCS form. The STAC form expanded the protocols to include air conditioners;

facilitated the use of the subcooling test (for more precise testing of units with TXVs); included a mandatory split temperature test (to help detect a malfunctioning TXV) and a calculation for heating and cooling output (to be compared to manufacturer's stated outputs); and required checking of the amount of auxiliary heat to come on with the defrost and limiting the defrost to 5 kW. Next, a Field Commissioning Booklet for Heat Pumps and Air Conditioners was developed. This can be used with the widely popular Northwest Duct System Diagnostic Field Guide. A training video was also developed, following the Heat Pump and AC Commissioning Form, in order to increase the effectiveness of contractor education. The training video also highlights the findings of the STAC study. Finally, the diagnostic system developed for the field testing portion of the STAC project could be utilized to troubleshoot installations and provide additional assistance and training to installers. This still needs to be developed into a publicly available product before it can be incorporated into the production market.

The cost study found that commissioning typically cost around \$225-\$350. David Baylon of Ecotope used this data to analyze the cost-effectiveness of commissioning, which has been used to reexamine the cost-effectiveness of heat pumps and to promote the creation of stand-alone incentives for commissioning. Demonstrating the importance of commissioning, regional incentives are now available for commissioning of all heat pumps, including minimum code models.

"Must Meet" Criteria - Source Energy and Whole Buildings Benefits

The use of proper heat pump sizing, installation and commissioning protocols will help to eliminate many of the issues that result in subpar system performance. In this manner, the implementation of these protocols will provide both source energy savings and whole building performance benefits (in the form of improved home comfort) compared to systems installed without the protocols. Source energy savings will be realized as performance impediments are identified and resolved prior to occupation of the home. Home comfort will be improved as the properly installed systems will be able to better handle extreme weather conditions.

The STAC report estimated savings from proper commissioning of air-source heat pumps (exclusive of savings gained from typical set-up practices) ranged anywhere from around 250 to over 500 kWh/yr. These results were based off of an estimate of a 5% improvement to compressor efficiency due to commissioning; this is basically a measure of how "out of compliance" systems are without proper commissioning. The 2200 sq. ft. model home was run in six different locations ranging from mild (Roseburg, Oregon) to cold (Jackson Hole Wyoming) climates, representing the sites used for the field inspections. This analysis also benefited from the use of a thermal simulation model (SEEM) that had been improved as part of earlier results in the STAC study. Full results and modeling assumptions can be found beginning on Pg. 18 of the STAC report. The report did not, however, look at demand (kW) savings.

Peak electricity demand has not typically been an issue in the PNW. Without large cooling loads, and with significant hydro power resources, the region does not have summer peaking

issues like many parts of the country. However, there is evidence that with large numbers of heat pumps there is the real possibility of early morning peaking as the night setback transitions to the day time setting and the thermostat calls for heating. The commissioning protocols discussed in the this report can be a significant mitigating factor toward avoiding this issue as peaking problems are caused from the misuse of electric resistance back-up heat (controls, settings issue).

“Must Meet” Criteria - Performance-Based Code Approval

Given that heat pumps are a mature technology, and this research focuses on optimizing off the shelf technologies, there are no code issues at this time to discuss.

“Should Meet” Criteria -- Prescriptive-Based Code Approval

Given that heat pumps are a mature technology, and this research focuses on optimizing off the shelf technologies, there are no code issues at this time to discuss.

“Should Meet” Criteria -- Cost Advantage

The incremental cost associated with heat pump commissioning will depend heavily on the protocols being specified, local or regional requirements and what individual contractors consider “standard practices”. Theoretically, these would be the same drivers for energy savings from commissioning. In other words, as incremental cost goes up or down from case to case, so would your estimated energy savings.

Incremental costs for the PTCS (or comparable) commissioning were obtained from two sources: the Oregon Tax Credit, including data on 435 installed systems, and a STAC mail survey, including responses from 37 installers. Incremental costs for the Oregon Tax Credit ranged anywhere from \$15 to \$900 (average \$225); for the STAC mail survey, costs were between \$100 to \$800 (average \$345). Using an incremental cost of \$350, the expected payback would generally be under three years for the regions examined in the STAC project, based on expected kWh savings. Payback and cost-effectiveness will additionally vary by regional utility prices. There is anecdotal feedback from WSU suggesting commissioning should cost no more than \$250 after contractors are trained.

“Should Meet” Criteria -- Reliability Advantage

The reliability of heat pump commissioning will depend on the complexity of requirements, effectiveness of training, availability of reference and support materials and the degree of quality assurance.

If performed properly, the commissioning will improve the reliability and durability of the heat pump system. Ease of operation could also increase as the heat pump performs to

manufacturer specifications, potentially requiring less overrides by the homeowner. All of these are net added values for new homes.

There is also the concern that settings from commissioning could be changed, thus reducing or even eliminating the energy and cost benefits. There are three main components of the commissioning standards: control settings, air flow and refrigerant charge. These components are all difficult or impossible for untrained homeowners to alter, and thus are likely only to be modified by a service technician in the event of comfort complaints. Once the system is commissioned, persistence of commissioning settings should be a function of comfort. If there are no comfort issues, there is no motivation for a technician to alter settings. A small sample of interviews with occupants using commissioned systems has shown no major comfort complaints.

One additional way to help ensure comfort is to reduce duct leakage to unconditioned space by either placing ducts in conditioned space or properly insulating and sealing them using Building America specifications or similar. One or the other will be mandatory in Washington's upcoming code, largely driven by BIRA's research on ducts inside conditioned space. An improved duct system will reduce or eliminate the concern of cold blow, a common comfort complaint in heating climates. When the system is in defrost mode, conditioned air remains in the supply ducts until the defrost cycle ends or the auxiliary heater is turned on. A poorly insulated duct system will readily conduct heat out of this conditioned air; a leaky system will gradually replace it with cold, unconditioned air. This will result in cold air blowing from the registers for a period of time after system start-up. With a properly designed and installed duct system, this concern is greatly mitigated.

"Should Meet" Criteria -- Manufacturer/Supplier/Builder Commitment

The primary commitments required would be those of the builder, relevant subcontractors and any necessary enforcement agencies. The efforts in the Northwest have created and improved commitments from subcontractors, utilities and energy offices. Such efforts would need to be repeated in other regions prior to being utilized in prototype homes there.

The STAC team has received positive reaction from Honeywell's thermostat division. The current Honeywell heat pump thermostats do not allow electric resistance lockout below 40°F, when the recommended balance point is between 30-35°F (PTCS calls for lockout to 35°F). WSU is working with a receptive Honeywell to alter this. WSU is also working with ASHRAE to integrate lessons learned from the STAC report; this work is led by Michael Lubliner.

"Should Meet" Criteria -- Gaps Analysis

The STAC study, along with its predecessors, demonstrates two main problems facing heat pumps today: incomplete system sizing, installation and commissioning protocols and poor implementation and enforcement of these standards. These problems may be caused by many

factors including complexity of the requirements, lack of proper training and support and insufficient incentives to follow the standards (or disincentives for not properly following them). While the protocols are gradually being addressed through research such as the STAC heat pump study, the standards being developed have been crippled without proper oversight.

In order to incorporate these findings into the Building America Program there are four main steps that must be taken:

- 1) BA-sponsored research efforts must be expanded to other regions (such as cooling-dominated or mixed climates) where heat pumps are or can be effectively utilized.
- 2) The results of these efforts, including improved protocols and additional training materials, must be incorporated into existing NAHB Research Center (RC) scopes of work and other Building America commissioning standards and training practices. Along with NAHB RC scopes of work, this information may be suitable for Building America Best Practices related to the larger Pacific Northwest (Cold and Marine Climates). BIRA will be in close coordination with PNNL during the process to update the Marine Builders Challenge/Best Practices Guide.
- 3) The benefits of proper heat pump sizing, installation and commissioning need to be considered for inclusion into future Building America modeling software (e.g. BEopt).
- 4) Mandatory quality assurance protocols should be considered for heat pumps installed in any BA project in order to ensure that the new standards are being followed.

Task 3: Stage Gate 2 -- Prototype House Evaluations

3.1 Design, Analysis, and Test Plans for Stage Gate 2 House Projects in Multiple Climates (Marine, Hot/Dry, and Cold)

The objective of these evaluation plans is to provide documentation of BIRA's test and analysis plans for evaluating prototype homes against the Stage Gate 2 "Must Meet" and "Should Meet" criteria. The plans provide key contact information, information about the home design and its energy analysis. These plans identify the advanced features, project schedule, and solicit any assistance needed from the NREL technical team.

The goal of BIRA's testing is to determine how well the advanced systems in these home integrate with production building practices and whether the homes meets the Stage Gate 2 "Must Meet" and "Should Meet" criteria.

The homes identified for Stage Gate 2 Design, Analysis and Test Plans are shown in the table below.

House/Location	Builder/Contact	Advanced Features	Target WHES/Climate
<i>Budget Period 1 (2008)</i>			
Citihouse II Fresno, CA	AlvisProjects, Inc. Marlin Alvis	SunCache Solar Water Heating, CSIP Walls	50% Hot/Mixed
"Newport" South Jordan, UT	Kennecott Land Gold Medallion	PVT, SIP and Oasys Evap Cooler	40% Cold
"Liverpool" South Jordan, UT	Kennecott Land Liberty Homes	N/A	40% Cold
"Carmichael" South Jordan, UT	Kennecott Land Holmes Homes	N/A	40% Cold
"Craftsman" South Jordan, UT	Kennecott Land Rainey Homes	Bosch Solar Hot Water System	40% Cold
NextGen, Las Vegas, NV	NextGen	ICF Walls, 2 Speed Heat Pump hybrid system, LED lightings, electric tankless WH	50% Hot/Mixed Dry

Kent Model 2294 Vancouver, WA	New Tradition Homes	Ducts in Conditioned Space	50% Marine
Martha Rose	Martha Rose	Ducts in Conditioned Space	50% Marine
<i>Budget Period 2 (2009)</i>			
Artistic Homes Albuquerque, NM	Artistic Homes Tom Wade, Principal, Artistic Homes Tom@ArtisticHomes.com	PVT system, Verve whole house lighting, outlet control system, with feedback display	50% Hot/Mixed Dry
Snow Creek Cottages Park City, UT	R & O Builders Ogden, Utah 933 Wall Ave. 84404 (801) 627-1403 Fax (801) 399-1480	SIPs exterior walls and roof, PVs, geothermal systems, solar hot water, HRV	50% Cold
GEOS Solar Cottage Arvada, CO	GEOS Homes Norbert Klebl norbert@discovergeos.com	Earthlinked DX GSHP for space heating, cooling and DHW, RecoupAerator 200DX ERV with EarthTubes	50% Cold
David Cohan SIPs House Portland, OR	David Cohan	SIP walls, solar water heating, high efficiency mini-split ductless heat pumps, green roof design	50% Marine
Forest City, HI NZEH Kaneohe Marine Base	Forest City, HI Will Boudra, Development Manager Forest City Hawaii Military Communities, LLC WilliamBoudra@forestcity.net	Verve Living Systems lighting controls and demand response, solar hot water	50% Hot- Humid
Forest City, HI Mololani Waikulu, Kaneohe Marine Base	Forest City, HI Will Boudra, Development Manager Forest City Hawaii Military Communities, LLC WilliamBoudra@forestcity.net	All around energy efficiency package, Verve Living Systems lighting controls	50%+ Hot- Humid

		and demand response, solar hot water	
<i>Budget Period 3 (2010)</i>			
New Tradition Homes “Parade Home” Ridgefield, WA	New Tradition Homes Steve Tapio, Quality Control Warranty Manager and Building Science Team Leader Steve.tapio@newtraditionhomes.com (360) 448-4714	Tankless HW, Two (2) high efficiency mini-split heat pumps, Heat recovery ventilator (HRV)	50% Marine
Artisan Groups Olympia, WA	Artisan Groups Tessa Smith tessa@artisansgroup.com (360) 870-6280	Tankless WH, Solar Hot Water, Energy recovery ventilator (ERV)	50% Marine

Table 115: Stage Gate 2 Design, Analysis and Test Plans

New Tradition Homes: 50% Marine Prototype Evaluation Plan

New Tradition Homes (NTH) is constructing a Building America (BA) 50% Marine prototype home in Ridgefield, WA. This “Parade Home” will be the focus of this Building America Stage Gate 2 evaluation plan. (Stage Gate 2 Performance requirements can be found in Appendix A of the final report.) The builder is committed to working with the Building Industry Research Alliance (BIRA) and will be working with the team through the entire BA Stage Gate process with the goal of building energy efficient, cost-effective and marketable homes. The builder will collaborate with a team of experts and other stakeholders throughout the process of building these energy efficient homes.

Background

New Tradition Homes (NTH) was started as a family business in 1987 by Alvar and Nancy Helmes. The company has grown to be one of the largest homebuilding companies in Clark County, Washington. In 2006, NTH decided to build all of its homes to Northwest ENERGY STAR® and Earth Advantage standards, and is currently participating in the Department of Energy’s Builders Challenge. In addition to participating in this current BA study, NTH successfully completed a 40% Marine community level project in 2008, which is documented in the “Landover Commons” case study.

In 2007, NTH won the Regional ENERGY STAR® Builder of the Year award from Northwest ENERGY STAR®. These distinguished awards demonstrate that NTH has a strong commitment to energy efficiency which is also validated by the fact that they have their own building science team that

continues to strive for more energy efficient and higher quality homes.

The prototype of this study is priced at \$399,000, and generally would be targeted at middle class homeowners or first time buyers looking for a high quality home. The home was featured in the 2010 Clark County Parade of Homes in Ridgefield, WA, which is sponsored by the Building Association of Clark County. Clark Public Utilities provides electricity and Northwest Natural provides natural gas. The prototype was originally developed in 2008, but due to slowed market conditions, the home was not constructed until 2010 with some modifications.

For more information on NTH, contact Steve Tapio, Quality Control Lead at Steve.Tapio@NewTraditionHomes.com or visit their website at: www.NewTraditionHomes.com.

"Parade Home" Location

The NTH prototype “Parade Home” is located in Ridgefield WA near Pioneer St. and NW 31st Ave.

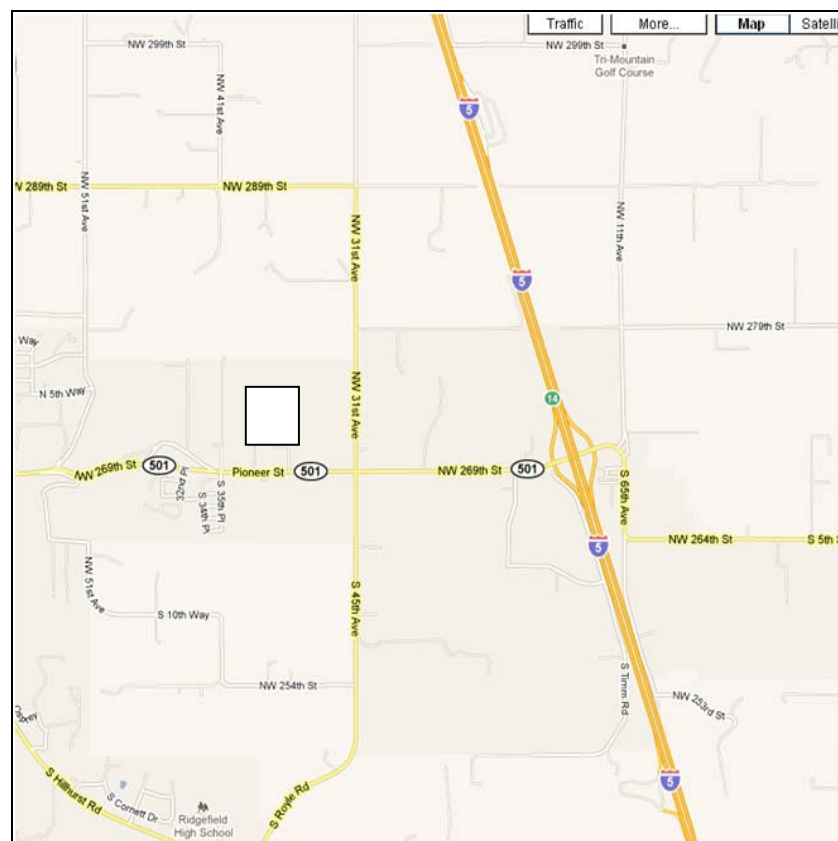


Figure 83. NTH “Parade Home” location

The picture below is of the home under construction. Floor plans can be found in evaluation

report Appendix C.



Builder: New Tradition Homes

Total Sq. Ft: 1811

Bedrooms: 3

Baths: 2 ½

Selling Price: \$399,000

Figure 84. NTH “Parade Home”

Climate

The building site in Ridgefield, WA is about 15 miles north of Portland, OR and has similar climate conditions. The average minimum temperature in the winter is 34.8°F and the average maximum summer temperature is 78.0°F. Average precipitation in Portland is 30 inches annually.

Annual Average Maximum Temperature	78.0°F
Annual Average Minimum Temperature	34.8°F
Annual Average Total Precipitation	30 inches

Table 116. Portland, OR annual climate data

Average Temperatures			
Winter (°F)	Spring (°F)	Summer (°F)	Fall (°F)
Maximum: 47.2	Maximum: 61.1	Maximum: 78.0	Maximum: 63.3
Minimum: 34.8	Minimum: 42.2	Minimum: 55.4	Minimum: 45.4

Table 117. Portland, OR temperature data

Utility Providers

The electricity provider for this home is Clark Public Utilities and the gas provider is Northwest Natural Gas. Table 118 illustrates the electricity and gas rates.

Electricity Rate		
	Utility	Clark Public Utilities
	Marginal	\$0.0736/kWh
	Fixed	\$6.40/month
Natural Gas Rate		
	Utility	Northwest Natural
	Marginal	\$1.128/therm
	Fixed	\$5.00/month

Table 118. Utility rates

Overall Test and Analysis Objective

Stage Gate 2 evaluates the feasibility of integrating advanced systems with production building practices using targeted field tests and energy simulations. This report describes BIRA's plan to evaluate the implementation, performance, and cost-effectiveness of the features listed below. These features represent the work developed with BIRA, builder partners and NTH. Table 119 lists the proposed features for a 50% Whole House Energy Savings (WHES) relative to the Building America Benchmark.

50% WHES Features
R-38 Floor over crawlspace
R-60 Ceiling with raised heel truss
R-21 +R-5 2x6 advanced framing
2.4 ACH50
0.30 U-value/0.32 SHGC windows
ENERGY STAR® appliances
100% ENERGY STAR® CFL or LED
26 SEER, 10 HSPF & 15.5 SEER, 8.5 HSPF mini-split heat pumps with no backup electrical heaters
Heat recovery ventilator with filtration
93% condensing tankless water heater

Table 119. 50% WHES "Parade Home" base case features

NTH 50% Prototype Performance Measurement Plans

The following sections describe plans for analyzing the home's performance relative to each of the Stage Gate 2 Criteria.

“Must Meet” Gate Criteria - Source Energy Savings

Utility bill data from Clark Public Utilities and Northwest Natural Gas will be used to determine actual energy use and will be compared to the Benchmark energy consumption. BIRA, with the help of the Washington State University Energy Program (WSUEP), will be monitoring the indoor conditions of the home, space conditioning energy, DHW energy and combined other loads to determine how effective the systems are performing.

As designed, the home achieves a 48.0% WHES level relative to the BA Benchmark. The energy savings was below 50% because BEopt is unable to model some key features. The heating system uses two mini-split heat pumps. The system was evaluated in relation to the seasonal energy efficiency ratio (SEER) and heating seasonal performance factor (HSPF). A one ton single head system (SEER 26, HSPF 10) provides conditioning to the core of the house. A second two ton system (SEER 15.5, HSPF 8.5) with two heads provides conditioning to the core through a fan box located in conditioned space that distributes air to each bedroom. BEopt has difficulty modeling high performance heat pumps and multiple systems. The mini-split heat pumps were modeled as a single 18 SEER, 9.2 HSPF, which was based off a weighted average of the actual efficiencies. The duct system was modeled as ductless (See Appendix A of the evaluation report for analysis details).

“Must Meet” Gate Criteria - Prescriptive-Based Code Approval

Prior to the start of construction, construction documents, which include all systems incorporated into the home, were submitted and approved to ensure the structure and systems met applicable safety, health, and building code requirements. Typically, any code violation must be corrected and plans must then be resubmitted before final approval is granted. Construction can only begin after final approval is received and a building permit granted.

The “Parade Home” was approved by the City of Ridgefield and construction is now complete.

“Must Meet” Gate Criteria - Quality Control Requirements

Earth Advantage will conduct ENERGY STAR® and Earth Advantage field testing and inspections. They will be testing for flow rates of air entering and leaving the house. BIRA will also conduct third-party testing and inspections. Third-party inspectors will conduct quality control inspections to verify that all systems and structures are installed per designs and specifications. The inspectors will provide final documentation and approval only if the home passes the inspections. Copies of documentation will be made available to BIRA.

“Should Meet” Gate Criteria - Cost Neutrality

BEopt 0.9.5 will be used to perform an analysis of the advanced features’ incremental cost to

the builder. The final cost data is expected to be available in a few months. The costs will be used to determine whether the builder can maintain relatively low building costs while implementing energy efficiency features. The preliminary analysis using BEopt will determine whether the 50% WHES can provide sufficient reduction in energy bills, in turn reaching the neutral cost target.

Utility bill data, builder costs, and energy costs based on current utility rates will be used to calculate the net annual cash flow to the homeowner. This data will be used to predict whether, on a production basis, the incremental annual cost of energy improvements will be off-set by the annual reduction in utility bill costs.

A review of the costs and construction timeline will then be reviewed and optimized for cost neutrality. The incremental costs of additional features will be examined from the builder's cost perspective as well as the impact on the homeowner's monthly mortgage payments. The "cost-neutral" goal is for the homeowner to have utility bill savings greater than, or equal to, the increased monthly payment of the 30-year mortgage.

For this particular design, the following incentives were available through Clark Public Utilities and Northwest Natural Gas, as well as state and federal agencies.

Appliances	Description	Incentive Amount
Clark Public Utilities		
Northwest ENERGY STAR® Home	Meets NW ENERGY STAR® standards	\$600
Heat Pump Rebate Program	Purchase and install a NW ENERGY STAR® rated heat pump	\$750
Additional Measures	Installation of an ENERGY STAR® clothes washer	\$25
	Installation of an ENERGY STAR® Refrigerator	\$50
Total:		\$1,425
Northwest Natural Gas, & Federal Incentives		
Federal Tax Credit Home	50% reduction in heating and cooling when compared to 2004 IECC standards. 1/5 of the energy savings measures from improved envelope	\$2,000
Tankless Water Heater	Rebate for installing a Rinnai tankless water heater	\$200
Total:		\$2,200

Appliances	Description	Incentive Amount
Total Available Incentives:		\$3,625

Table 120. Available incentives

NTH can take advantage of the available incentives in Table 120. The final amount of the incentives and the final costs for building the “Parade Home” has not been determined at this time. When the final builder costs and selected incentive benefits are obtained, BIRA will determine any additional costs to the homeowner’s monthly mortgage and utility payments to verify whether the advanced features are cost-neutral.

“Should Meet” Gate Criteria - Quality Control Integration

All final permitting information and any issues associated with final permitting of the advanced systems will be documented. BIRA is working with NTH to ensure that the design is followed. To ensure proper implementation, BIRA has met with the superintendent for this home and discussed points on the construction schedule to assure that quality control mechanisms such as proper testing and inspections are included in their processes.

“Should Meet” Gate Criteria - Gap Analysis

A post-construction evaluation will examine construction and installation issues gathered through questionnaires, interviews and reviews of installation documentation. This analysis will capture any actions required to guide future installations and better ensure the construction of a prototype house that yields a 50% WHES relative to the BA Benchmark.

Key information gathered during the gaps analysis includes:

- Subcontractor scopes of work and any related issues
- Training and/or certifications for advanced system, evidence of compliance with requirement for installation, any related issues
- Training issues
- Supply issues
- Code issues
- Design issues
- Installation issues
- Cost issues
- Labor issues

Proposed Test and Analysis Schedule

- House completed and monitoring equipment, installed Fall 2010
- Possible unoccupied testing in August 2010
- Monitoring to be completed at least one year after commencement, depending on agreement with owner

Description of Test Results Required by Industry Partners

WSU is required to provide assistance in setting up monitoring equipment as well as data collection.

Artisans Group: 50% Marine Prototype Evaluation Plan

Artisans Group has partnered with the Building America (BA) team and is constructing a BA 50% Marine prototype home in Olympia, WA. This particular home is considered a “Passive House”, which meets rigorous standards in energy efficiency in buildings and will be the focus of this BA Stage Gate 2 evaluation plan. (Stage Gate 2 Performance requirements can be found in Appendix A of the evaluation report). The builder is committed to working with the Building Industry Research Alliance (BIRA) and to assist through the entire BA Stage Gate process with the goal of building energy efficient, cost-effective and marketable homes. The builder will collaborate with a team of experts and other stakeholders throughout the process of building this energy efficient home.

Background

The Artisans Group (AG) is established as the design build experts in the energy-efficient certified Passive House Standard, in South Puget Sound. Established in 1997, AG focused mainly on high-end remodel projects for the first several years of their business. During the past five years, the company has designed several award-winning new home projects. All new construction designs have been built to the Passive House Standard, Built Green or LEED rating. Tessa Smith, co-owner of AG, acts as the lead designer and is a certified Passive House Consultant. The president and owner, Randy Foster, has recently completed training for certification and will take the final exam in November 2010.

AG designs homes to meet the performance standards designated by the Passive House Institute US (PHIUS). Homes are simply designed, yet are built with functional elegance and enduring qualities. The offered designs attract people who require freedom of choice and value the flexibility that comes with purposeful design. Homes are built solar ready, and are intended to be the most cost-effective method to achieve net-zero energy usage, west of the Cascades.

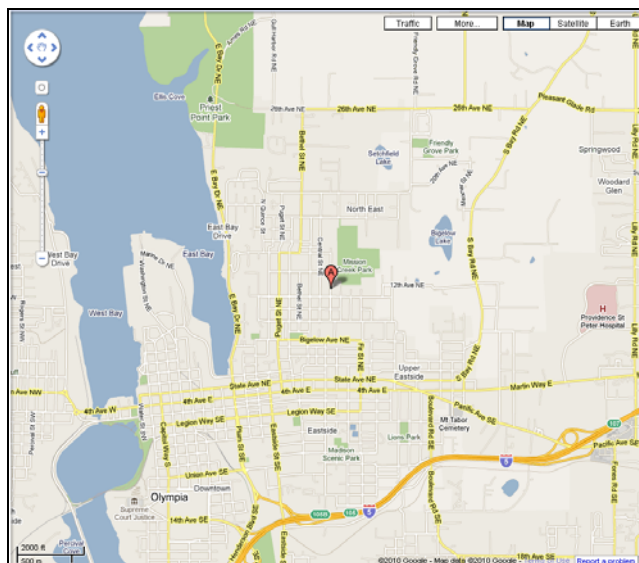
AG’s intent is to implement the world’s leading edge technological solutions toward resource savings. They continue to identify, test and advance best practices as forerunners in the residential energy conservation industry. They believe resource preservation is the single greatest way to affect the world at large.

The prototype for this study is priced at \$360,000 and generally would be targeted at middle class buyers looking for a high quality home. It is only the second home permitted in the State of Washington that has been designed to meet the stringent requirements of PHIUS certification.

For more information on Artisans Group contact Tessa Smith, <mailto:tessa@artisansgroup.com> or visit the Artisans Group website, www.ArtisansGroup.com.

“Passive House” Location

The AG prototype “Passive House” is located at 1116 Marion St NE, Olympia, WA.



Builder: Artisans Group
Total sq. ft. 1984
Bedrooms: 3
Baths: 3
Selling Price: \$360,000

Figure 85. AG “Passive House” location

The drawing below is an architectural rendering. Floor plans can be found in the evaluation plan Appendix C.



Figure 86. AG “Passive House”

Climate

Olympia, WA has 5655 HDD₆₅ and only 101 CDD.

Annual Average Maximum Temperature	60.2°F
Annual Average Minimum Temperature	39.2°F
Annual Average Total Precipitation	50.6 inches

Table 121. Olympia, WA annual climate data

More detailed monthly weather data is provided in the evaluation plan Appendix E.

Utility Provider

The electricity and gas provider for this home is Puget Sound Energy. Table 122 has electrical and gas rates effective 7/1/2010.

Gas		
Base Charge		Rate per therm
\$10.00/month		\$1.048850
Electric		
Base Charge	First 600 kWh	Over 600 kWh
\$7.50/month	\$0.085202	\$0.103185

Table 122. Utility rates

Overall Test and Analysis Objective

Stage Gate 2 evaluates the feasibility of integrating advanced systems with production building practices using targeted field tests and energy simulations. This report describes BIRA's plan to evaluate the implementation, performance, and cost-effectiveness of the features listed below. These features represent the work developed with BIRA, builder partners and AG. Table 123 lists the proposed features for a 50% WHES relative to the BA Benchmark.

The PHIUS standard is the only North American approved adaptation of the European Passive Haus standard developed in Germany. The designers have used the PHPP design tool to develop the project and seek PHIUS certification. The process emphasizes an extreme reduction in heating and cooling loads by using high levels of insulation; extremely efficient fenestration; minimal thermal bridging and extremely tight construction with heat recovery ventilation. The process allows the elimination of a conventional heating system in most cases.

"Passive House" WHES Features
R-50 Slab on grade R-16 Perimeter
R-80 Ceiling with raised heel truss
R-47.5 Double wall
0.6 ACH ₅₀
0.20 U-value/0.55 SHGC windows
ENERGY STAR® appliances
80% ENERGY STAR® CFL
Heat Recovery Ventilator with electric resistance heat
98% condensing tankless water heater
40 sq. ft. closed loop solar thermal

Table 123. 50% WHES "Passive House" base case features

AG 50% Prototype Performance Measurement Plans

The following sections describe plans for analyzing the home's performance relative to each of the Stage Gate 2 criteria.

"Must Meet" Gate Criteria- Source Energy Savings

The Prototype home must provide targeted WHES savings based on BA performance analysis procedures and energy performance measurements. BIRA will use BEopt 0.9.5 to analyze the expected source energy savings. Utility bill data from Puget Sound Energy will be used to determine actual energy use and will be compared to the Benchmark energy consumption. BIRA, with the help of the Washington State University Energy Program (WSUEP), will be

monitoring the indoor conditions of the home, space conditioning energy, DHW energy and combined other loads to determine how effective the systems are performing.

As designed, the home achieves a 59.4% WHES level relative to the BA Benchmark. The score may seem low because BEOpt is unable to model some key features. The high levels of insulation make the design very sensitive to thermal bridging, and internal and solar gains (See Appendix A of the evaluation plan for analysis details). One of the hoped outcomes is to be able to compare the modeling in BEOpt to the predictions derived from PHPP as confirmed in actual monitored performance.

“Must Meet” Gate Criteria - Prescriptive-Based Code Approval

Prior to the start of construction, construction documents, which include all systems incorporated into the home, were submitted and approved ensuring that the structure and systems meet applicable safety, health, and building code requirements. Typically, any code violation must be corrected and then plans resubmitted until final approval is granted. Construction can only begin after final approval is received and a building permit granted.

The “Passive House” was approved by the City of Olympia and construction has begun.

“Must Meet” Gate Criteria - Quality Control Requirements

Viridian Northwest will conduct ENERGY STAR® and Built Green field testing and inspections. They will be testing for flow rates of air entering and exiting the house. BIRA will also conduct third-party testing and inspections. Third-party raters will conduct quality control inspections to verify that all systems and structures are installed per design and specification plans. The inspectors will provide final documentation and approval only if the home passes the inspections. Copies of these documents will be made available to BIRA.

“Should Meet” Gate Criteria - Cost Neutrality

BEOpt 0.9.5 will be used to perform an analysis of the advanced features’ incremental cost to the builder. The final cost data is expected to be available in a few months. The costs will be used to determine whether the builder can maintain cost neutrality while implementing these energy efficiency features. This preliminary analysis using BEOpt will be used to determine whether the 50% WHES can be anticipated to provide sufficient reduction in energy bills to reach the neutral cost target.

Utility bill data, builder costs, and energy costs based on current utility rates will be used to calculate the net annual cash flow to the homeowner. This data will be used to predict whether, on a production basis, the incremental annual cost of energy improvements will be off-set by the annual reduction in utility bill costs.

A review of the costs and construction timeline will then be evaluated and optimized for cost neutrality. The incremental costs of additional features will be examined from the builder's cost perspective as well as the impact on the homeowner's monthly mortgage payments. The "cost-neutral" goal is for the homeowner to have utility bill savings greater than, or equal to, the increased monthly payment of the 30-year mortgage.

For this particular design, the following incentives were available through Puget Sound Energy, as well as state and federal agencies.

Appliances	Description	Incentive Amount
Puget Sound Energy		
ENERGY STAR® Bonus		\$100
Additional Measures	Installation of an ENERGY STAR® clothes washer	\$100
	Installation of an ENERGY STAR® Refrigerator	\$50
	Lighting ENERGY STAR® Fixtures up to \$400	\$20/fixture
	Lighting ENERGY STAR® Lamps up to \$300	\$3/screw in CFL
	Natural Gas Tankless DHW	\$150
Total:		Approx. \$600
Federal Incentives		
Federal Tax Credit Home	50% reduction in heating and cooling when compared to 2004 IECC standards. 1/5 of the energy savings measures from improved envelope	\$2,000

Table 124. Available incentives

The incentives in Table 124 are the available incentives to AG. The final amount of the incentives and costs for building the "Passive House" has not been determined at this time. When the final builder costs and selected incentives benefits are obtained, BIRA will determine any additional costs to the homeowner's monthly mortgage and utility payments to verify whether the advanced features are cost-neutral.

"Should Meet" Gate Criteria - Quality Control Integration

All final permitting information and any issues associated with final permitting of the advanced systems will be documented. BIRA is working with AG to ensure that the design is followed. To ensure proper implementation, BIRA will meet with the superintendent for this home and discuss points on the construction schedule to assure that quality control mechanisms such as proper testing and inspections are included in the process.

“Should Meet” Gate Criteria - Gap Analysis

A post-construction evaluation will examine construction and installation issues gathered through questionnaires, interviews and reviews of installation documentation. This analysis will capture any actions required to guide future installations and better ensure the construction of a prototype house that yields a 50% WHES relative to the BA Benchmark.

Key information gathered during the gaps analysis includes:

- Subcontractor scopes of work and any related issues
- Training and/or certifications for advanced system, evidence of compliance with requirement for installation, any related issues
- Training issues
- Supply issues
- Code issues
- Design issues
- Installation issues
- Cost issues
- Labor issues

Proposed Test and Analysis Schedule

- House completed and monitoring equipment will be installed during the winter of 2010
- The project was pre-sold and monitoring will begin with occupancy. Monitoring to be completed at least one year after commencement, depending on agreement with owner and continued funding

Description of Test Results Required by Industry Partners

WSU is required to provide assistance in setting up of monitoring equipment as well as data collection.

3.2 Stage Gate 2 Prototype House Report: Performance Evaluations in Preproduction Prototypes

The BIRA team completed the Stage Gate 2 prototype house performance evaluations for 23 homes shown in the table below during the three Budget Periods; all of which are at varying stages of completion.

House/Builder	Stage Gate 2 Status
<i>Budget Period 1 (2008)</i>	
Citihouse II Alvis Projects, Inc.	Dropped – Financing never approved
“Newport” Gold Medallion	Completed
“Liverpool” Liberty Homes	Completed
“Carmichael” Holmes Homes	Completed
“Craftsman” Rainey Homes	Completed
Kent Model 2294 New Traditions	In construction during this Budget Period
NextGen, Las Vegas, NV	Completed
Martha Rose	Completed and monitored
<i>Budget Period 2 (2009)</i>	
Artistic Homes (2 homes)	Homes finished and sold. Performed per design and led Artistic to offer as standard on some homes and option in all communities.
GEOS Homes Solar Cottage	In Process. Construction is still pending.
Gold Medallion	Completed and monitored
Cohan Residence	Constructed and monitored
Snow Creek (2 homes)	Under construction. Monitoring sensors installed.
Forest City, HI Mololani	Under construction
Forest City, HI NZEHS (2 homes)	Scheduled to be built in early 2010.
<i>Budget Period 3 (2010)</i>	
Snow Creek Cottages	These homes remain at Stage Gate 2. The two homes are currently

House/Builder	Stage Gate 2 Status
(2 units) Park City, UT (Cold)	being monitored. Data has been collected for approximately 3 months. For additional details outlining results, please refer to the Snow Creek Cottages Interim report.
Net-ZEH Mololani Oahu, HI (Hot-Humid)	The Net-ZEH prototype homes' performance have been evaluated and results are included in the Stage Gate 2 report satisfying criteria for this gate. A ZEH retrofit was also designed, implemented and evaluated. New Construction packages accepted and implemented, and demonstrated to produce 50% savings (data from bills collected by Forest City)
New Tradition Homes Ridgefield, WA (Marine)	The study conducted on the New Traditions Home, located in the Marine Climate, has been completed and satisfies criteria for Stage Gate 2.

Table 125: Prototype House Evaluation

Artistic Homes - Albuquerque, NM BP2 (2009)

This report describes the summary for two (2) prototype homes in Albuquerque, NM, a Hot-Dry climate, targeted at 50% whole house energy savings (WHES) relative to the Building America (BA) benchmark. These homes are being developed by Artistic Homes, a progressive, family-owned production builder that has been constructing high performance homes (some through Building America) throughout New Mexico for over four decades. The overall objective of this study is to evaluate these homes relative to the Stage Gate 2 criteria, leading to energy efficient homes that are cost effective and marketable.

As mentioned above, Artistic Homes' standard home design is based on high performance, energy saving measures, although they also offer a true net-ZEH as an option. The primary prototype home completed construction in early September and will be located at 9512 Cache Creek Rd in Albuquerque, NM. There is one additional prototype home that is being constructed in Farmington, NM, though its floor plan is about half the size of the other home. Its address is 1201 Katherine Ave. Some features found in Artistic Homes' houses are listed below. A full list can be found in Appendix D of the final report.

- OVE framing:
 - o R-21 wall insulation
 - o R-50 attic insulation
- 0.31/0.31 U-value/SHGC windows
- 9.0 HSPF, 15 SEER heat pump
- Ducts inside conditioned space
- 70 cfm garage ventilation fan and HEPA HRV system



Figure 87. Front view of the Albuquerque House

Artistic's current ZEH designs rely on large solar arrays, which is expensive. The Albuquerque house will use a 5.7 kW DC PV system and a flat plate, closed loop glycol solar thermal system. The Farmington house will use an integrated 3.7 kW PV and solar thermal system. Therefore, they are always interested in finding cost-effective ways to reduce this cost through improved energy efficiency or solar system performance. Artistic has previously worked with BSC to improve envelope efficiencies, including OVE framing, ducts inside conditioned space, high performance windows and high-efficiency HVAC equipment. BIRA's involvement with Artistic Homes will focus on renewable generation (the ZEH option includes both PV and solar thermal, but neither system has previously received much attention) and devices to reduce MELs.

Artistic Homes understands that high-performance home designs are always improving and therefore is quite interested in this research opportunity. BIRA looks forward to working with Artistic Homes to assist them in achieving their goal, and sees them as a leader and critical partner in the Hot/Mixed-Dry Climate Zone.

Key Results

The Albuquerque house is calculated to have 55.7% WHES without PV. The Farmington house is calculated to have 57.0% WHES without PV. This level of WHES can be attributed to many

above-code features, as listed in Appendix D of the final report. Submittal plans have been approved by the jurisdiction. These features will reduce the annual energy bills to offset the additional incremental cost of the above-code features, thus resulting in a neutral cost when financed as part of a 30-year mortgage (refer to Appendix F of the final report). Construction for the Albuquerque house has been recently completed and will soon be occupied. Energy usage data via utility bills will be collected when they are available.

Gate Status

Artistic Homes' prototypes are still in Stage Gate 2. The Farmington house is still under construction, and both homes have yet to have any data collected to verify energy savings. BIRA and Artistic Homes will also collaborate to include checklists used by Artistic Homes to assist in ensuring proper future construction practices.

Conclusion

Energy simulations show that the houses have met the 50% WHES level. However, the homes have yet to be occupied, so utility bills to verify the energy usage and savings simulations will be collected once the residents move in. The utility bills will also serve to determine the energy savings of Verve, the whole house lighting and outlet control system, as the bills will be compared before and after Verve becomes fully functional inside the house.

The houses have passed the Must Meet Prescriptive-Based Code Approval gate criteria. With its above-code features, the houses have been accepted by the jurisdiction and are nearing completion of construction. Besides the Verve, the features and systems being installed into the houses did not require additional training, as they were within Artistic's typical construction practices. Documentation and a checklist and documentation will be obtained once the houses are built to assist in developing a production construction process that ensures correct installation steps.

The houses' above-code features have resulted in a substantial reduction in monthly energy bills. While financed over a 30-year mortgage at 7% interest, the incremental cost to install the features has been determined to be offset by the lower utility bills. The overall annual cost will be reduced to near \$500, thus meeting the neutral cost target.

Builder/Project Overview

In late April 2009, BIRA met with Artistic Homes to discuss possible prototype opportunities. Artistic Homes is a leading-edge, family-owned production builder in the southwest region and continues to push the envelope with their LEED-H Platinum, near-zero energy production homes.

Recently, Artistic Homes has committed to providing high performance, energy saving homes as

their baseline, while offering true ZEH as an option. They have led the way in New Mexico in terms of energy-efficient designs while demanding high standards of construction. This allows them to include an energy use and home comfort guarantee with every home.

Artistic Homes has asked BIRA to assist them in areas in which Building America had not previously worked with them. This includes solar renewable energy options and lighting and MELs controls. Artistic has proposed the use of a ZEH home in Albuquerque and Farmington, NM to use as prototypes. BIRA and Verve Living Systems were able to provide equipment for this project. Artistic Homes plans on utilizing Verve's whole house lighting and outlet control system and whole house feedback display.

Refer to the systems report to see additional information about Verve.

For more information on Artistic Homes, visit their website at <http://www.artistichomes.com/>.

"Must Meet" Gate Criteria -- Source Energy Savings

The projected source energy savings was derived with Energy Gauge. Without PV generation, the Albuquerque home is projected to have a WHES of 55.7%. The Farmington house is projected to have a WHES of 57.0%. PV generation will boost the projected savings to over 90% WHES. This is due to the more energy efficient, above code features installed into the house.

Description End Use	Estimated Annual Source Energy		Estimated Source Energy Savings
	Benchmark (Mbtu/yr)	Actual (Mbtu/yr)	
Space Heating	121.2	31.7	73.9%
Space Cooling	38.0	6.7	82.2%
DHW	42.3	6.3	85.0%
Lighting	27.7	8.0	72.1%
Appliances and MELs	64.5	62.3	3.4%
Outside Air Ventilation Fan	2.1	16.4	-696.6%
Total	296.8	131.4	55.7%

Table 126: Albuquerque WHES Summary

Description End Use	Estimated Annual Source Energy		Estimated Source Energy Savings
	Benchmark (Mbtu/yr)	Actual (Mbtu/yr)	
Space Heating	98.6	27.8	71.8%
Space Cooling	15.9	3.4	78.8%
DHW	39.3	2.7	93.2%

Description End Use	Estimated Annual Source Energy		Estimated Source Energy Savings
	Benchmark (Mbtu/yr)	Actual (Mbtu/yr)	
Lighting	18.5	5.2	72.1%
Appliances and MELs	53.1	54.3	-2.3%
Outside Air Ventilation Fan	1.3	4.2	-231.5%
Total	226.7	97.5	57.0%

Table 127: Farmington WHES Summary

As shown in Table 126 and Table 127, both Artistic Homes prototypes exceed the next Building America goal of 50% whole house energy savings in the Hot/Dry climate with respect to the BA benchmark. Except for Verve and the photovoltaic and solar thermal panels, the features installed into the homes were selected prior to BIRA involvement. Artistic Homes had previously worked with the Building Science Consortium (BSC), another Building America team, and came to use the majority of these features in their standard home design. The critical above code energy reduction features implemented in order to reach these savings levels are as follows:

- OVE framing:
 - o R-21 wall insulation
 - o R-50 attic insulation
- 0.31/0.31 U-value/SHGC windows
- 9.0 HSPF, 15 SEER heat pump
- Ducts inside conditioned space
- Flat plate collector solar hot water with 80 gallon storage tank (in Albuquerque house)
- Integrated photovoltaic and solar thermal panels with a 100 liter storage tank (in Farmington house)
- 100% fluorescent lighting

Both prototype homes are all electric. The Albuquerque house is expected to use 11,124 kWh annually, while generating 10,570 kWh via the photovoltaic panels. 554 kWh is the estimated net electricity used. The Farmington house is expected to use 7,919 kWh annually, while generating 6,969 kWh via the photovoltaic panels. 949 kWh is the estimated net electricity used.

These energy simulations do not include any energy savings contributed by Verve, as there is currently no definite way to estimate the energy savings. One methodology to determine the benefits of Verve is discussed in the Gaps section.

“Must Meet” Gate Criteria -- Prescriptive-Based Code Approval

As stated previously, Artistic Homes’ standard design for a house is near-ZEH. To help achieve this, the homes incorporate several energy efficient features that exceed the current minimum

for the 2006 International Energy Conservation Code. Appendix C of the final report shows a comparison between the base 2006 IECC minimums versus what is being installed into the prototype homes.

In addition to the 2006 IECC, the homes will also meet ASHRAE 62.2's requirements for fresh air intake. This is done by the use of a heat recovery ventilator (HRV) to draw in outside air.

"Must Meet" Gate Criteria -- Quality Control Requirements

Although the prototype houses incorporated multiple energy efficient features, the majority of them were within Artistic's typical building practices. Outside of Verve, no additional trainings were necessary to learn systems and features, as they were still within standard construction practices.

Since Artistic Homes is new with Verve, BIRA set up multiple meetings between Artistic and Verve to go over how the system worked and have questions answered. Once Artistic was comfortable enough to incorporate Verve into their houses, a representative from Verve was onsite to train Artistic's electrician, Kelly Sivage from Prestige Electric. The training, which covers proper installation practices, optimal wiring routes, and other potential installation issues that might arise, lasts no longer than a single business day. On top of the installation manual that is provided with each of its controllers, Verve also designed a worksheet and supplemental installation material for the electrician. Both items simplify the process for the installer, making it less likely that there will be any significant problems during installation. Verve also went through the floor plans for each of the units to layout controller locations and how the wiring would run for each of the channels. A special program is used and a printout of the schematics is provided for easy replication in other houses with similar floor plans.

Once the houses are complete, BIRA will collect documentation and checklists from the installed systems and inspection processes. These will be used to develop a production construction process that ensures correct installation steps that meets building standards.

"Should Meet" Gate Criteria -- Neutral Cost Target

The 55.7% reduction in the Albuquerque house's whole house energy savings provides a substantial reduction in energy bills. The incremental cost calculation (in Appendix F of the final report) shows that despite adding in the advanced energy features, the savings in utility bills will offset the additional cost. When financed as part of a 30-year mortgage at 7% interest, the incremental annual cost will be reduced by \$483.09.

Similarly, the 57% reduction of whole house energy savings in the Farmington house will also result in a reduction in energy bills. The Farmington house's incremental annual cost when financed as part of a 30-year mortgage at 7% interest will result in a reduction of \$500.51 per year.

Based on this information, it is clear that the incremental annual cost of energy improvements is less than the annual reduction in utility bill costs. Thus, the Artistic prototype homes pass the Neutral Cost Target “Should Meet” criteria.

“Should Meet” Gate Criteria -- Quality Control Integration

BIRA conducted multiple meetings to introduce Artistic to Verve, attended Verve’s training, and did a site visit to document its installation. This helped to assure that the progress was being managed and that information was exchanged between partners. Because Artistic has had previous experience with installing high energy efficient features, BIRA will collect documentation and checklists regarding proper installation practices that help assure health, safety, durability, and comfort.

“Should Meet” Gate Criteria -- Gaps Analysis

As mentioned above, a current gap BIRA has come across is that currently, there is no way to quantify the energy savings of Verve. In a previous survey, it was estimated that Verve will save 40% of the appliances and MELs load. Such a reduction will result in a 9% WHES increase in both the Albuquerque and Farmington houses. Some variables that make it difficult to pinpoint the savings include user behavior, number of appliances and electronics inside the house. What BIRA will do to gain a measurement is in two phases. In the first phase, we had the electricians install Verve to initially behave like a normal light switch. Data from utility bills will be collected for a minimum of 6 months, and then in the second phase, the electricians will go back into the same house and tweak the wiring so that the homeowner can fully control Verve. BIRA will continue to collect data and then compare this new data to the previous utility bills to measure savings from Verve. While the features in both prototype houses will already meet 50% WHES, having knowledge of the energy saving benefits of Verve will potentially help other prototypes and communities to achieve the next tier in the Joule milestone.

Kelly Sivage from Prestige Electric has installed similar systems in the past, so he and his crew have some familiarity with the concepts. During the site visit, Sivage stated that the installation was coming along smoothly. The installation time took longer than a traditional wiring setup, but this was likely due to the time to learn the system, as this was their first installation with Verve. Sivage and his crew believed that after no more than 5 houses, Verve would not take any longer than a traditional wiring setup.

Geos “Solar Cottages” BP2 (2009)

This report is an interim evaluation of the Geos Development’s “Solar Cottage” as a 50% whole house energy savings (WHES) prototype home when compared to the Building America (BA) Benchmark in the Cold Climate Zone. The Geos – D “Solar Cottage” was evaluated based on BA Stage Gate 2 “Must Meet” and “Should Meet” Gate Criteria. Key research partners in this endeavor are Norbert Klebl of Geos Development and Adam Stenftenagel of Sustainably Built.

The Geos Neighborhood has an energy target of net-zero energy.

The 1,842 sq. ft., two story, prototype with 800 sq. ft. finished basement option discussed in this report has not been priced yet. The home is will be targeted at people of all lifestyles looking for a high quality home. The homes prices for the Geos Neighborhood begin in the \$200,000s. To achieve a true net-zero energy community, all of the units use only electric power. Arvada, Colorado is provided electricity by Xcel Energy.

Arvada, Colorado is in IECC Climate Zone 5 at an elevation of about 5,640 ft. Arvada has approximately 6,158 heating degree days (HDD°F) and 553 cooling degree days (CDD°F). The area receives an average of 16 inches of rain annually.

Key Results

Based on a preliminary energy analysis performed using BEopt 0.9.03, incremental costs based on builder estimates, and additional information gained first hand from Geos Development, it has been determined that the “Solar Cottage” qualifies as a Building America 50% prototype in the Cold Climate Zone. Some of the advanced features could not be properly modeled in BEopt and the estimated associated costs were high enough to not meet the cost neutrality target. In the current building environment, Geos Development has not constructed the proposed prototype as they are still undergoing features and systems selection. Construction is expected during the first quarter of 2010.

Gate Status

An energy analysis performed on the “Solar Cottage” prototype shows energy savings of 58.9% compared to the Building America Benchmark without the 5 kW PV system. Based on the energy cost savings from BEopt and incremental costs estimated by Geos Development, it has been determined that the homeowner expects to see an annual utility bill savings of approximately \$2,441; however the increase in mortgage equates to \$3,060 annually. Finalized cost will be evaluated once it becomes available. More refined energy modeling to show net-zero energy usage will be done at a later date.

Standard quality control requirements and integration procedures are to be incorporated. The “Solar Cottage” should undergo the plan checking process and field inspections to ensure health, safety, durability, and comfort. Construction of the “Solar Cottage” is expected during the first quarter of 2010.

Conclusions

Supply, design, installation and labor issues have not all been determined nor resolved as the Geos Neighborhood has not begun construction. Some issues that have arisen occurred with the proposed Earthlinked direct expansion ground source heat pump. The proposed system,

used for space heating, cooling, and water heating, received high bids from the contractors for installation due to their lack of familiarity with the system. Geos Development has since gone back to looking at other options for space conditioning and water heating. Geos is currently planning on using a water to water heat pump for space conditioning and water heating.

“Must Meet” Gate Criteria -- Source Energy Savings

Using BEopt 0.9.03, an energy analysis was performed on “Solar Cottage” floor plan. Floor plans and elevations can be found in the final project report. The “Solar Cottage” is a 1,842 sq. ft. two-story house with an optional 800 sq. ft. conditioned basement. With the basement option, the “Solar Cottage” has four bedrooms, and three and a half bathrooms. The plan was modeled as a 50% Building America prototype in the Cold Climate Zone.

As designed, the home achieved 58.9% WHES level relative to the BA Benchmark when the basement was conditioned. When the 5.0 kW PV system was added, the WHES was 82.9% relative to the BA Benchmark. Certain assumptions were needed as BEopt is limited in the advanced systems that it can model. The HVAC system, which is a water-to-water heat pump connected to a horizontal ground loop providing space conditioning with electric baseboard backups, was modeled as an air-to-air 16 SEER, 8.4 HSPF heat pump with ducts in conditioned space. The water-to-water heat pump system also provides domestic hot water (DHW) heating, with a COP of 2.8, to a 40 gallon tank with electric backup that was modeled as an electric tankless. See the final project report for a diagram of the HVAC system.

The R-10 basement floor insulation was modeled as a regular slab floor, which explains the lower energy savings for heating. All windows were averaged to 0.29 U-value and 0.49 SHGC. Actually window specifications are 0.20 U-value / 0.25 SHGC windows with 0.27 U-value / 0.62 SHGC South facing windows. (See the final project report for BEopt analysis details).

Figure 88 shows a graphical comparison of the BEopt Source Energy Use for the “Solar Cottage” vs. the BA Benchmark and IECC Standard as the reference homes.

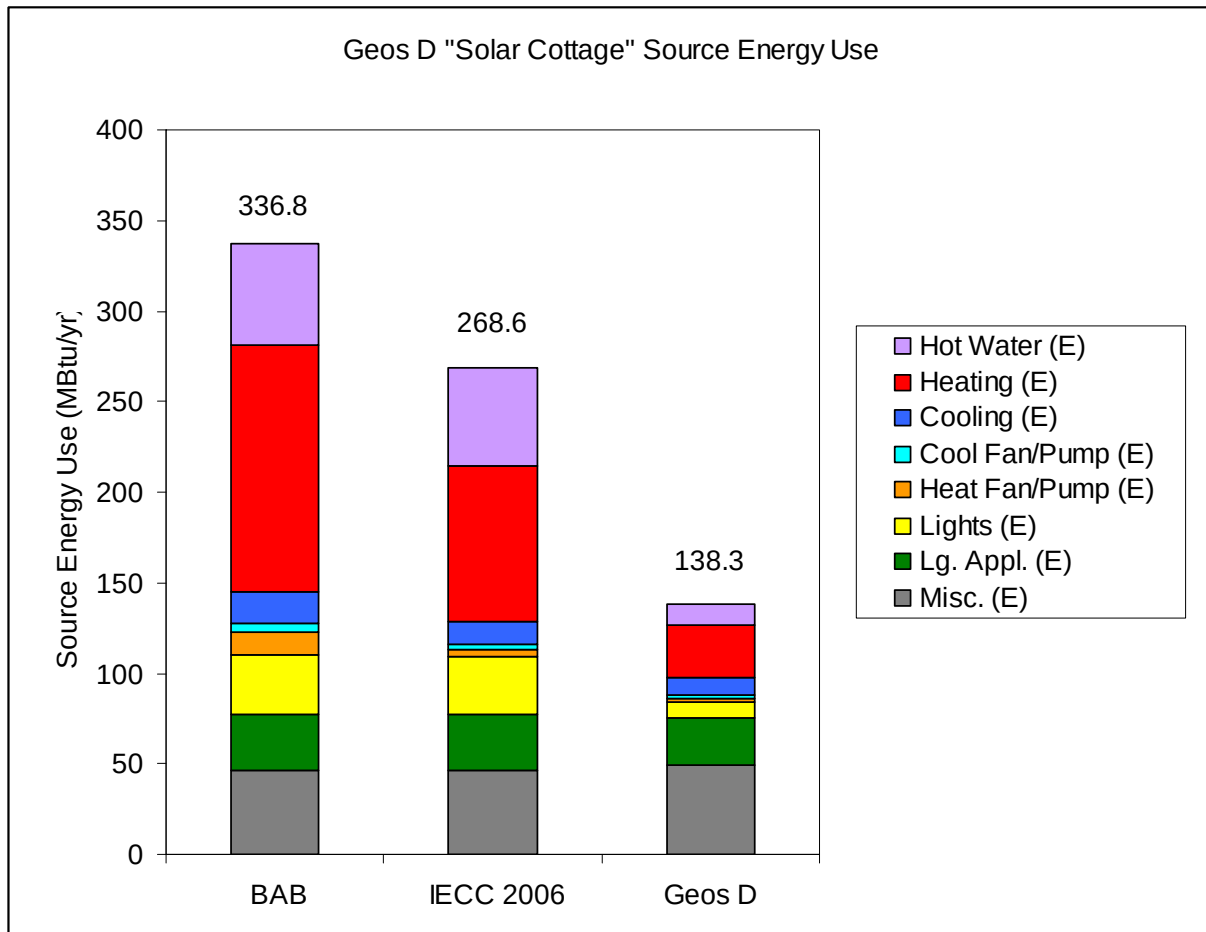


Figure 88: BEopt Source Energy Use “Solar Cottage” with BA Benchmark and IECC Standard as the Reference Homes

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	CO Code Home	Solar Cottage	Percent of End Use		Percent of Total	
	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	148.3	90.7	30.2	79.6%	66.7%	35.1%	22.5%
Space Cooling	23.0	14.6	11.5	50.1%	21.5%	3.4%	1.2%
DHW	55.5	53.7	12.1	78.2%	77.5%	12.9%	15.5%
Lighting	32.4	32.4	9.1	72.1%	72.1%	6.9%	8.7%
Appliances and MELs	77.6	77.1	75.5	2.7%	2.1%	0.6%	0.6%
PV	0.0	0.0	-80.9	n/a	n/a	24.0%	30.1%
Total Usage/Savings	336.8	268.6	57.4	82.9%	78.6%	82.9%	78.6%

Table 128: Source Energy Savings for the “Solar Cottage” Floor Plan

As shown in Table 128, the 50% “Solar Cottage” meets the Building America goal of 50% energy savings in the Cold Climate Zone with respect to the BA Benchmark. The critical above code energy reduction features implemented in order to reach this goal are as follows:

- ENERGY STAR refrigerator, dishwasher, and clothes washer
- 90% hardwired CFL lighting
- 98% EF electric tankless water heater
- 0.6 ACH₅₀ infiltration
- R30 SIP Above Grade Walls
- R50 SIP Roof
- R22 ICF Basement Walls
- 16 SEER, 8.4 HSPF Heat Pump
- Ducts in conditioned space
- Windows 0.29 U-value and 0.49 SHGC (averaged)
- RecoupAerator 200DX ERV
- Electric cooking range and clothes dryer

Based on the BEopt simulation providing 58.9% energy savings compared to the BA Benchmark, Geos Development’s “Solar Cottage” prototype passes the Source Energy Savings “Must Meet” criteria.

“Must Meet” Gate Criteria -- Prescriptive-Based Code Approval

All measures in the Solar Cottage prototype meets or exceed prescriptive and performance safety, health and building code requirements for new homes.

“Must Meet” Gate Criteria -- Quality Control Requirements

A third party for testing and inspections has not been selected at this time. Third-party inspectors will conduct quality control inspections to verify that all systems and structures are installed per designs and specifications. The inspectors will provide final documentation and approval only if the home passes the inspections. Copies of these documents will be made available to BIRA.

“Should Meet” Gate Criteria -- Neutral Cost Target

Geos Development has not reached the point in their construction process where they can collect a comprehensive set of bids from all trades. At this time, they only have an estimated cost breakdown to the homeowner of \$38,318 for improvements to the thermal barrier, HVAC system, and the 5.0 kW PV system, which is the cost after federal and utility rebates.

Utility rates from Xcel Energy are listed in the table below.

Service & Facility Charge	Energy Charge per kWh
\$6.25/month	\$0.10

Table 129: Current Utility Rates for Arvada, Colorado

When mortgaged over 30 years, the \$38,318 cost increase relative to current energy code, which includes contingencies and after incentives are taken, equates to a \$255 increase in the monthly mortgage payment (assuming 7% APR over 30 years). BEopt 0.9.03 analysis estimates the annual utility bill savings of \$2,441, approximately \$204 a month. This utility savings offsets 80% of the increase in monthly mortgage payments. If Geos does not mark up the homeowner cost by \$15,000, the monthly mortgage would only increase would by \$155, yielding a net cash flow to the customer of \$49 per month. A markup of \$7,252 to the homeowner would result in a \$0 net cash flow. A final cost analysis will be done when construction is completed and real costs are determined.

“Should Meet” Gate Criteria -- Quality Control Integration

Incorporating new building features means that new building methods and procedures need to be addressed in the planning stages to ensure a smooth construction process and quality product. The plan to integrate the new methods and procedures should cover health, safety, durability, comfort, and energy related quality assurance. Contractors have not been selected for the Geos Neighborhood so there have not been any meetings to coordinate or train them on quality control measures. Once all trades have been selected, the trades should coordinate these features into their construction plans and should ensure that all plans necessary for city submittal are compliant with applicable building codes and jurisdictional requirements.

All final permitting information and any issues associated with final permitting of the advanced systems will be documented. BIRA will be working with Geos Development in ensuring the design will be followed. To insure proper implementation of the design, BIRA will meet with the superintendent for these homes and discuss points on the construction schedule to ensure that quality control mechanisms such as proper testing and inspections are included in their processes.

“Should Meet” Gate Criteria -- Gaps Analysis

Since construction has not yet begun, there are no lessons learned or market barriers to discuss. When construction begins, an evaluation will examine construction and installation issues gathered through questionnaires, interviews and reviews of installation documentation to determine if there are extraneous circumstances that would prevent a production builder from using the methods and systems explored in this prototype. That analysis will capture any actions required to guide future installations and better ensure the construction of a

production house that yields a 50% WHES relative to the Building America Benchmark in a Cold climate.

The gaps analysis provides the final information needed to determine how well the advanced systems integrate into production building practices and how each process may be altered to achieve that goal. BIRA will look to see how well the heating system will integrate with the ERV system. Supply and installation issues have not arisen yet because the project has not progressed far enough. Construction is scheduled for the first quarter of 2010. At that time, the previously mentioned issues will be addressed.

One training issue occurred which was related to the proposed Earthlinked system. The contractor bids were too high and in an effort to lower those bids, Geos Development provided product education to the contractors as well as a preliminary design layout for the contractors use in bidding. The second round of bids was still not low enough to fit within Geos Development's budget. The Earthlinked system was later deemed to not completely meet the space conditioning and water heating needs of the project.

Snow Creek Cottages BP2 (2009)

Snow Creek Cottages, 2061 Park Avenue, Park City, UT 84068, is a planned affordable housing project located at a site adjacent to Snow Creek consisting of 13, energy efficient homes. The project will not be serviced by natural gas – electricity is the sole utility energy source. The units will be heated using Ground-Coupled Heat Pumps (GCHPs), with ground heat coupling provided via U-tube boreholes. Two units will be evaluated, Fox A (#10) and Deer A (#11), each with unique features:

Test Home Details	
Fox A (#10) Unit Description	Deer A (#11) Unit Description
Two story, single family detached unit	Three story, single family detached units
2 bedrooms, 2 baths	3 bedrooms, 3 baths
single car parking in garage	single car parking in garage
26' x 30' footprint	26' x 30' footprint
Approximately 1,560 square feet of living and utility space	Approximately 2,340 square feet of living and utility space
3 U-Tube Boreholes to 100'	4 U-Tube Boreholes to 100'

To reduce the overall energy use by 50%, several energy saving/producing building technologies will be employed. These include:

- SIP exterior walls from foundation to roof bearing
- SIP roof structure

- Photovoltaic (PV) cells
- Ground-Coupled Heat Pump Heating
- Solar hot water systems
- Clearstory roof windows
- Heat recovery ventilation

Each energy-saving technology has other impacts besides energy reductions, namely construction schedule modifications and costs. Data was gathered to compare traditional construction to energy efficient construction to determine the schedule and cost impacts of 2 homes.

As the houses are still being constructed, this Stage Gate 2 Prototype Home Evaluation Report documents some of the findings and identifies the status of critical-path tasks when compared to Building America's Must Meet and Should Meet Criteria (see Appendix A of the final report).

Park City is committed to working with BIRA and to assist through the entire BA Stage Gate process with the goal of building energy-efficient, cost-effective, and marketable homes. The overall objective of this study is to evaluate these homes relative to the Stage Gate 2 criteria, leading to energy efficient homes that are cost effective and marketable.

Park City understands that high-performance home designs are always improving and therefore is quite interested in this research opportunity. BIRA looks forward to working with Park City to assist them in achieving their goal, and sees them as a leader and critical partner in the Cold Climate Zone.

Key Results

Snow Creek Cottages' "Deer" floor plan is calculated to have 50.7% WHES. The Snow Creek Cottages' "Fox" floor plan is calculated to have 50.3% WHES. This level of WHES can be attributed to many above-code features, as listed in Appendix G of the final report. Submittal plans have been approved by the jurisdiction. These features will reduce the annual energy bills to offset the additional incremental cost of the above-code features, thus resulting in a neutral cost when financed as part of a 30-year mortgage (refer to Appendix J of the final report).

To date, the key results of the Stage Gate 2 Prototype Home Evaluation are the same as the key results for the GCHP and SIPs studies. Specifically:

Thermocouples have been installed on inside and outside surfaces of the SIP panels at four different locations in both houses (see Appendix D of final report).

Park City was unfamiliar with SIP construction and therefore followed the code standard, which was congruent with Premier submittals. This led to delays in the submittal and permitting process.

Foundations were poured only after submittals were provided and permitting process was reviewed and accepted by all parties. If the panels had been designed and submittals had occurred during site preparation and excavation there would not have been the month delay due to design, submission and code review miscommunications.

The framing contractor came in late because R&O Construction could not find a framing contractor with SIP experience. The site architect reports that the gap between supply and install is great from a code and submittal perspective.

Most of the field work required to evaluate the U-tube borehole performance has also been completed:

- The GCHP design has been obtained and reviewed with Frederick Broberg from Colvin Engineering Associates, Inc., Project Manager for the Snow Creek development
- Installed thermocouples on the methanol liquid lines at 6 points on the tubing within a U-tube borehole in two locations (one for each unit), and the exit and entering points of the tubing of other two or three U-tube boreholes supplying the ground coupling for the heat pumps.
- Installed a passive thermosiphon heat pipe and two valves to divert the methanol liquid through the thermosiphon condenser. Thermocouples were placed at three different fixed points.
- Installed ½ inch PEX pipe in the two instrumented U-tube boreholes (and adjacent to the thermosiphon) to allow detailed manual interrogation of vertical temperature profiles.
- Observed borehole installation details. Those observations will be compared with specifications obtained from Colvin Engineering Associates, Inc.
- Obtained soil logs (data). Soil logs will give indications of permeability and thermal conductivity.
- The hydraulic gradient is that of the adjacent creek. Groundwater was observed in the trenches carrying the borehole piping near the tops of the U-tube boreholes.
- Heat pumps are now being delivered to the site, and once the models are identified, their rated performance characteristics will be obtained and compared to design specifications.

Gate Status

The prototype homes are currently under construction with occupancy planned for May 2010. Energy simulations have been conducted. The primary energy efficiency equipment includes Ground Coupled Heat Pumps and Structural Insulated Panels; detailed studies are being conducted on these two technologies to generate information on their costs and effectiveness.

Conclusions

Energy simulations show that the houses have met the 50% WHES level. However, the homes

have yet to be occupied, so utility bills to verify the energy usage and savings simulations will be collected once the residents move in, BIRA will provide an updated prototype report 4th quarter of 2010.

The houses have passed the Must Meet Prescriptive-Based Code Approval gate criteria. With its above-code features, the houses have been accepted by the jurisdiction and are nearing completion of construction. The features and systems being installed into the houses did not require additional training, as they were within Park City's typical construction practices. Documentation and a checklist and documentation will be obtained once the houses are built to assist in developing a production construction process that ensures correct installation steps.

The houses' above-code features have resulted in a substantial reduction in monthly energy bills. While financed over a 30-year mortgage at 7% interest, the incremental cost to install the features has been determined to be offset by the lower utility bills. The overall annual cost will be reduced to near the \$224 to \$570 range, thus meeting the neutral cost target.

Delays in schedule were due to difficulties with SIP submittals and code review. Additional familiarization with SIP building would likely alleviate that problem.

Likewise, the framing contractor began SIPs installation at a rate slower than standard installation. However, as assembly techniques improved, the framing contractor moved more quickly to finish the exterior wall and roof installation than if using standard framing construction techniques.

The U-tube boreholes, the test thermosiphon, and the horizontal piping to the houses were installed according to industry standards. The geology at the site is challenging with shallow groundwater, variable soils types, and numerous 6" size boulders underground. These features made drilling difficult on the site, resulting in days of down-time for repair of the drill rig.

Builder/Project Overview

Park City is the developer of the 13 unit affordable housing development in Snow Creek. Park City has a Sustainability Team that connects the missions of various departments in order to achieve a balance between meeting the goals of economic development, community development, and environmental impact reduction. It has set up a website that allows its citizens to download reports on carbon emissions as a function of City operations. Residents of the City may also visit the interactive tool on the website to calculate their own carbon footprint including energy consumption. Park City is therefore committed to affordability and environmental sustainability in its operations and future developments. The Snow Creek development is in line with the mission of the City to reduce energy consumption in its operations and faculties.

Elliott WorkGroup is the Architect on the project and R&O Construction is the contractor. Roger Durst of Elliott WorkGroup is National Green Building Standard Certified and

implemented passive and active design strategies in the design of the houses. The architect does not however have experience in SIP construction or GCHP technologies. R&O Construction is primarily a commercial builder and was hired because of the volume of building that we being bid out. R&O does not have any experience to date with energy efficient building techniques including SIP Construction and GCHP.

The SIP supplier is Premier Building Systems out of Montana and the installer is AKI Framing. Premier is the largest polystyrene SIP manufacturer in the U.S. with 9 plants in 9 states. AKI Framing does not have experience with SIP construction. For this project, AKI has hired the installer of SIPs from the Gold Medallion Home in Daybreak, Utah, a current Building America Home that is being monitored. The SIPs panels have been installed AKI and instrumented with thermocouples in the two units of interest. Siding and sheetrock can now be installed without problem. The University of Utah team is working with Park City, R&O, Elliott WorkGroup, Premier, and AKI to gather information on delays, costs, schedules, and performance specifications.

The installation of the GCHP boreholes and horizontal tubing was completed by Palace Geothermal. Mechanical contractors will soon be on site to hook the heat pumps to the ground coupled tubing inside the buildings. The research team from the University of Utah will assist in the GCHP commissioning including flow rate measurements, pressure balancing, and inlet/outlet temperature measurements at the methanol inlet and outlet ports of the heat pump. The research team from the University of Utah will also assist in the air flow rate measurements across the condenser in the air duct.

The prototype houses are scheduled to be completed in February. However since the development is a 13 unit land locked site, an individual house will not be given a certificate of occupancy until all of the houses are complete. This is estimated by R&O Construction to be in May of 2010.

"Must Meet" Gate Criteria -- Source Energy Savings

The projected source energy savings was derived with Energy Gauge. Park City's Snow Creek "Deer" prototype is projected to have a WHES of 50.7%. The "Fox" prototype is projected to have a WHES of 50.3%.

Description	Annual Source Energy		Estimated Source Energy Savings
	Benchmark	Prototype	Percent of End Use
End Use	(MBtu/yr)	(MBtu/yr)	vs. Benchmark
Space Heating	172.7	61.8	64.2%
Space Cooling	32.8	16.1	50.8%

Description	Annual Source Energy		Estimated Source Energy Savings
	Benchmark	Prototype	Percent of End Use
End Use	(MBtu/yr)	(MBtu/yr)	vs. Benchmark
DHW	45.1	19.1	57.7%
Lighting	26.9	7.5	72.1%
Appliances and MELs	63.9	63.9	0.0%
PV	0.0	0.0	n/a
Total Usage/ Savings	341.4	168.4	50.7%

Table 130: “Deer” WHES Summary

Description	Annual Source Energy		Estimated Source Energy Savings
	Benchmark	Prototype	Percent of End Use
End Use	(MBtu/yr)	(MBtu/yr)	vs. Benchmark
Space Heating	98.3	33.2	66.2%
Space Cooling	19.7	7.3	62.9%
DHW	37.8	14.1	62.7%
Lighting	19.6	5.5	72.1%
Appliances and MELs	53.9	53.9	0.0%
PV	0.0	0.0	n/a
Total Usage/ Savings	229.2	114.0	50.3%

Table 131: “Fox” WHES Summary

As shown in Table 130 and Table 131, both Snow Creek prototypes exceed the next Building America goal of 50% whole house energy savings in the Hot/Dry climate with respect to the BA benchmark.

Energy data provided by sensors installed in the Snow Creek Prototype units and modeling against a BA benchmark will provide targeted whole house source energy savings estimates based on BA performance analysis procedures and energy performance measurements. This will be accomplished by making the following assumptions:

- The evaluations will be contrasted against the Building America Benchmark House of identical size and configuration as the case houses in Snow Creek. The benchmark

house will be modeled and simulated for performance and stand as the control for comparison to the monitoring data from the case houses. The Benchmark is generally consistent with mid-1990s standard practice, as reflected in the Home Energy Rating System (HERS) Technical Guidelines (RESNET 2002). A reference guide is provided by the DOE Building America Program that aids in defining the parameters of the Benchmark House for a given climate, and design configuration.

- Space heating, water heating, and standard electrical energy needs (refrigerator, lights, electronic equipment) are the primary energy demands to be evaluated. The temperatures in Park City during most of the year are cold, and there are only a few weeks where cooling may be required. During those times, it is assumed that the homes will utilize passive natural ventilation systems to remain cool and not rely on any mechanical active cooling.
- The options and possibilities for various types and combinations of finishes are unlimited. In order to remain consistent in the comparison of the benchmark house to the houses at Snow Creek, the same finishes will be modeled in the simulation as occur at the Snow Creek Houses respectively.

Two methods will be utilized in order to better understand the energy use in the two houses. The first method is to conduct an overall energy balance on each unit. The second method is to model each unit and compare the model results with models of houses with the same configurations but with conventional construction and energy systems (as controls). The conventional comparison will utilize the BA Benchmark House as the baseline. The overall energy balance will include data on the SIPs R-values, temperatures on exterior and interior surface of SIP on each floor, and temperatures on interior and exterior of roof panels on north and south slopes.

All temperature and electrical use data will be collected automatically using a data logger that can be accessed remotely via a dial-up modem. Units 10 and 11 have been fully fitted with thermocouple wires that include 12 points on each unit. Much effort was taken to route wires through precut chases in the SIP panel exterior walls, however the holes were not lined up from floor to floor and required drilling and fishing continually. See Addendum D for points list and as built locations of sensors on the exterior and interior surfaces of the panels and other locations within the parameters of the building proper (excluding geothermal sensors). The GCHP instrumentation will be connected to the same data loggers.

In order to verify the performance of the test houses, the data from the performance monitoring of the two houses will be compared to performance of simulated models of BA Benchmark House with identical size and configurations. The spatial data (3-D) from the architect, given in a Revit file or developed new in a 3D software platform, will be transferred to EnergyPlus for energy simulation for Park City climate scenario. Other software tools including BEopt by NREL, DOE-2, etc. will be used as necessary in order capture as accurate analysis of the benchmark house as possible. It is assumed that the orientation, location, and outdoor design conditions will be similar. Previous studies by Building America teams have used DOE-2

as the benchmark simulation tool. For this study Energy Plus will be used to evaluate the capacity of the tool to model residential buildings and the feasibility of such for future Building America and Department of Energy research in residential building performance using Energy Plus. No modeling has been completed at this time. This is a task for year 2010.

“Must Meet” Gate Criteria -- Prescriptive-Based Code Approval

Several issues were identified that impacted prescriptive or performance safety, health and building code requirements for new homes:

- Park City was unfamiliar with SIP construction and therefore followed the code standard, which was congruent with Premier Building Systems submittals. BHB Structural Engineers wanted a slightly different system that consisted of additional hold downs and provisions for additional lumber and structure on the interior of the SIP panels. These specifications were not standard and therefore led to delays in the submittal and permitting process.
- Foundations were only poured once submittal and permitting process was reviewed and accepted by all parties. If the panels had been designed and submittals had occurred during site preparation and excavation there would not have been the month delay due to design, submission and code review miscommunications.
- AKI Framing in late because R&O Construction could not find a framing contractor with SIP experience. Contractors with experience in the installation of SIPs in Utah are still relatively few. The architect reports that the gap between supply and install is great from a code and submittal perspective.
- There were no permitting issues or delays identified for the installation of the GCHP system.

“Must Meet” Gate Criteria -- Quality Control Requirements

Critical design details, construction practices, training, quality assurance, and quality control practices required to successfully implement new systems with production builders and contractors are being obtained. To accomplish this task, equipment is routinely inspected to determine whether the each energy saving technology device is being installed according to design specifications. In addition, personal interviews have been conducted with the SIP supplier, R&O construction, Park City and the architect. The following has been determined:

- Gaps exist between the sill plate and the concrete stem wall foundation. This can be attributed to the lack of quality control in the foundation pour. AKI, the install contractor for the SIP panels, did not know how to mitigate this discrepancy and was prepared to grind the concrete. Shims have been used to make up the gap structurally, but foam was not used to mitigate air infiltration. It is suggested that mastic be placed between the sill plate and concrete as well as a foam insert to remove the thermal transfer and potential air infiltration gap. Air infiltration gaps are also present in many

locations of fenestration (i.e. window and door openings). These gaps in the fenestration have been sealed with spray in foam insulation. Verification is needed to ensure that sealing has occurred at the sill to foundation location.

- The plan for construction was inefficient. The contractor requested one crew per house. However this led to great inefficiencies in the first 2 weeks of erection until the crews became knowledgeable of the system. It is estimated that house 14 and 13 took 2 weeks to install compared with the anticipated 5 days to install. Roof panels were the most difficult due to geometrical challenges. This was mitigated in the last units that estimated under a week to erect according to onsite observation.
- The trenching associated with the horizontal runs of tubing from the boreholes to the heat pumps caused significant site disruption. It is unclear how those disruptions would impact single unit construction activities. This will be followed up in the 2010.

“Should Meet” Criteria -- Neutral Cost Target

The 50.7% reduction in the “Deer” prototype’s whole house energy savings provides a substantial reduction in energy bills. The incremental cost calculation (in Appendix of the final report) shows that despite adding in the advanced energy features, the savings in utility bills will offset the additional cost. When financed as part of a 30-year mortgage at 7% interest, the incremental annual cost will be reduced by \$570, as seen Figure 89.

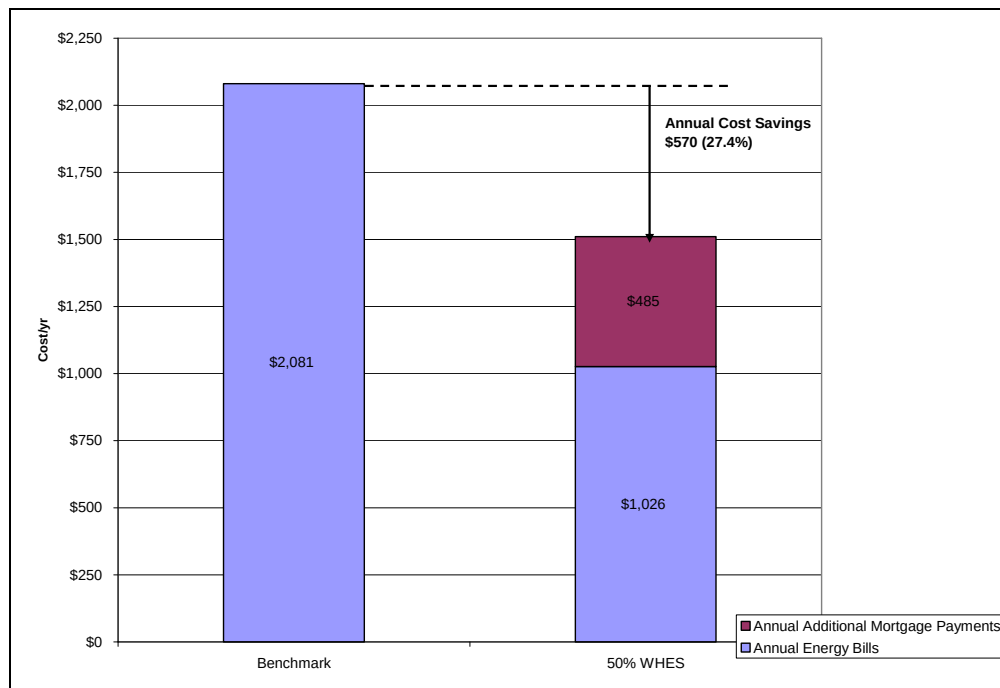


Figure 89. Cost Neutrality for “Deer” Model

Similarly, the 50.3% reduction of whole house energy savings in the “Fox” prototype will also result in a reduction in energy bills. The “Fox” prototype’s incremental annual cost when

financed as part of a 30-year mortgage at 7% interest will result in a reduction of \$224 per year, as seen in Figure 90.

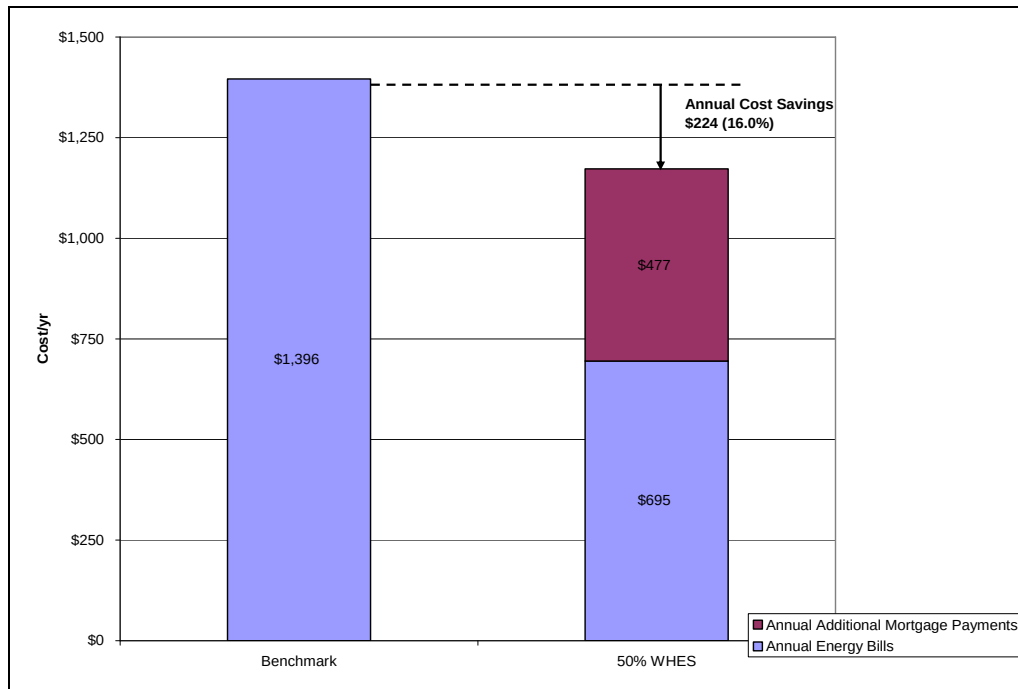


Figure 90. Cost Neutrality for “Fox” Model

Based on this information, it is clear that the incremental annual cost of energy improvements is less than the annual reduction in utility bill costs. Thus, the Snow Creek prototype homes pass the Neutral Cost Target “Should Meet” criteria.

“Should Meet” Gate Criteria -- Quality Control Integration

Health, Safety, Durability, Comfort, and Energy related QA, QC, training, and commissioning requirements are being monitored. The data obtained will be integrated within construction documents, contracts and BA team scopes of work.

To evaluate construction methodology and to identify problems that can be documented and analyzed to learn from for future projects, Tuesday meetings in Park City have been attended where we will take notes and photos and catalog in an archive for later reference during the analysis period.

Attendance at weekly meetings occurred up through the middle of October when the research team was asked to not attend. The reason for the request was that the contractor and architects were not able to talk as freely or candidly concerning budgetary concerns with the owner if we were present. Although the research team has not been able to attend weekly construction meetings, weekly site visits continue to occur with a walk around the site

accompanied by the contractor and architect. Construction documentation has been thoroughly carried out to determine the challenges of the energy saving systems as compared with traditional construction.

Construction was stalled initially due to issues with dewatering the site and the submittal process surrounding the SIPs for a total of 2 months. Accordingly the completion date has been moved back to May 2010 in order to avoid some winter months. Currently, siding is being placed on the exterior of the houses and it is unclear when interior plasterboard will be installed.

The SIP design, engineering, submittal, and installation difficulties contributed to schedule delays on the site of one month. The SIP panels have been promising and problematic due to the following issues:

DESIGN:

- The houses were designed to maximize interior volume and minimize exterior surface area. The houses are 2 – 3 stories for heating efficiency.
- The houses were initially designed to have stick framing with batt or foam insulation, but the bid for SIPs was competitive and attractive to the design team and owner. The SIPs design promised fast installation, durability, easy to install due to prefabrication, environmentally friendly due to recycled material content, all while decreasing on-site labor.
- SIP walls are 6.5" and roof is 12" with a polystyrene core.
- Because it is not originally designed for SIP construction, the house does not adopt efficiencies of SIP module, and is over structured - excess lumber exists within the SIP envelope, adding to thermal bridging problems.
- Coordination between the architect, engineer and SIP manufacturer was non-existent during design, leading to coordination problems all the way through design to install process.

SUBMITTALS:

- The SIP panels were specified by BHB Structural Engineers for Seismic D Zone. Premier Building Systems produces Seismic A, B & C rated panels but not D rated panels. Premier was the low bidder and not accustomed to doing larger residential or commercial work that require a higher level of submittal specification and clarity.
- Submittals were not detailed enough for the architect and structural engineer, including locations of post and beam embeds in walls in drawings being left out, having no connections to foundation or transitions at fenestrations, and the specification submissions were also generic and not specific to the project.
- BHB Structural Engineers wanted a bit different design than what Premier could

produce. BHB wanted a Seismic 'D' zone rating including locations of hold downs. The design process went back and forth between the two, resulting in pushing the City submittal date further back.

The majority of the problem is the unfamiliarity with SIPs from the architect and engineer which led to multiple revisions in the design submittal. Also, the SIPs supplier, Premier, did not have much experience working directly with architects and engineers, and therefore had difficulty in meeting their requests.

Gold Medallion 50% Prototype BP2 (2009)

The objective of this study is to evaluate the energy use of a 50% Prototype home through field testing and energy simulation. The 50% prototype Gold Medallion Home is located in the cold, dry climate zone of Salt Lake Valley, Utah, in the Daybreak sustainable development community.

The house contains a comprehensive network of sensors monitoring nearly every aspect of energy usage that occurs: thermocouples are embedded in the walls, floors, ducts and plumbing; pulse meters track energy usage, water and gas flows. House performance data are collected on minute, 15 minute and 60 minute and daily basis. The data were utilized to monitor the energy usage, water usage, gas usage and for performing energy balance on the PVT system to measure the efficiency, etc. Essential data patterns for any user-specified day are plotted in graphs on the 50% Prototype house website. The URL for the website is: www.zeroenergyhome.utah.edu.

This report documents the performance of the 50% prototype Gold Medallion house for the period of occupation (April 2009 to present). Example performance of individual devices on the Summer solstice (June 21, 2009), on a monthly basis, and year-to-date totals are presented. Example Energy Plus simulations using 2002 weather data are presented in the appendices. Monthly cumulative energy data match values specified in the power and gas bills.

EnergyPlus (version 2.2.0) is employed to evaluate annual electrical energy consumption and the total energy use of the prototype house. Design Builder a graphical interface package is used to perform the EnergyPlus simulations for a better visualization. EnergyPlus is being used to evaluate the energy use in the prototype house to be compared to simulations of a benchmark standard house built with construction methods and materials commonly used by the local builders in order to assess the Building America Gate 2 goal of a 50% energy savings.

Key Results

Overall behavior of the house's energy performance can be summarized by the total energy consumption. The following chart (Figure 91) shows a comparison of energy consumption and PV panel electricity production on a monthly basis.

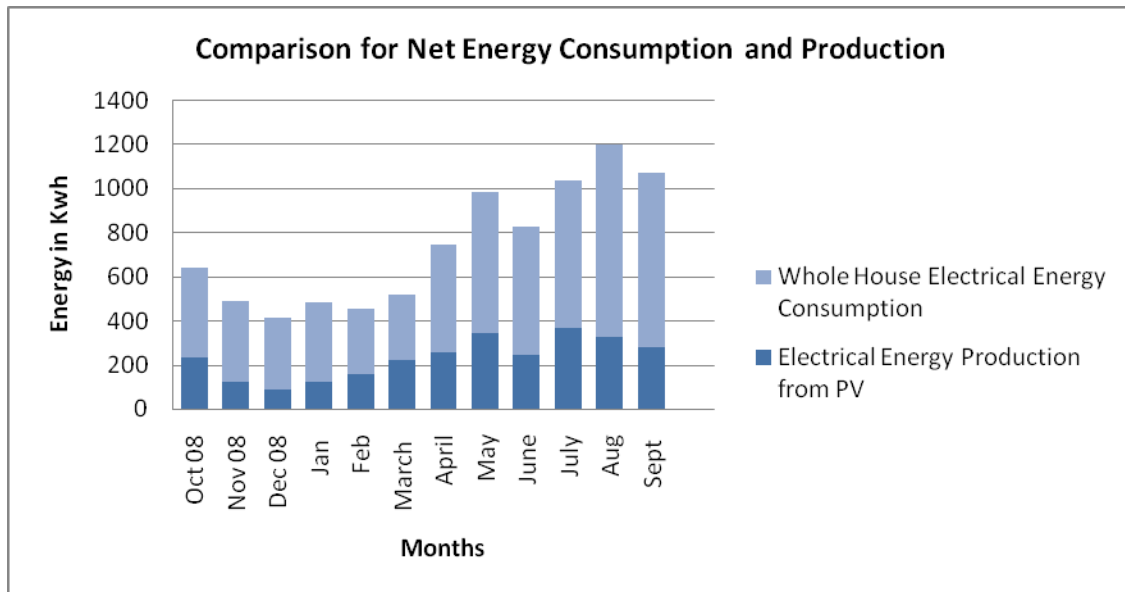


Figure 91: Monthly comparison of energy consumption and production.

Comparison of net energy production and consumption with the values from the power bills from Rocky Mountain Power is shown in Figure 92.

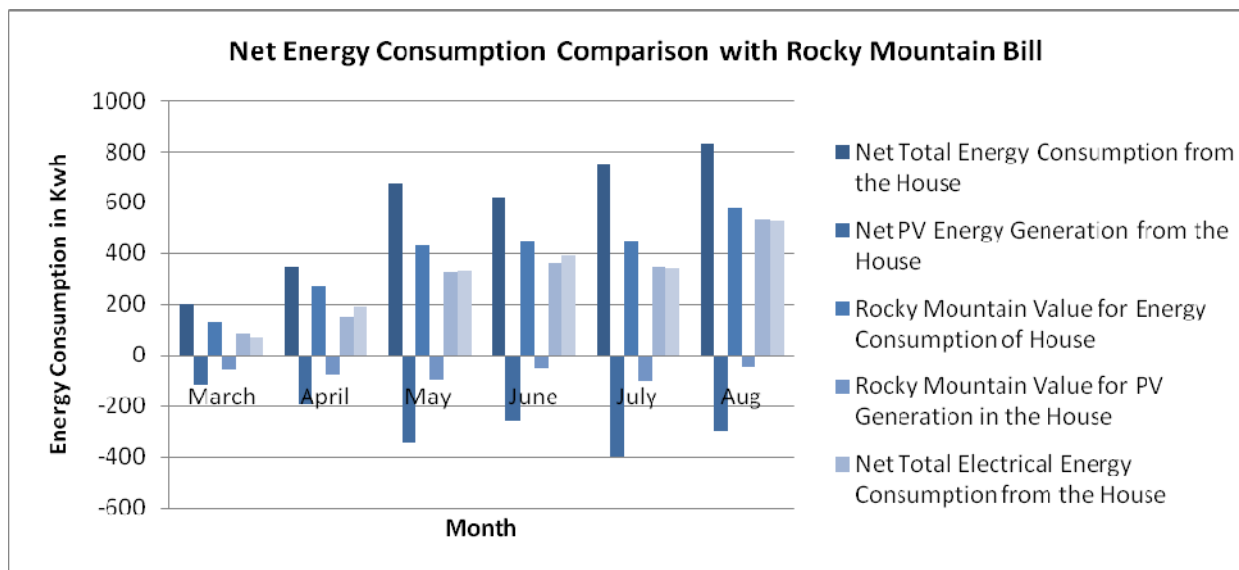


Figure 92: Comparison of net energy production and consumption with the values from Rocky Mountain Power bills.

The net consumption of electrical energy proves to be the same for both the set of values. However, the individual meter readings for the energy production and consumption measured by the Rocky Mountain Power meters and those connected to the data loggers differ. Further study will determine the reason for the difference in the readings.

Thermal energy from the solar panels in summer (~ 160 kWh thermal/month) is about 1/20 the monthly gas use for heat in the winter (~3300 kWh thermal/month).

Overall EnergyPlus simulations using 2002 weather data agree reasonable well with these field measurements. Details are presented in Appendix C of the final report. New EnergyPlus simulations will be performed using actual weather data and EnergyPlus 4.0. Those simulations will allow more specific evaluation of the accuracy of the simulation code input parameter data set. Based on that evaluation, the internal gains and other external loads that are not estimated in the EnergyPlus simulation will be included in the changes to obtain EnergyPlus output that matches the actual performance.

Once the EnergyPlus results match the observed performance, a new input data set will be created to reflect specifics of a standard house. The primary changes will be the exterior wall construction (frame vs. SIPs), the elimination of the solar PVT energy inputs, and the details of the air conditioning equipment (OASys replaced with a conventional vapor compression system). Final comparisons will be made between monthly and annual energy uses from simulations and actual measurements in order to assess the 50% energy reduction goal.

Gate Status

As reported in “Task 3.2 Stage Gate 2 Prototype House Report: Performance Evaluations in Preproduction Prototypes, Task Order DE-FC26-08NT00431, Deliverable Number 3.2.a, December 2008, the Gold Medallion home has been constructed and extensive monitoring equipment has been installed. BIRA contracted building monitoring and data evaluations on the PVT and two-stage OASys evaporative cooler to the University of Utah in July, 2009. It is expected that the University of Utah will continue to monitor and analyze the energy use through a full year of occupancy at a minimum. Energy efficiency benefits and costs are now being quantified and evaluated to verify that the house meets the 50% goal.

Conclusions

Data collected and analyzed to date show that the PV electrical energy production is significant compared to electrical energy use and generally matches net values from Rocky Mountain Power. The large percentage of building energy compared to electrical energy use considers both the reduction of energy use through installation of energy appliances such as the OASys cooler and consistent PV power. Solar thermal has yet to show its potential since occupancy has been during warm months. However, there is reason to believe that the goal of 40% reduction relative to the BA benchmark will be achieved.

“Must Meet” Gate Criteria -- Source Energy Savings

The 50% Prototype house at Daybreak incorporates many energy-saving features, solar power generation and supplemental solar water heating. Major energy saving features include: (1)

Evaporative Cooler (OASys) (2) Photovoltaic Thermal Panels (PVT) (3) On-demand tankless water heater (4) hydronic furnace and (5) Structurally Integrated Panels (SIPs) for walls. The house also has other energy saving features like the florescent lighting, radiant heat barrier in the attic, low emissivity windows, and ducts that run in conditioned space.

The EnergyPlus (version 2.2.0) simulation code was employed to evaluate annual electrical energy consumption and the total energy use of the prototype house using 2002 weather data. Comparison between simulations using actual weather data and measured energy use will allow model calibration. EnergyPlus will then be used to evaluate the energy use in the prototype house compared to simulations of a benchmark standard house built with construction methods and materials commonly used by the local builders in order to assess the Building America Gate 2 goal of a 50% energy savings.

Data are now routinely available to assess actual energy use. Once actual weather data is integrated into the modeling using EnergyPlus 4.0, and a full year of data is available for calibration, adjustments to house input data files will be made to accurately assess the source energy savings. The 50% Prototype home energy analysis will provide targeted whole house source energy savings projections based on Building America performance analysis procedures and energy performance measurements. Preliminary EnergyPlus calculations using 2002 weather data are presented in Appendix C of the final report.

“Must Meet” Criteria -- Prescriptive-Based Code Approval

As reported in *Task 3.2 Stage Gate 2 Prototype House Report: Performance Evaluations in Preproduction Prototypes*, Task Order DE-FC26-08NT00431, Deliverable Number 3.2.a, December 2008, “By working with the City to educate them and address any issues prior to construction, the BIRA team was able to prevent code related issues in incorporating these advance features.”

“Should Meet” Criteria -- Quality Control Requirements

As reported in *Task 3.2 Stage Gate 2 Prototype House Report: Performance Evaluations in Preproduction Prototypes*, Task Order DE-FC26-08NT00431, Deliverable Number 3.2.a, December 2008,

“This home incorporated multiple advanced systems and insuring the systems were installed properly, as specified, required additional effort on BIRA’s part. Monthly meetings were conducted to address any issues in the incorporation of the BA design features. Although, the design required equipment and construction practices beyond the typical Gold Medallion building practices, they did not have any issues. BIRA worked with Gold Medallion in developing and meeting milestones to assure that progress was made and that designs were implemented properly. Monthly builder meetings were also used to incorporate and coordinate third-party testing and verification.”

The present team will work to acquire and assimilate further cost and quality control information from the BIRA team compiling that data.

“Should Meet” Criteria -- Neutral Cost Target

This research team was not involved in cost data collection during the construction phase. Thus there is no opportunity to report on the incremental annual cost of energy improvements, when financed as part of a 30 year mortgage. Once actual weather data is integrated into the modeling using EnergyPlus 4.0, and a full year of data is available for calibration, adjustments to house input data files will be made to accurately assess the annual reduction in utility bill costs relative to the Building America Benchmark.

“Should Meet” Criteria -- Quality Control Integration

According to the *Task 3.2 Stage Gate 2 Prototype House Report: Performance Evaluations in Preproduction Prototypes*, Task Order DE-FC26-08NT00431, Deliverable Number 3.2.a, December 2008,

“BIRA conducted monthly meetings to address any issues in the incorporation of the advanced design elements. Since the Gold Medallion Homes utilized the PVT, OASys, hydronic heating, and SIPS, BIRA worked with them in developing and meeting milestones. This helped to assure that progress was being managed and provided a mechanism for information exchange with the industry partners. PVT and OASys worked with the builder to ensure proper installation and commissioning of each system. Monthly builder meetings were used to incorporate and coordinate third-party and industry partner testing and verification. PVT worked with the builder to provide installation assistance and commissioned the system at completion.”

“Should Meet” Criteria -- Gaps Analysis

Once data is available for a year and calibrated EnergyPlus simulation results are available, prototype house gaps analysis, lessons learned, and an evaluation of major technical barriers to achieving the targeted performance level will be identified and reported.

Forest City, HI – 50% Hot/Humid Mololani Prototype BP3 (2010)

The Forest City Military Community LLC (“Forest City”) prototype home was evaluated relative to the Building America Stage Gate 2 “Must Meet” and “Should Meet” Gate Criteria (See Appendix A of the final report) at the 50% Hot/Humid whole house energy savings (WHES) level.

Forest City is the master developer of several housing developments for the US Navy and Marines in Hawaii. The home builder participating in this Mololani community project is Costal Homes. The homes constructed are not for sale but are made available to Navy and Marine

personnel with rent and utilities paid by the property manager. Forest City, as a property manager, is motivated to build durable and energy efficient homes that minimize living cost. They are committed to working with BIRA through the entire BA Stage Gate process with the goal of building energy efficient, cost-effective, and marketable communities.

Key Results

The Mololani Prototype home evaluated in this study achieved the 50% Hot Humid WHES which will impact the energy profile of a master-planned community of close to 3,000 homes. BIRA's partnership with Forest City provides a significant opportunity to further improve the developer's energy efficiency and sustainable design practices. Forest City remains committed to improving their current standards, even in this economic climate.

Gate Status

The prototype home was built as designed at the 50% WHES level and has been verified to meet Stage Gate 2 Criteria. The prototype home provided a proof of concept and all homes in the Mololani development will be built to this level. Forest City and Costal Homes are committed to continued work with BIRA to complete research on the prototype home and to move forward with community scale developments.

Conclusions

The ultimate goal of this work was to explore construction practices beyond the current Military Construction guidelines that are both cost-effective and maintainable. The greatest hurdle to achieving a 50% WHES level was that current construction practices were not adequate with what is required to take full advantage of the more energy efficient features. The increased efficiency level impacted all areas of construction, from the framing to lighting. However, changes to current building practices were still within typical construction practices. The additional costs for Forest City to achieve the 50% WHES level are not difficult for them to justify due to the high electricity rates in Hawaii.

Builder/Project Overview

In 2007, BIRA partnered with Forest City to assist them in improving their construction practices and to increase their energy efficiency. The partnership led to a 41.9% WHES level relative to the BA benchmark for a 500+ home community. Two years later, Forest City is now committed to building its future communities at the 50% WHES level. BIRA was asked to provide feasible 50% WHES design strategies that focused on cost-effectiveness and maintainability. Maintainability is very important to Forest City since they are also a property management company for the military and must service the homes for 50 years. Energy efficiency is also important because the homes are provided to military personnel rent- and utility-free.

This was an important partnership for BIRA since Forest City plans to build close to 1,000 homes in 2010 and 2011 and is the only developer for the Navy and Marines in Hawaii. BIRA proposed a 50% WHES design relative to the BA benchmark, which was an approximately 15% improvement over their current building practices. The Prototype is a 1,693 sq. ft., 3 bed/2.5 bath, two-story townhouse. The prototype is the middle unit of a four-plex.

Through this project and other communities developed with Forest City, BIRA has been able to collaborate with key partners and stakeholders, listed below, to understand the local environment and develop strategies that work. BIRA will be working with these organizations to further impact the hot/humid climate.

- Builder Partners:
 - Forest City Military Communities LLC. - Master Developer
 - Costal Homes
- Local Energy organizations and Consultants:
 - Hawaii Electric Company (HECO)

Location

The prototype home is located within the Mololani Community on the Marine Corps Base in Kaneohe, Hawaii. The community is replacing existing units to maximize land usage, and increase the efficiency of all of the homes.

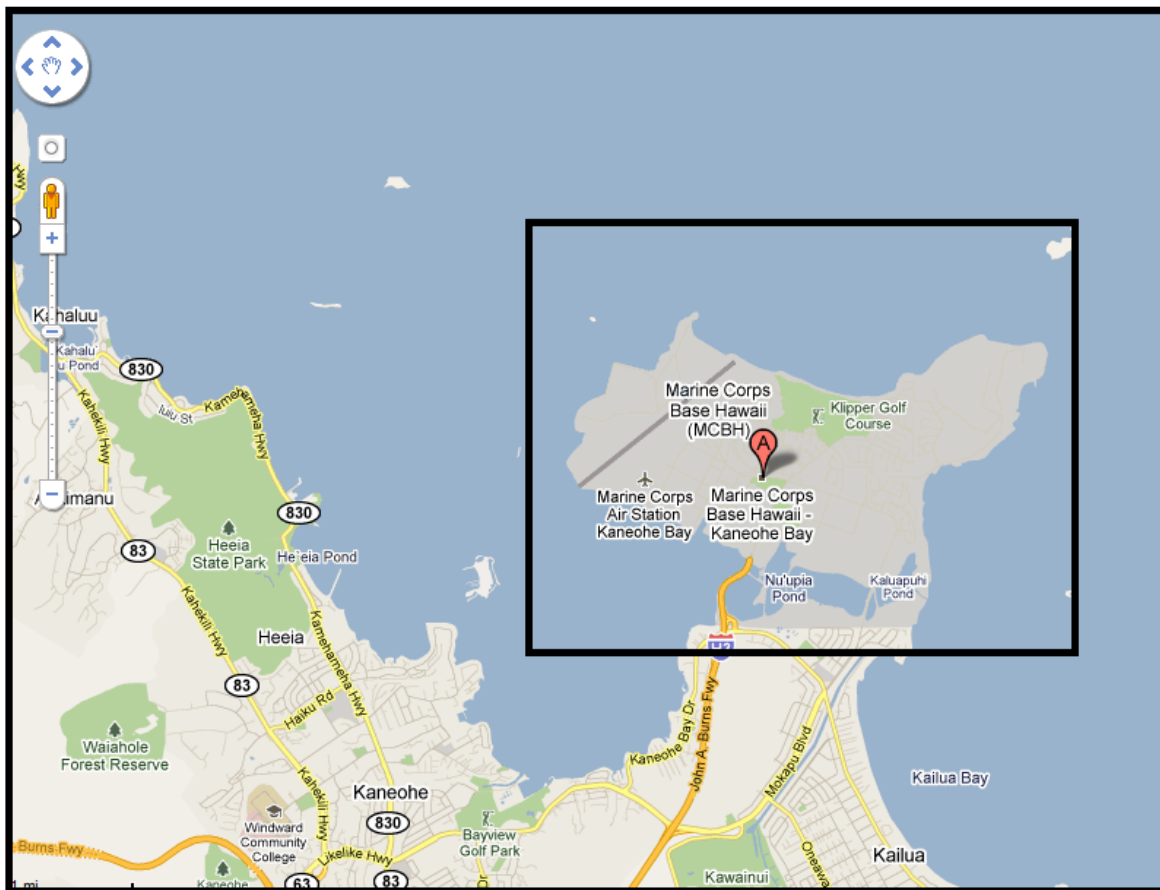


Figure 93. Prototype home location

Climate

Kaneohe has 3406 CDD and only 3 HDD₆₅.

Annual Average Maximum Temperature	90.2°F
Annual Average Minimum Temperature	75.4°F
Annual Average Total Precipitation	37.24 inches

Table 132. Kaneohe, HI annual climate data

Utility Provider

The electricity provider for this home is HECO. Table 133 shows electrical rates, effective 2/20/2010.

Electricity Rate		
	Utility	Hawaii Electric Company
	Marginal	\$0.18
	Fixed	\$8.00/month

Table 133. Utility rates

Detailed Description of Test Home

Design for the prototype home began with Forest City's 41.9% benchmark. Upgraded features include:

- Metal framing:
 - R-15 wall insulation
 - R-49 attic insulation with Radiant Barrier
- 0.20/0.20 U-value/SHGC windows
- 21 SEER HVAC unit
- 40 sq. ft. solar hot water
- 100% fluorescent lighting
- ENERGY STAR® appliances
- 6.0 kW DC PV unit



Figure 94. Mololani Unit 110 home

Builder

Costal Homes

Total sq. ft.
1,693

Bedrooms
3

Baths
2 ½

Monthly Price
\$2,500/mo.

“Must Meet” Gate Criteria - Source Energy Savings

The Mololani home meets the 50% whole house source energy savings based on BA performance analysis and energy performance measurements. Analysis was conducted using EnergyGauge® and resulted in 53.5% WHES (see prototype report Appendix B for results).

“Must Meet” Gate Criteria - Prescriptive-Based Code Approval

The greatest hurdle to achieving a 50% WHES design was that the current construction practices were not adequate with what is required to take full advantage of the more energy efficient features. For example, the insulation subcontractors compressed and left gaps in the wall cavities. Additional costs for Forest City to achieve the 50% WHES level are not difficult to justify due to the high electricity rates in Hawaii.

Table 134 compares the features of Forest City’s original construction guidelines vs. the 50% WHES Hot/Humid design. The upgraded features of the 50% WHES design did not generate any code related issues. The energy efficiency design strategy did not incorporate any exotic features that have not yet been evaluated by local building officials. Also, prior to the start of construction, all required documents including systems incorporated into the home, were submitted to the building officials to ensure that the structures and systems met applicable safety, health, and building code requirements. Forest City did not experience any code related issues in the incorporation of this design.

Basic Information			
Builder	Forest City As-Built	Forest City 50% Prototype	
Development	Baseline	Mololani	
House Type	Single Family Attached	Single Family Attached	
Current Energy Savings (BA Benchmark)	41.9%	53.5%	
Envelope			
Wall Insulation	R11 batts 2x4 16"o.c.	R15 batts 2x4 16"o.c.	
Attic Insulation	R19 Cellulose	R49 Cellulose	
Garage Ceiling	R11 Fiberglass	R11 Fiberglass	
Radiant Barrier	Yes	Yes	
Infiltration	0.00050 SLA	0.00020 SLA	
Thermal Mass			
Exposed Slab	No Exposed Floor	40% exposed	
Windows & Shading			
Window Areas	16.0% F50 B50 L0 R0	16.0% F50 B50 L0 R0	
Window Type	U-value/SHGC (.40/.40)	Low-E low SHGC (.20/.20)	
Lg. Appliances			
Refrigerator	Standard	ENERGY STAR®	
Cooking Range	Electric	ENERGY STAR® – Electric	
Dishwasher	Standard	ENERGY STAR®	
Clothes Dryer	Electric	ENERGY STAR® - Electric	
Clothes Washer	Standard	ENERGY STAR® (H-Axis)	
Lighting			
Hardwired Lighting	50% CFL	100% CFL	
Equipment			
Air Conditioner	SEER 13	SEER 21	
Water Heater	Electric 0.58 EF	120 Gal .80 EF Electric	
Ducts	R-4 Attic Insulation	R-6 Attic Insulation	
Renewables			
Solar DHW	None	40 Sq. Ft Solar DHW	
Solar DHW	None	6.0 kW System	

Table 134. 50% Hot/Humid design feature comparison

“Must Meet” Gate Criteria - Quality Control Requirements

Forest City built the home within the design specifications. Table 135 shows a comparison of the prototype specifications vs. the actual implementation specifications. Initially, there were some building techniques that required improvement. The local subcontractors were not

educated on maximizing the benefits of the energy efficient features that they were using. BIRA spent a lengthy amount of time on-site to educate each of the different subcontractors, including framers, insulators, and HVAC professionals, to improve each of their building techniques. In the end, the trainings were extremely beneficial at improving building quality. BIRA performed a final detailed testing and inspection to confirm that equipment and feature installations were completed properly. Testing and inspections included an audit of such features as duct leakages, and building air infiltration systems. The air infiltration result was significantly higher than the design specifications, however this was entirely due to the joined walls between the attached units. BIRA is currently working with Forest City to develop a building approach to achieving a tighter common wall-to-ceiling approach. Below are the actual leakage test results, which also achieved Builders Challenge certifications.

Features	Prototype Specifications	Actual Test Results
Air Infiltration	SLA: 1.5	SLA: 3.8
Duct Leakage	<48 cfm	16 cfm
Cooling	SEER 16	SEER 16
Water Heating	Solar Thermal	Solar Thermal with 120 gal .80 EF storage

Table 135. Verified equipment and infiltration results for Mololani homes

“Should Meet” Gate Criteria - Cost Neutrality

The energy efficient designs incorporated into this house were completed with the full cooperation of Forest City. BIRA worked to develop a cost-effective design package that exceeded the current energy guidelines and reached a 50% WHES relative to BA benchmark. Forest City has shared their post-construction costs with BIRA, which conformed to the previous analysis conducted in the Stage Gate 1A design development. A detailed analysis of cost neutrality can be found in the prototype report Appendix C. The cost analysis indicates that when compared to Forest City’s 41.9% design strategy, this home design is cash positive. Deducting incentives from incremental costs results in a monthly cash positive value of \$1,575.05, using Hawaii’s electric rates.

“Should Meet” Gate Criteria - Quality Control Integration

BIRA conducted monthly meetings to address any issues in the incorporation of BA design features. Although the design required equipment or construction practices above typical Forest City building practices, they did not encounter any issues. BIRA worked with Forest City in developing and meeting milestones to assure that progress was made and that the designs were implemented properly. Monthly builder meetings were used to incorporate and coordinate third-party testing and verifications. In the end, Forest City adopted DOE Builder’s

Challenge's rigorous QA/QC quality protocols to maintain quality building practices.

"Should Meet" Gate Criteria - Gap Analysis

The 50% design does not require any construction practices that would be considered atypical from Forest City's current building practices. The features in this prototype home are based on high efficiency, standard features available today. No further testing is required on these features as the performance has already been monitored and proven to provide the required energy savings. Primarily due to the high electricity rate in Hawaii, improving the energy efficiency of their buildings is very cost-effective.

Forest City did have a few problems with proper sealing of the home and the installation of insulation and ducting. Construction practices in Hawaii are not as refined or rigorous as in some other parts of the nation and even though Forest City is committed to more efficient homes, BIRA experienced some difficulties in getting subcontractors to meet the required installation techniques, or QA/QC. These difficulties were overcome with sufficient training and improved Forest City QA methods. However, infrastructure for good market penetration of these quality construction practices is currently lacking in Hawaii.

Problems also included gaps and compression in the insulation, air gaps in the top and bottom plates, and unsealed air handlers and plenums. Fortunately, these issues were easy to address to subcontractors who were eager to learn. The prototype home is now testing at $<4.0^{23}$ SLA and $<4\%$ duct leakage with very good insulation standards.

In the future, Forest City plans on working with Building America to continue to develop increasingly efficient homes that further reduce heating and cooling loads.

Snow Creek Cottages BP3 (2010)

Snow Creek Cottages, an affordable housing project located at a site adjacent to Snow Creek, consists of 13 energy efficient residential units with electricity as the sole utility energy source. This report discusses the construction findings relative to the Building America Stage Gate 2 "Must Meet" and "Should Meet Criteria" (see Appendix A of the final report). The statuses of critical path tasks are identified.

Key Results

Preliminary analysis of the building designs, using RemRate software, shows HERs Indexes of 46 and 50 for the Fox Unit (smaller) and the Deer Unit (larger), respectively.

²³ The high SLA was largely due to the shared common walls between the units, and not infiltration from the exterior.

Each home costs an average of \$131.88/sq. ft. including renewable technologies, and an average of \$115.39/sq. ft. without renewable technology. The BA Benchmark costs were an average of \$109.76/sq. ft. without renewable technology, an incremental cost of \$ 5.60/sq. ft.

Gate Status

Snow Creek Cottages remain in Stage Gate 2. Cost analysis and qualitative interviews with project players have been, completed. Energy simulations are being conducted to establish baselines for calibration against actual performance data. Detailed studies are still needed to assess the prototypes' effectiveness in achieving 50% WHES

Conclusions

The greatest obstacle encountered were the difficulties with unfamiliar construction practices including SIPs submittals and code review. Additional familiarization with SIPs building practices and coordination early in project delivery would have likely alleviated this problem. The framing contractor began SIPs installation at a rate slower than standard installation. However, as assembly techniques improved, the framing contractor finished the exterior wall and roof installation more quickly than if using standard framing construction techniques.

Introduction

This Stage Gate 2 Prototype Report documents the status of the Snow Creek Cottages Prototype Homes and their effectiveness in achieving 50% whole house energy savings (WHES) in the Cold Climate, relative to the Building America Stage Gate 2 "Must Meet" and "Should Meet Criteria" (see Appendix A of the final report).

Snow Creek Cottages is an affordable housing project located at a site adjacent to Snow Creek. The 13 energy efficient residential units are subsidized by the Park City municipality to serve as work-force housing to meet the growing demand of the mountain community. The project is not serviced by natural gas and electricity is the sole utility energy source.

To reduce the overall energy use by 50%, several energy saving/producing building technologies were employed. These include:

- Structurally Insulated Panel (SIPs) exterior walls from foundation to roof bearing
- SIPs roof structure
- Photovoltaic (PV) cells
- Ground-coupled heat pump (GCHP) space heating
- Evacuated tube solar hot water system
- Clearstory roof windows
- Heat recovery ventilation (HRV)

Each energy-saving technology has other impacts in addition to energy reductions, namely construction schedule modifications and life cycle costs. Data was gathered through an interview cycle with key project players to compare the BA Benchmark to the energy efficient prototype to determine the schedule and cost impacts of the development.

As the construction for the houses were completed in late summer of 2010, monitoring equipment was not successfully installed to measure whole house energy usage until early November.

Background

Park City is the developer of the 13 unit affordable housing development in Snow Creek. Park City has developed a sustainability team that connects the missions of various departments to achieve a balance between meeting economic and community development goals while reducing environmental impact. The city has created a website that allows its citizens to download reports related to carbon emissions as a function of city operations. Residents of may have access to an interactive tool, located on the website, which calculates their own carbon footprint including energy consumption. The Snow Creek development is in line with the city's mission to conserve energy and furthermore reinforce its commitment to affordability and environmental sustainability in its operations and future developments.

Roger Durst of Elliott WorkGroup, the project architect, is National Green Building Standard Certified and is known for implementing passive and active design strategies for energy-efficient residential applications. However, there was lack of experience in the energy efficient systems or whole house energy efficiency design at the scale of Snow Creek. Although R&O Construction's commercial division had prior experience with SIPs and ground-coupled heat pump (GCHP) construction, the residential team on the project did not have any experience with innovative building techniques.

The SIPs supplier was Premier Building Systems based in Montana and the installer was AKI Framing. Premier is the largest polystyrene SIPs manufacturer in the U.S. with nine (9) plants in nine (9) states. AKI Framing did not have previous experience with SIPs construction but hired the SIPs installer from the Gold Medallion Home in Daybreak, Utah, a Building America home that was monitored previously. Post-SIPs construction, thermocouples were installed in the two units of interest in order to capture the impact the wall system has on reducing energy consumption and controlling heat transfer.

The installation of the GSHP boreholes, U-tubes and horizontal tubing was completed by Palace Geothermal. Mechanical contractors have connected the heat pumps to the ground coupled tubing inside the buildings.

The University of Utah (UofU) team worked with Park City, R&O, Elliott WorkGroup, Premier, and AKI to gather information on delays, costs, schedules, and performance specifications. The

UofU assisted in the GSHP commissioning including flow rate measurements, pressure balancing, and inlet/outlet temperature measurements at the methanol inlet and outlet ports.

Location

Park City, Utah is located 32 miles southeast of Salt Lake City in Summit and Wasatch Counties on the eastern side of the Wasatch Mountain Range. The city is a mountain resort with winter and summer recreational opportunities. Park City has experienced an increase in population due to the 2002 Winter Olympics when various venues were located within the city limits. New residents have been attracted to opportunities in the city, but their arrival has changed demographics in the city. Summit and Wasatch Counties, host to Park City and other mountain cities, are the wealthiest counties in Utah. The community, made up of 9,000-10,000 residents, is well educated, liberal and progressive. As the population grows, the need for a municipal work-force including teachers, police, and utility workers has also grown. The largest obstacle has been a lack of affordable housing for municipal workers. To overcome this obstacle and provide housing within the city, Park City has developed Snow Creek Cottages to aggressively pursue energy efficiency.

Park City is located at 6,500-7,000 feet above sea level and is considered a dry cold climate. The cold climate designation is defined by requiring more than 5,400₆₅ heating degree days (HDD) and fewer than 9,000₆₅ HDD.

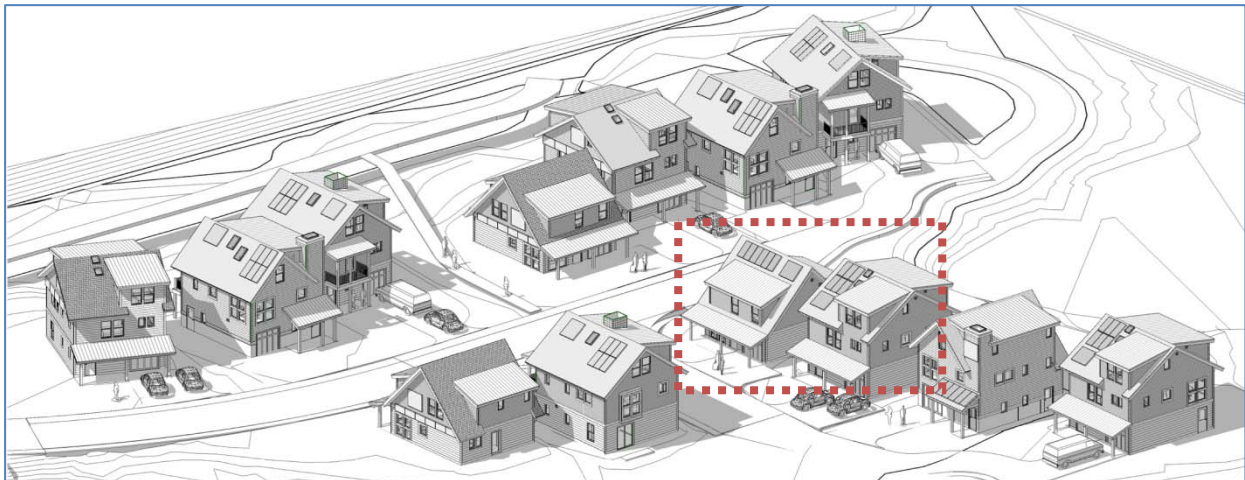


**Figure 95. 13-Unit Snow Creek Development
Fox A (#10) on left & Deer A (#11) on right**



**Figure 96. Snow Creek Cottages Development Area
Located at 6,800 elevation in Cold Climate Designation**

Utility Provider

The electricity provider for the prototype houses is Rocky Mountain Power (RMP) which is owned by Pacific Energy. Utah experiences some of the lowest utility rates in the nation averaging below \$0.09/kwh according to Edison Electrical Institute, a 3rd party power research center. Residential rates are being monitored simultaneously with the energy monitoring to determine cost effectiveness of whole house energy.

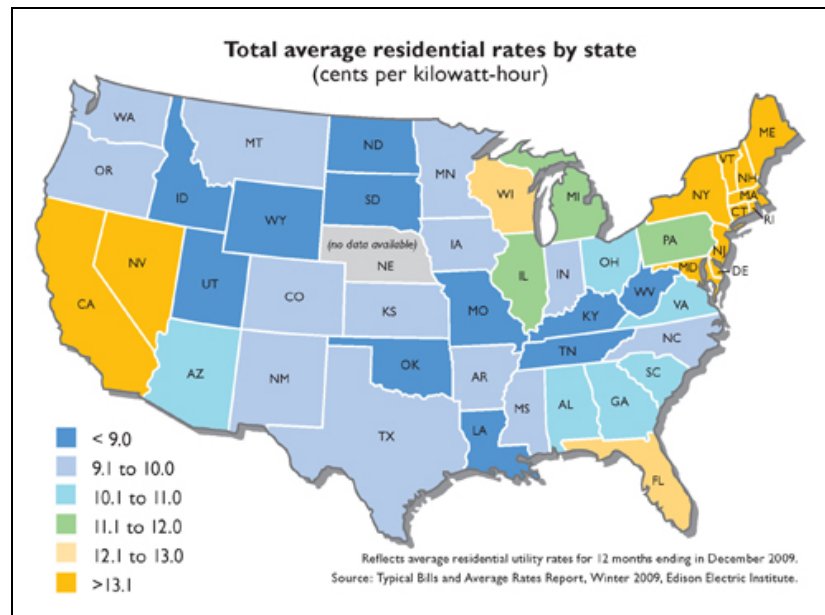


Figure 97. Average electricity rates by state indicating that Utah charges the least amount for power in the nation

Detailed Description of Prototype Houses

Two units are currently being evaluated, Fox A (#10) and Deer A (#11), each with unique features listed in Table 136.

Test Home Overview	
Fox A (#10) Unit Description	Deer A (#11) Unit Description
Two story, single family detached unit	Three story, single family detached unit
2 bedrooms, 2 baths	3 bedrooms, 3 baths
single car parking in garage	single car parking in garage
26' x 30' footprint	26' x 30' footprint
Approximately 1,560 square feet of living and utility space	Approximately 2,340 square feet of living and utility space
3 U-Tube Boreholes to 100'	4 U-Tube Boreholes to 100'

Table 136. Description of Snow Creek Cottages Prototypes (Unit #10 and #11)

Prototype Fox A (Unit #10) and Deer A (Unit #11) at Snow Creek have the following specifications:

- 6.5" SIPs Wall Construction (R-21 to R-23)
- 12.25" SIPs Roof Construction (R-45 to R-47)
- 1.5" Rigid Insulation under slab @ 48" from perimeter
- 1.5" Rigid Insulation at stem wall to top of footing
- 3-4 U-borehole at 100' depth and GSHP WaterFurnace Envision

- 30 evacuated tube per unit solar hot water collector
- Superstor AR Solar Hot Water Tank (size varies per unit)
- (6) per unit - 58.3" x 26.6" 125 W DC Polycrystalline PV Cell
- Heat Recovery Ventilator (HRV) RenewAire
- Amsco vinyl .35 / .29 U-value/SHGC typical
- ENERGY STAR® appliances
- CFL Lighting
- Compact design – low exterior wall surface to interior volume ratio
- Hot roof, not ventilated attic space
- Roof Windows with stack venting



Figure 98. Snow Creek Cottages, Unit 10 (left) and 11 (right) with PV and Evacuated Tube Solar Hot Water

Prototype Home Status

Preliminary modeling has been performed for the two prototype houses in various modeling platforms including RemRATE, EQuest/DOE2 and E+/DOE 2 Blast in preparation for calibration of the monitoring data scheduled in 2011.

Construction of the houses was completed in July 2010, with occupancy beginning in late summer of that year. Sensors have been tested and have been functional with data streaming since late November 2010.

All field work required prior to evaluating the prototype homes was completed; BIRA installed monitoring equipment to begin collecting data in late November.

Modeling of SIPs heat transfer will involve both the application of simulation models and actual sensor data collected from the devices placed in interior and exterior wall surfaces for analysis of the impact SIPs has on whole house energy efficiency when compared to the BA Benchmark.

Subsurface temperature monitoring sensors were successfully installed and thermocouple wires have been bundled and run in PVC conduit to the data acquisition unit location. Ground source heat pump (GSHP) performance data from this installation is now being collected to provide overall energy savings and cost data for “must meet” whole building benefit evaluations. Modeling of the heat transfer from the U-tube boreholes will involve both the application of approximate models of heat flow and the expanded three-dimensional simulations of the transient temperature field near the boreholes.

Stage Gate 2 Research Objective

Results from field tests, construction monitoring and energy simulations are being used to evaluate the capacity to integrate advanced energy systems with production building practices in prototype homes. The following results will be available once the energy monitoring evaluations are completed for the Deer Unit, #11 and Fox Unit #10:

- Quantification of the reduction in energy consumption that can be achieved in cold environments by using SIPs exterior walls and SIPs roof structure, GCHPs for heating, solar hot water heating, and PV electricity production when compared with IECC 2006 Code Standard House (BA Benchmark) to ensure 50% WHES.
- Estimation of the return on investment (ROI) of utilizing energy reducing equipment and methods compared with BA Benchmark using Park City monthly energy prices for cost competitiveness of energy efficient housing.
- Documentation of any difficulties or problems encountered while designing and installing the various energy reducing equipment and systems during the construction process.

“Must Meet” Gate Criteria -- Source Energy Savings and Whole Building Benefits

Energy data from sensors installed in the Snow Creek prototype units, energy simulation models against the Building America (BA) benchmark, and the collection of whole building performance data will provide targeted source energy savings estimates based on BA performance analysis procedures and energy performance measurements. This will be accomplished through calculations based on the following assumptions:

- The evaluations will be contrasted relative to the BA Benchmark. The benchmark home will be modeled and simulated for performance following the reference guide provided by the BA Program.
- Space heating, water heating, and standard electrical energy needs (refrigerator, lights,

electronic equipment) are the primary energy demands to be evaluated. Park City temperatures require little cooling energy. During those times, it is assumed that the homes will utilize passive natural ventilation systems to remain cool and not rely on any mechanical active cooling.

- The options and possibilities for various types and combinations of finishes are unlimited. In order to remain consistent in the comparison of the benchmark house to the houses at Snow Creek, the same finishes will be modeled in the simulation as occur at the Snow Creek Houses.

Two methods will be utilized to better understand the energy use in the two houses. The first method is to conduct an overall energy balance on each unit which will include data on the SIPs' R-values, temperatures on exterior and interior surfaces of SIPs on each floor, temperatures on interior and exterior of roof PV, and temperatures on the evacuated tube solar hot water panels on north and south slopes.. The second method is to model each unit and compare the model results with models of houses with the same configurations but with conventional construction and energy systems (as controls). This comparison will use the BA Benchmark as the baseline.

All temperature and electrical use data will be collected using a data logger remotely accessed via a dial-up modem. Units 10 and 11 have been fully fitted with thermocouples. See prototype report Appendix D for points list and "as-built" locations of sensors on the exterior and interior surfaces of the panels and other locations (excluding geothermal sensors).

To verify the performance of the prototype houses, the R-values of the SIPs panels and the data from performance monitoring will be compared to the simulated models of the BA Benchmark. The spatial data (3-D) from the architect has been transferred to EnergyPlus for energy simulation in the Park City climate.

Preliminary "as-built" modeling has been completed using DOE 2 and Energy Plus. However, these models remain to be calibrated with actual data from the monitoring process to develop an accurate comparison. Once the models have been calibrated with actual energy data, the BA Benchmark will be modeled to provide the baseline for comparison with the actual prototype house performance. This task will be performed in 2011, refer to report's Appendix H for preliminary energy modeling results.

As part of the design process, Park City hired a consultant, Wasatch Engineering, to perform energy evaluations of the two prototypes and produce HERs ratings in connection with the National Green Building Standard guidelines. The HERs rating provides a baseline for energy performance which will be used in addition to the collected data gathered during 2011 for BA Benchmark comparisons. See Appendix G in the prototype report for the HERs Report.

“Must Meet” Gate Criteria - Prescriptive-Based Code Approval

Several issues were identified that impacted prescriptive or performance safety, health and building code requirements for new homes. In order to meet 50% WHES, the following prescriptive measures must be met regarding SIPs: (more detailed review of challenges covered in the “Should Meet” - Gaps Analysis)

- Better coordination is needed between municipality (code enforcing institution), system’s engineer (SIPs), and the design engineer (structural) early in the process to determine what code requirements are needed and the responsibility of the manufacturing engineer vs. the design engineer of the panel sizes, locations and connection. This is especially an issue in high wind or seismic regions where certain energy saving systems may not be designed to withstand environmental forces.
- Select an experienced SIPs framer, or provide onsite training to crews, to ensure correct installation for structure, air tightness and other trade integration (i.e. electrical and plumbing).

Regarding the GCHP system:

- Critical design details have been defined and construction practices, training, quality assurance, and quality control practices required to successfully implement new systems with production builders and contractors have been observed.

“Must Meet” Gate Criteria -- Quality Control Requirements

Critical design details, construction practices, training, quality assurance, and quality control practices have been documented to verify that the project meets prescriptive safety, health and building code requirements for new homes. To accomplish this task, equipment is routinely inspected to ensure that each energy saving technology or device is being installed according to design specifications. In addition, personal interviews have been conducted with the following groups concerning whole house integration (the interviews are documented in the prototype report’s Appendix F):

- Architect / design teams
- Suppliers / equipment vendors
- Builder
- Job superintendent
- Installing contractor and individual crew members
- Coordinating trades, i.e. plumbers
- Building inspector
- Homeowner
- Post-installation service technician

The interviews included the following questions through post-construction evaluation:

- What problems, if any, were encountered during the installation? Were there problems with coordination between contractors?
- What measures could be taken to streamline the implementation process in future installations?
- What solutions might exist for problems encountered?
- What criteria does the building inspector expect to be met?
- What is the level of homeowner satisfaction with the performance of the house?

In addition to qualitative data gathering, the team is evaluating post-occupancy air infiltration through blower door tests to verify air infiltration levels and to satisfy the requirements of the National Green Building Standard certification the houses received. This data will be used for the simulations and will be reported in 2011.

“Should Meet” Criteria -- Neutral Cost Target

The incremental annual cost of energy improvements, when financed as part of a 30-year mortgage, will be compared to the annual reduction in utility bill costs relative to the BA Benchmark. It is expected that the incremental annual cost of energy improvements should be less than or equal to a reduction in energy bills.

Cost data was provided by Elliott Workgroup and Park City. Costs were then analyzed, excluding site and infrastructure costs, see Table 137.

Residential Unit Construction Cost	\$115.39/sq. ft.
Renewable Technology Cost	\$16.49/sq. ft.
Total per Unit Cost	\$131.88/sq. ft.

Table 137. Cost data for Snow Creek Prototypes

This cost analysis was compared with a cost simulation based on R.S. Means 2009 data for BA Benchmark specifications. One gap identified in this data was the lack of existing information in data tables regarding renewable technologies. A regional multiplier of 0.92 was assigned based on feedback from local and regional builders regarding construction cost comparisons of Park City with Salt Lake City. In addition, the multiplier for Boulder, CO, a comparable resort town, was used to confirm the relative accuracy of the 0.92 multiplier. The cost simulation resulted in a \$109.79/sq. ft. cost excluding renewable technology. This reflects a \$ 5.60/sq. ft. difference when compared to the \$115.39/sq. ft. cost for construction at Snow Creek. Considering the added benefits of air tightness and increased R-value of SIPs construction, the High R-Wall construction compares fairly with standard 2x6 construction. In addition, given the added benefits of GCHP technologies to reduce energy costs throughout the lifecycle, the cost is competitive with traditional heating equipment.

A detailed analysis of the actual versus simulated cost correlation study can be read in prototype report [Appendix E](#). This data will be used in 2011 to compare to overall energy reductions for lifecycle cost and ROI evaluation of the SIPs and GCHP systems.

“Should Meet” Gate Criteria -- Quality Control Integration

Health, safety, durability, comfort, and energy related training, and commissioning requirements are being monitored. The data obtained will be integrated within construction documents, contracts and BA team scopes of work. Attendance at weekly meetings occurred throughout the middle of October 2009 when the research team was asked to not attend. The reasoning for the request was that in the research team’s presence the contractor and architects were not able to talk with the owner as freely or candidly related to budgetary concerns. Although the research team has not been able to attend weekly construction meetings, weekly site visits continue to occur. In addition to the weekly site visits, construction documentation has been completed to determine the challenges of the energy saving systems compared with traditional construction.

“Should Meet” Gate Criteria -- Gaps Analysis

Construction was initially stalled for a total of two (2) months due to issues with dewatering the site and the SIPs submittal/acceptance process. Accordingly, the completion date was pushed back to May 2010 to avoid winter months. The houses were finally completed in July of 2010. The SIPs design, engineering, plan submittal/acceptance, and installation difficulties contributed to schedule delays of one (1) month on the site. The SIPs panels have proved to be both promising and problematic due to the following issues:

DESIGN:

- a. Because it was not originally designed for SIPs construction, the house did not adopt the efficiencies of SIPs module, and is over-structured, (i.e. too much lumber exists within the SIPs envelope adding to thermal bridging problems).
- b. Coordination between architects, engineers and SIPs manufacturers was non-existent throughout the design, leading to coordination problems from design to installation.

SUBMITTALS:

- a. SIPs panels were designed for Seismic D Zone, but the SIPs suppliers produced Seismic A, B & C but not D.
- b. Submittals were not detailed enough for architect and structural engineers, leaving out locations of post and beam embeds in walls in drawings. No connections to foundation or transitions at fenestrations. Specification submissions also were generic and not specific to the project.
- c. The consulting engineers, BHB, wanted to bring the design up to ‘D’ zone rating

including location of hold downs which is a slightly different design than Premier could accommodate. Submittal process, back and forth, was inefficient and fraught with error and argument.

- d. The core of the problem lies in the lack of system knowledge on the part of the architect and engineer, which resulted in demanding a higher level of shop submittals. In addition, the supplier was not familiar with working directly with architects and engineers and therefore had difficulty delivering on their requests for detailed engineering information regarding the panels in submittals.

In addition, personal interviews have been conducted with the team members regarding SIPs and GSHPs and can be found in the individual systems reports.

Marine - New Tradition Homes 50% Prototype Report (BP3 (2010))

BIRA Builder Partner, New Tradition Homes, constructed a Building America (BA) 50% Marine prototype home in Ridgefield, WA. This report describes the evaluation of this “Parade Home” to determine if it meets Building America’s 50% whole house energy savings goal compared to the Building America Benchmark in the Marine Climate zone. The prototype will be evaluated based on Building America’s Gate 2 “Must Meet” and “Should Meet” Gate Criteria (Stage Gate 2 Performance Criteria can be found in Appendix A of the prototype report).

Key Results

As modeled, simulation indicates that the home achieves a 48.9% whole house energy savings (WHES). However, BEopt’s 0.9.5 was not able to properly model the dual mini-split heat pump systems installed in this home. The BIRA team believes that continued monitoring of the home will verify that the actual measured performance does meet the 50% WHES. Based on the energy analysis, prescriptive-based code approval, and quality control requirements, the prototype home meets the Building America 50% Stage Gate 2 Criteria in the Marine Climate zone.

Gate Status

Based on these study results, the prototype home meets both the Stage Gate 2 “Must Meet” and “Should Meet” criteria.

Conclusions

BIRA and the Washington State University Energy Program (WSUEP) recommend continued monitoring of the home to determine how well the systems are performing. Utility bill data would be used to determine actual energy use and would be compared to the Benchmark energy consumption. This will help to ensure the actual measured performance meets the 50%

WHES.

Introduction

New Tradition Homes (NTH) constructed a Building America (BA) 50% Marine prototype home in Ridgefield, WA. This “Parade Home” is the focus of this BA Stage Gate 2 initial report. (Stage Gate 2 Performance Criteria can be found in Appendix A of the prototype report).

Stage Gate 2 evaluates the feasibility of integrating advanced systems with production building practices using targeted field tests and energy simulations. This report presents the evaluation of the implementation, performance, and cost-effectiveness of the features included in this project (See Table 138). These features represent the work developed with BIRA, builder partners and NTH.

50% WHES Features
R-38 Floor over crawlspace
R-60 Ceiling with raised heel truss
R-21 +R-5 2x6 advanced framing
2.4 ACH ₅₀
0.30 U-value/0.34 SHGC windows
ENERGY STAR® appliances
100% ENERGY STAR® CFL or LED
26 SEER, 10 HSPF & 15.5 SEER, 8.5 HSPF Mini-Split Heat Pumps (without backup electrical heater)
Heat Recovery Ventilator (HRV) with filtration
93% condensing tankless water heater

Table 138. 50% WHES “Parade Home” base case features

Background

New Tradition Homes (NTH) was started in 1987 by Alvar and Nancy Helmes and their family. The company has grown to be one of the largest in the homebuilding industry within the Clark County, Washington region. In 2006, NTH decided to build all of its homes to Northwest ENERGY STAR® and Earth Advantage standards and is currently participating in the Department of Energy’s (DOE) Builders Challenge Program. One year later, New Tradition won the Regional ENERGY STAR Builder of the Year award from Northwest ENERGY STAR. In addition, they have their own building science team who continues to provide solutions for more energy efficient and higher quality homes.

The prototype discussed here is priced at \$399,000, and generally targeted at a middle class

homeowners or first time buyers looking for a high quality home. The home was featured in the 2010 Clark County Parade of Homes in Ridgefield, WA I. The prototype was originally developed in 2008 but because of market conditions was not constructed until 2010 with some design modifications.

“Parade Home” Location

The NTH prototype “Parade Home” is located in Ridgefield WA near Pioneer St. and NW 31st Ave.

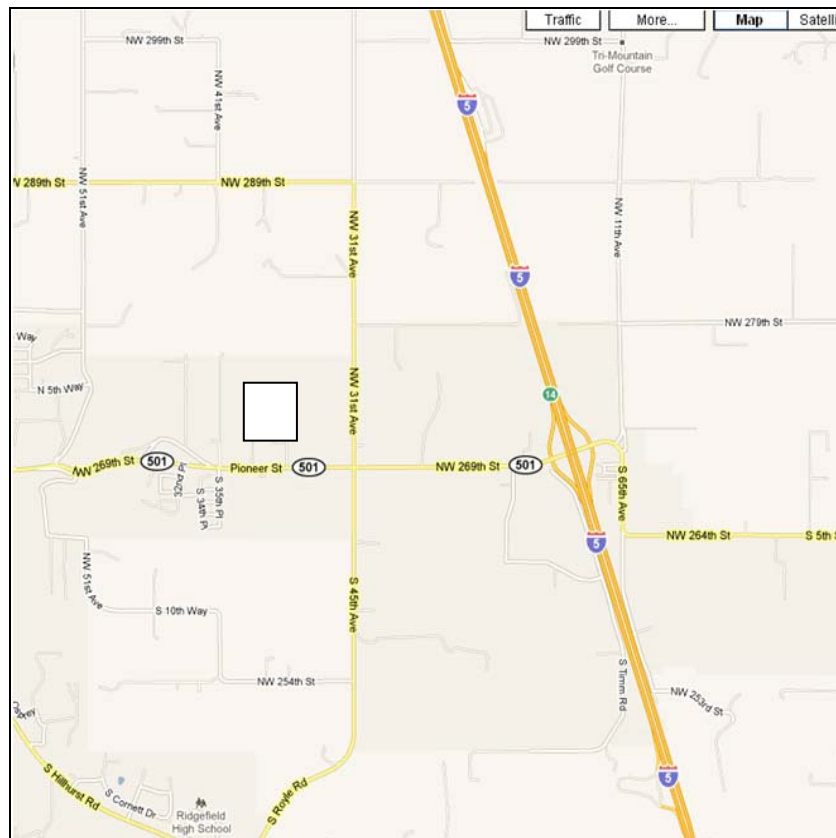




Figure 100. NTH “Parade Home”

Builder

New Tradition Homes

Total sq. ft.

1811

Bedrooms

3

Baths

2 ½

Selling Price

\$399,000

Climate

The building site in Ridgefield, WA is located approximately 15 miles north of Portland, OR and has similar climatic conditions. The average minimum temperature in the winter is 34.8°F and the average maximum summer temperature is 78.0°F. Average precipitation in Portland is 30 inches annually. See Table 139 for a more detailed breakdown of average temperatures experienced in Portland, OR for all four seasons.

Annual Average Maximum Temperature	78.0°F
Annual Average Minimum Temperature	34.8°F
Annual Average Total Precipitation	30 inches

Table 139. Portland, OR annual climate data

Average Temperatures			
Winter (°F)	Spring (°F)	Summer (°F)	Fall (°F)
Maximum: 47.2	Maximum: 61.1	Maximum: 78.0	Maximum: 63.3
Minimum: 34.8	Minimum: 42.2	Minimum: 55.4	Minimum: 45.4

Table 140. Portland, OR temperature data

Utility Providers

The electricity provider for this home is Clark Public Utilities and Northwest Natural Gas. Table 141 shows electricity and gas rates for the site.

Electricity Rate	
Utility	Clark Public Utilities
Marginal	\$0.0736/kWh
Fixed	\$6.40/month
Natural Gas Rate	
Utility	Northwest Natural
Marginal	\$1.128/therm
Fixed	\$5.00/month

Table 141. Clark Public Utilities & Northwest Natural Gas rates

“Must Meet” Gate Criteria - Source Energy Savings and Whole Building Benefits

BIRA used BEopt 0.9.5 to analyze the expected source energy savings. As designed, the home achieved a 48.9% whole house energy savings (WHES) level relative to the BA Benchmark. The modeled energy savings was below 50% due to BEopt’s inability to model some key features. The heating system used two mini-split heat pumps. A one-ton single head system (SEER 26, HSPF 10) conditioned to the core of the house. A second, two-ton system (SEER 15.5, HSPF 8.5) with two heads provides conditioning to the core and, through a fan box within conditioned space, ducts air to each bedroom. The system was evaluated using the seasonal energy efficiency ratio (SEER) and heating seasonal performance factor (HSPF). However, the version of BEopt that was used had difficulty modeling high performance heat pumps incorporating multiple systems. This limitation was addressed by modeling the mini-split heat pumps as a single 18 SEER, 9.2 HSPF using a weighted average of the actual efficiencies. The duct system was modeled as ductless (See prototype report Appendix B for analysis details).

BIRA and the Washington State University Energy Program (WSUEP) recommend continued monitoring of the indoor conditions of the home, space conditioning energy, domestic hot water (DHW) energy and combined other loads to determine how effective the systems are performing. Utility bill data from Clark Public Utilities and Northwest Natural Gas will be used to determine actual energy use and will be compared to the Benchmark energy consumption. This will help to ensure the actual measured performance does meets the 50% WHES.

“Should Meet” Gate Criteria - Prescriptive-Based Code Approval

Prior to the start of construction, construction documents, which include all systems incorporated into the home, were submitted and approved to ensure the structure and systems met applicable safety, health, and building code requirements. Typically, any code violation must be corrected and plans must then be resubmitted before final approval is granted. Construction could only begin after final approval is received and a building permit granted.

The “Parade Home” was approved by the City of Ridgefield and construction is now complete.

“Must Meet” Gate Criteria - Quality Control Requirements

Earth Advantage conducted ENERGY STAR® and Earth Advantage field testing and inspections. They performed blower door testing of the house. BIRA also conducted third-party testing and inspections. Third-party inspectors provided quality control inspections to verify that all systems and structures were installed per designs and manufactures’ specifications.

“Should Meet” Gate Criteria - Gaps Analysis

An evaluation of the home building process was conducted to determine if any extraneous circumstances exist that may prevent a production builder from using the methods and systems explored in this prototype. The gaps analysis provides the final information needed to determine how well the advanced systems integrate with production building practices and whether each process may be altered to achieve that goal.

A post-construction evaluation will examine construction and installation issues gathered through questionnaires, interviews and reviews of installation documentation. The analysis attempts to capture any actions required to guide future installations and better ensure the construction of a prototype house that yields a 50% WHES relative to the BA Benchmark.

Key areas in the gaps analysis include:

- Implementation of advanced air leakage control measures
- Ductless heat pump (DHP) installation
- Supply issues with windows
- Code requirements on ventilation distribution
- Installation of insulated sheathing

Advanced air leakage control of 2.0 ACH₅₀ was achieved on the Parade House prototype. NTH has consistently been achieving air tightness around 4.0 ACH₅₀ on their production homes. The transition to this higher level of performance on a production basis will require an integrated approach including crew training; design review and adaptation; and review of methods and materials. The process in the prototype proved labor intensive but achievable.

DHP installation proved to be straight forward in this first time application in a NTH home.

The system was designed without any electric resistance backup heating, as required in more traditional split system heat pump installations, and based on system specifications accepted by the local code jurisdiction. Cost reduction can be anticipated with standardization of design and quantity purchase.

Availability of high performance windows proved to be an issue. The inclusion of this project in the local parade of homes provided excellent public exposure for the project, but imposed a very tight construction schedule. NTH chose to stay within their normal supply chain and the windows available were considered only marginal for the project but were at significant premium in price. Additional energy savings at no additional cost should be available through an expanded supply chain such as the new DOE R-5 bulk procurement program

Unanticipated issues were encountered with the ventilation system. NTH has always met the Washington whole house ventilation system code requirements with a system integrated using a standard central forced air systems. In this prototype, including both DHPs and an ERV system, no integration of distribution was experienced. The ERV was installed as a fully ducted system and duct layout to serve all “habitable” zones proved difficult and resulted in some ventilation ductwork in the unconditioned attic. Better design integration should resolve any future issues.

Alternative ventilation strategies adaptive to use with DHP systems is an area for additional investigation.

Installation of insulated sheathing went smoothly and does not appear to be a major challenge in the production environment.

“Should Meet” Gate Criteria - Neutral Cost Target

BEopt 0.9.5 was used to perform an analysis of the advanced features’ incremental cost to the builder. The analysis using BEopt modeling software determined that the 50% WHES can be anticipated to provide sufficient reduction in energy bills, achieving the neutral cost target.

Builder costs and energy costs, based on current utility rates, were used to calculate the net annual cash flow to the homeowner. This analysis was used to predict whether, on a production basis, the incremental annual cost of energy improvements will be offset by the annual reduction in utility costs.

The incremental costs of additional features were examined from the builder’s cost perspective, as well as the impact on the homeowner’s monthly mortgage payments over a 30-year mortgage.

For this particular design, the following incentives shown in Table 142 were available through Clark Public Utilities and Northwest Natural Gas, as well as state and federal agencies during the project.

Appliances	Description	Incentive Amount
Clark Public Utilities		
Northwest ENERGY STAR® Home	Meets NW ENERGY STAR standards	\$600
Heat Pump Rebate Program	Purchase and install a NW ENERGY STAR rated heat pump	\$750
Appliances	Installation of an ENERGY STAR clothes washer	\$25
	Installation of an ENERGY STAR Refrigerator	\$50
Lighting	Lighting ENERGY STAR Fixtures or CFLs * LEDs	\$
Total:		\$1,425
Northwest Natural Gas, & Federal Incentives		
Federal Tax Credit Home (Renewal Pending)	50% reduction in heating and cooling when compared to 2004 IECC standards. 1/5 of the energy savings measures from improved envelope	\$2,000
Tankless Water Heater	Rebate for installing a Rinnai tankless water heater	\$200
H. Efficiency Heat Pump	HSPF of 9.0 or higher, EER or 12.0 or higher, valid AHRI Certification number	
Total:		\$2,200
Total Available Incentives:		\$3,625

Table 142. Available incentives

The top half of Table 143 details the annual utility bill savings for each of the five main end use categories in comparison to the BA Benchmark. As shown in Table 142, the annual utility bill savings according to BEopt is \$989.83. It should be noted that this includes no fluctuations in utility rates or inflation.

Description	Annual Source Energy		Estimated Source Energy Savings		
	Benchmark	50% Design	Percent of End Use	Percent of Total	Annual Utility Bill Savings
End Use	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Benchmark	vs. Benchmark
Space Heating	117.7	39.6	66.4%	33.2%	\$280.95
Space Cooling	8.5	2.7	67.9%	2.5%	\$44.84
DHW	23.7	11.5	51.3%	5.2%	\$146.62
Lighting	26.3	12.4	52.9%	5.9%	\$106.92
Appliances and MELs	59.0	54.0	8.6%	2.2%	\$410.50
Total Usage/ Savings	235.3	120.2	48.9%	48.9%	\$989.83
Energy Efficiency Feature					Annual Mortgage Cost vs. Code
R-38 Floor over crawlspace					\$62.93
R-60 Ceiling with raised heel truss					\$162.23
Infiltration= 2.04 ACH(50)					\$0.00
R-21 + R-5 2x6 advanced framing					\$225.70
Windows (U-Value 0.20, SHGC 0.20)					\$203.85
ENERGY STAR® Appliances					(\$72.81)
100% ENERGY STAR® CFL or LED					(\$107.86)
26 SEER, 10 HSPF & 15.5 SEER, 8.5 HSPF mini-split heat pump					(\$296.56)
Heat Recovery Ventilator with filtration					\$193.52
93% Condensing Tankless Water Heater					\$58.12
Total Annual Mortgage Cost					\$429.12
Net Annual Cash Flow to Consumer					\$560.71

Table 143. Economic analysis and cost neutrality

The bottom half of Table 143 is derived from the builder's first cost, detailed in the prototype report Appendix D, for each of the energy efficiency features listed. The builder cost was obtained from a meeting between BIRA representatives and New Tradition's purchasing agent, quality control lead, and vice president of operations. A 10% markup is assumed, where the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation is not considered.

Based on the cost analysis, the NTH "Parade Home" meets the "should meet" cost neutrality criteria.

"Should Meet" Gate Criteria - Quality Control Integration

Incorporating new building features means that new building methods and procedures had to be addressed in the planning stages to ensure a smooth construction process and output of a quality product. The plan to integrate the new methods and procedures covered health, safety, durability, comfort, and energy related quality assurance. All trades coordinated these features into their construction plans and ensured that all plans necessary for city submittal are compliant with applicable building codes and jurisdictional requirements.

BIRA worked with NTH to ensure that the design was followed. To ensure proper implementation, BIRA has met with the superintendent of the home and discussed points on the construction schedule to assure that quality control mechanisms, such as proper testing and inspection, were included in their processes. Third party testing and commissioning was successfully completed on the home

3.3 Stage Gate 2 Prototype House Reports: Northern Marine House Studies at 50% WHES - 2 minimum

The BIRA team was tasked with evaluating four Prototype Homes during the three year budget period. Each Prototype Home was evaluated based on Building America’s Stage Gate 2 “Must Meet” and “Should Meet” criteria.

The BIRA team evaluated the New Traditions Homes’ Kent Model 2264 home in Vancouver, WA and the Martha Rose Construction’s The Homestead in Seattle, Washington during Budget Period One to determine if they meet the Building America 50% whole house energy savings goal when compared to the Building America Benchmark for the Marine Climate Zone.

House/Builder	% WHES / Climate Zone	Stage Gate 2 Status
Kent Model 2264 / New Traditions Homes	51% Marine	NTH expects to construct the prototype upon sale of a custom upgrade package, likely within budget period 2. Based on the energy cost savings from BEopt and incremental costs estimated by NTH, it has been determined that the homeowner can expect to see approximately \$1,276 per year net cost savings versus the Building America Benchmark with a net \$752 annual positive cash flow.
Homestead / Martha Rose Construction	59% Marine	Based on the energy cost savings from BEopt and incremental costs estimated by MRC, it was been determined that the homeowner can expect to see approximately \$1,595 per year in energy cost savings based on the advanced features plus an additional \$181 per year from PV generation, for a net annual utility bill savings of \$1,776.

Table 144: Summary of Northern Marine Prototype House Studies

Budget Period 1

In Budget Period Two, the BIRA team evaluated another Northern Marine Prototype Home to determine if they meet the Building America 50% whole house energy savings goal when compared to the Building America Benchmark for the Marine Climate Zone. The David Cohan

“SIP” House was evaluated based on Building America’s Stage Gate 2 “Must Meet” and “Should Meet” criteria.

House/Builder	% WHES / Climate Zone	Stage Gate 2 Status
SIP House / David Cohan	51.2%% Marine	In Process. Refer to interim report for more details.

Table 145: Summary of Northern Marine Prototype House Studies

Budget Period 2

The BIRA team evaluated one (1) Cold Prototype Home in 2010 to determine if it met the Building America 50% whole house energy savings goal when compared to the Building America Benchmark for the Cold Climate Zone. The Gold Medallion House was evaluated based on Building America's Stage Gate 2 "Must Meet" and "Should Meet" criteria.

Prototype Home	Stage Gate 2 Status
Gold Medallion Home South Jordan, UT (Cold)	The Gold Medallion home has successfully completed the Stage Gate 2 Criteria. Refer to the completion report for more details related to prototype results.

Table 146: Summary of Northern Marine Prototype House Studies

Budget Period 3

New Traditions Homes – Kent Model 2264 – Vancouver, WA BP1 (2008)

The BIRA team evaluated the New Tradition Homes' (NTH) upgraded Kent Model 2264 as a 50% Marine prototype to determine if it meets Building America's 50% whole house energy savings goal compared to the Building America Benchmark in the Marine Climate Zone. The Kent Model 2264 was evaluated based on Building America's Gate 2 "Must Meet" and "Should Meet" Gate Criteria. Key research partners in this endeavor are David Hales, Michael Lubliner, and their staff at the Washington State University (WSU) Energy Program. New Tradition Homes is a committed Building America Builder having completed both 30% and 40% prototype and community level projects and was among the first Builder Challenge Builders recognized at the 2008 International Builders' Show.

New Tradition Homes was started in 1987 by Alvar and Nancy Helmes and their family. The company has grown to be one of the largest homebuilding companies in the Clark County, Washington region. In 2006, New Tradition decided to build all of its homes to Northwest ENERGY STAR® and Earth Advantage standards and is currently participating in the Department of Energy's Builders Challenge. In 2007, New Tradition won the Regional ENERGY STAR Builder of the Year award from Northwest ENERGY STAR. In addition, they have their own building science team that continues to strive for more energy efficient and higher quality homes.

New Tradition Homes' Marine projects are usually in or near Vancouver, Washington. The city is located in Building America's Marine Climate Zone and experiences an average annual

precipitation of 41.3 inches, has 4,399 annual heating degree days, and 291 annual cooling degree days. This climate provides the greatest opportunity for energy savings from reductions in space heating loads.

The 2,264 sq. ft. prototype discussed in this report will likely be priced between \$229,900 and \$269,900, and generally would be targeted at middle class homeowners or first time buyers looking for a high quality home. Vancouver, WA is provided electricity by Clark Public Utilities and natural gas by Northwest Natural.

For more information on New Tradition Homes contact Steve Tapio, Quality Control Lead, New Tradition Homes, Steve.Tapio@NewTraditionHomes.com or visit the New Tradition Homes website, www.NewTraditionHomes.com.

“Must Meet” Gate Criteria -- Source Energy Savings

Using BEopt 0.8.7, an energy analysis was performed on New Tradition’s Kent 2264 floor plan. Floor plans and elevations can be found in Appendix A of the task report. The Kent 2264 plan is a one-story house with a bonus room above the garage representative of a typical New Tradition’s house in Washington, with 2,264 square feet of finished floor area, four bedrooms, and three bathrooms. The plan was modeled as a 50% Building America prototype in the Marine Climate Zone, this analysis builds on New Tradition Home’s 40% home. The features for this home were optimized using BEopt, New Tradition Homes’ cost information and through conversations between the BIRA team and New Tradition Homes. Two separate simulations were run, one with the BA Benchmark as the reference house, and one with a Washington code house as the reference house. Figure 101 shows the BEopt source energy use graph for the Kent 2264 floor plan with the BA Benchmark as the reference house. All four cardinal orientations were simulated for both reference homes, the graph displays the average of the four orientations. Figure 21 summarizes the findings of both simulations. The energy savings for Kent 2264 are averaged over all four orientations and grouped into five main end use categories.

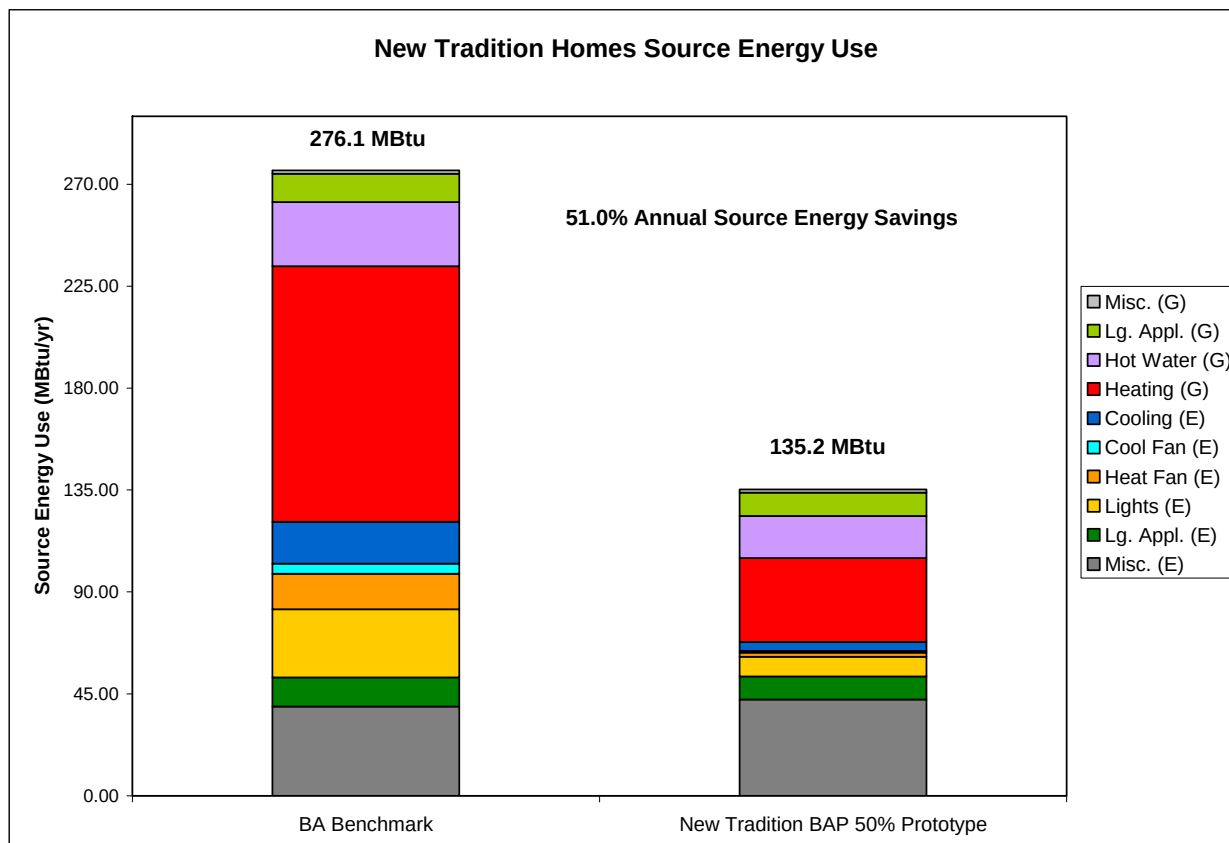


Figure 101: BEopt Source Energy Use
Kent 2264 with BA Benchmark as the Reference House

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Washington Code	Kent 2264	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	128.5	76.6	38.9	69.7%	49.2%	32.5%	18.0%
Space Cooling	22.9	4.9	4.7	79.4%	4.0%	6.6%	0.1%
DHW	28.3	25.8	18.6	34.3%	28.0%	3.5%	3.5%
Lighting	30.1	30.1	8.7	71.1%	71.1%	7.8%	10.2%
Appliances and MELs	66.2	71.5	64.3	2.9%	10.1%	0.7%	3.4%
Total Usage/ Savings	276.1	209.0	135.2	51.0%	35.3%	51.0%	35.3%

Table 147: Source Energy Savings for the Kent 2264 Floor Plan

As shown in the table above, the 50% New Tradition's house meets the next Building America goal of 50% energy savings in the Marine Climate Zone with respect to the BA Benchmark. The critical above code energy reduction features implemented in order to reach this goal are as follows:

- ENERGY STAR® refrigerator, dishwasher, and clothes washer
- 100% hardwired CFL lighting
- 80% EF gas tankless water heater
- 3.8 ACH₅₀ infiltration (typical New Tradition home = 5.2, improvement from foam and caulking lid)
- 2x6 walls with R21 batts, 24" oc + 1" foam
- R49 blown-in cellulose insulation in the attic
- 94% AFUE furnace
- Ducts in conditioned space
- 0.32 U-value windows (worst case, most windows have 0.31 or 0.30 U-value)
- HRV
- Gas cooking range and clothes dryer (gas dryer stub provided)

New Tradition Homes began with the features prescribed by Northwest ENERGY STAR®. By improving on these requirements, New Tradition was able to raise their homes to the federal tax credit level, which is equivalent to 40% whole house energy savings compared to the BA Benchmark. Beyond this BIRA worked with New Tradition to determine the most cost-effective way to achieve 50% savings. (For a complete list of BEopt inputs for both the Kent 2264 plan and the code house used as a reference house, see BIRA deliverable Task 3.3.a). One additional feature that cannot be modeled in BEopt is a seasonal damper that New Tradition installs on its homes. The homeowner is instructed to use this feature when moving from the heating to the cooling season to deliver more comfortable and efficient space conditioning.

Based on the BEopt simulation providing 51% energy savings compared to the BA Benchmark, New Tradition Homes' Kent Model 2264 prototype passes the Source Energy Savings "Must Meet" criteria.

"Must Meet" Gate Criteria -- Prescriptive-Based Code Approval

All measures in the Kent Model 2264 prototype meet or exceed prescriptive and performance safety, health and building code requirements for new homes.

"Must Meet" Gate Criteria -- Quality Control Requirements

The building trades in the Northwest Marine climate building market are not generally familiar with the use of exterior insulated foam sheathing. This represents the single most challenging measure in the proposed Kent Model 2264 50% prototype. Proper detailing for exterior finish; window and door installation; maintaining required wall shear strength in seismic zones; moisture management; and builder concerns on maintaining manufacturer warranties on material products are all challenges for gaining acceptance of the practice. Case studies of successful applications by progressive builders such as New Traditions with their strong commitment to industry education and process quality management with the support of

Building America is critical.

“Should Meet” Gate Criteria -- Neutral Cost Target

New Tradition Homes has been able to keep its costs relatively low while implementing energy efficiency features. They have done this by working with vendors to bring costs down, beginning with the most expensive elements. This effort is largely driven by the recent housing crunch - and it is definitely working. In addition, the 51% whole house energy savings provides substantial reduction in energy bills, resulting in few, if any, tradeoffs necessary to reach the neutral cost target. These costs are based on the current utility rates in Vancouver, Washington, summarized in the table below, and include both electric and natural gas energy sources.

Electricity Rate		
	Utility	Clark Public Utilities
	Marginal	\$0.0736/kWh
	Fixed	\$6.40/month
Natural Gas Rate		
	Utility	Northwest Natural
	Marginal	\$1.128/therm
	Fixed	\$5.00/month

Table 148: Current Utility Rates for Vancouver, Washington

Again, these values are averaged over all four orientations. As shown in Table 53 the annual utility bill savings according to BEopt is \$1,276. It should be noted that this includes no fluctuations in utility rates or inflation.

The bottom half of Table 53 is derived from the builder’s first cost for each of the energy efficiency features listed. The builder costs were gathered from a meeting between BIRA representatives and New Tradition’s purchasing agent, quality control lead, and vice president of operations. A 10% markup is assumed and the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation is not considered. For the 0.32 U-value windows and the gas cooking range and clothes dryer, it is assumed that there are no additional costs.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	Washington Code	Kent 2264	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	128.5	76.6	38.9	69.7%	49.2%	32.5%	18.0%	\$879.04
Space Cooling	22.9	4.9	4.7	79.4%	4.0%	6.6%	0.1%	\$126.87
DHW	28.3	25.8	18.6	34.3%	28.0%	3.5%	3.5%	\$100.11
Lighting	30.1	30.1	8.7	71.1%	71.1%	7.8%	10.2%	\$149.20
Appliances and MELs	66.2	71.5	64.3	2.9%	10.1%	0.7%	3.4%	\$21.00
Total Usage/ Savings	276.1	209.0	135.2	51.0%	35.3%	51.0%	35.3%	\$1,276.22

	Energy Efficiency Feature	Annual Mortgage Cost
		vs. Code
	Energy Star Appliances	(\$21.08)
	100% CFL Lighting (ES Requires 50%)	(\$10.54)
	80% EF Gas Tankless Water Heater	(\$64.28)
	Improved Duct Sealing, Envelope Sealing, and Testing	(\$118.56)
	2*6 Walls R 21 batts 24" oc	(\$43.91)
	1" foam on envelope	(\$85.62)
	R49 Attic Insulation	(\$28.10)
	94% AFUE Furnace	(\$39.52)
	HRV	(\$52.69)
	Moving Ducts Into Conditioned Space	(\$59.28)
	Total Annual Mortgage Cost	(\$523.58)

Table 149: Neutral Cost Analysis for the Kent 2264 Floor Plan

A very positive comparison to the \$700 cash flow simulated for the same plan built as a 44% savings house. Based on this information, it is clear that the incremental annual cost of energy improvements is much less than the annual reduction in utility bill costs and New Tradition Homes' Kent Model 2264 prototype passes the Neutral Cost Target "Must Meet" criteria.

This analysis does not include the \$2,000 federal tax credit that New Tradition receives for each new home built that achieves 50% energy savings for heating and cooling over the 2004 International Energy Conservation Code (IECC). This stems from Building America's goal of finding sustainable solutions. Since the tax credit that New Tradition Homes utilizes expires at the end of 2009, it was not considered appropriate to include this credit. It is important to note, however, that the federal tax credit, along with ENERGY STAR®, provides a crucial framework and starting point for builders seeking to build energy efficiently, including New Tradition

Homes.

“Should Meet” Gate Criteria - Quality Control Integration

New Tradition Homes has demonstrated a strong commitment to quality assurance. They have aggressive weatherization protocols and a separate, third-party weatherization contractor to ensure that sealing is done independently of the window installers and other subcontractors. This subcontractor caulks around the house’s bottom plate and other penetrations where typical builders might not. New Tradition Homes’ enclosed crawlspace foundations have exceptional drainage, including a sloped floor with a drain and gravel underneath for optimal water management. Superintendents have pre-drywall inspection protocols that must be adhered to before construction can continue. In addition, to qualify for Northwest ENERGY STAR® and Earth Advantage, the homes must meet prescriptive quality assurance and quality control protocols and pass commissioning testing of the envelop leakage and central forced air duct leakage. As a result of these practices, New Tradition has very few call backs.

Detailing for upgrade features such as the 1” insulated wall sheathing has been adopted from Building America Best Practices.

One area of quality control that New Tradition has exceptional control over is their HVAC installation. The long-term relationship they have with their HVAC subcontractor, Area Heating, and the high quality of their installations have allowed HVAC system call backs to avoid the Top-Ten call back categories.

“Should Meet” Gate Criteria - Gaps Analysis

New Tradition’s current strategy for moving ducts inside conditioned space involves the use of drop-downs and soffits. This method is three times more expensive than using bio-spray foam, including labor and materials but remains cost effective as seen in the modeling and is largely driven by scheduling with subcontractors. For example, using drop-downs requires the framer to return a second time. In one case, the framer actually framed the drop-downs when he first framed the house. This caused a problem when the HVAC installers arrived and had to work around the drop-down framing in order to install the ducts. This led to a very high cost for labor as well as a lower quality installation.

Bio-spray foam is much cheaper and involves placing the ducts in the attic and covering them with spray foam while keeping the furnace in conditioned space. Interestingly, even when New Traditions doesn’t put the ducts inside for their Kent floor plan, they still use drop-downs and soffits because they are architecturally pleasing and define the spaces and transitions between rooms.

In the future, New Tradition hopes to implement open-web trusses between the first and second floors to facilitate moving ducts inside. This design allows subcontractors the flexibility

to run plumbing, electrical, and ductwork easily between floors, with little to no “trade damage” or “trade fighting.” Additional costs for this new truss design can be offset by cost savings in the HVAC system equipment and installation. These cost savings can be made

possible through shorter, un-insulated duct runs and the purchase of smaller, less expensive furnaces due to reduced heating loads.

Another aspect New Tradition hopes to improve is further tightening of the house envelope. In the future, New Tradition plans to caulk and/or foam ceiling penetrations before installing attic insulation. This includes such ceiling penetrations as can lights, and is the one element of sealing New Traditions is not currently addressing.

The 50% prototype moves to 100% CFL lighting using screw-in CFLs for all fixtures. This increases lighting energy savings at a small cost. New Traditions currently estimates a cost of only \$24 per home, including a \$2 per lamp rebate from Clark Public Utilities.

Martha Rose BP1 (2008)

Martha Rose Construction (MRC) was started in 1987. Prior to that, Martha worked as a building official and has a 36-year building background and ‘real world’ experience. MRC has a long-standing reputation of being one of the top sustainable homebuilders in the Seattle market. MRC builds all its homes well beyond “green” programs such as Built Green and Northwest ENERGY STAR. The company has been an outstanding USDOE Building America partner and spokesperson, currently participating in the Department of Energy’s Builders Challenge. In 2007 MRC won the Regional ENERGY STAR® Builder of the Year award from Northwest ENERGY STAR.

MRC Homes’ projects are located in the Seattle area, in Building America’s Marine Climate Zone. This climate provides the greatest opportunity for energy savings from reductions in space heating and DHW loads.

Each of the three homes has 2,389 square feet of finished floor area with four bedrooms, and two-and-half bathrooms and sold in the \$800,000 price range. Above the attached garage are studio rental units that are used to offset some of the homeownership costs, thereby reducing the sale price to \$670,000.

Seattle City Light (SCL) is the electricity provider in Seattle, WA; natural gas is provided by Puget Sound Energy (PSE). Both utilities have very strong energy efficient and renewable new construction home programs that provide support to Building America in the area of RD&D, on other BIRA and BAIHP (Building America Industrialized Housing Project) projects.

For more information on Martha Rose Construction, see the MRC the web site <http://www.martharoseconstruction.com> and/or contact MRC’s owner, Martha Rose, at

martharoseconstruction@gmail.com.

“Must Meet” Gate Criteria -- Source Energy Savings

Using BEopt 0.8.7, an energy analysis was performed on Homestead floor plan, located at 15749 Greenwood Ave N. The two-story house contains 2,389 square feet of finished floor area, four bedrooms, and two and half bathrooms. (Floor plans are available in the Task report) The bonus, standalone apartment above the detached garage was not included in the energy analysis. Two separate simulations were run, one with the BA Benchmark as the reference house and one with a Washington code house as the reference house. The analysis for both the prototype home and the two reference homes was done with the as-built, northeast orientation.

Figure 22 shows the BEopt source energy use graph for the Homestead prototype home with the BA Benchmark as the reference house. Table 150: Source Energy Savings for the Martha Rose Homestead Plan

summarizes the findings of both simulations with the energy savings grouped into five main end use categories.

The advanced nature of several of the features in this home required the use of BEopt inputs that most closely matched actual prototype features. These features include: the 92% tankless gas boiler used for both DHW and space heating through hydronic radiators; the R-10 under slab insulation; and the evacuated tubes solar hot water system. Since BEopt does not offer hydronic space heating, a 92.5 AFUE furnace (no ducts) and 92% tankless water heater (for DHW) were used. The R-10 under slab insulation was modeled as R-10 perimeter insulation. Lastly, the evacuated tubes SDHW system was modeled as a closed loop system. Except for these features, BEopt was able to accurately represent the home. For more information regarding the analysis and how these homes were modeled, please see Appendix B of the Task report

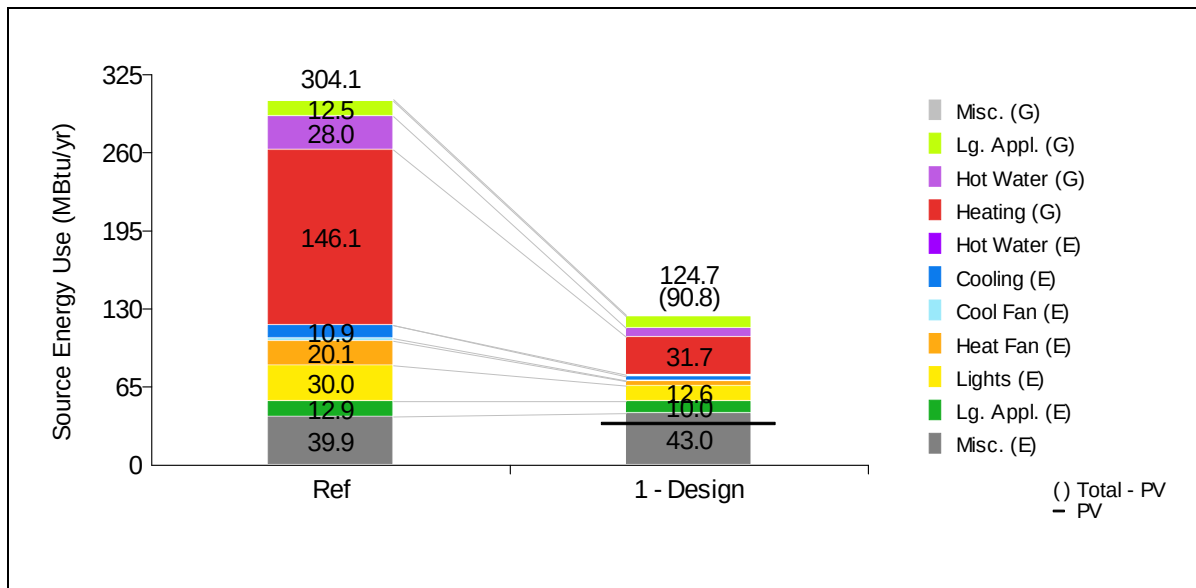


Figure 102: BEopt Source Energy Use
Martha Rose with BA Benchmark as the Reference House

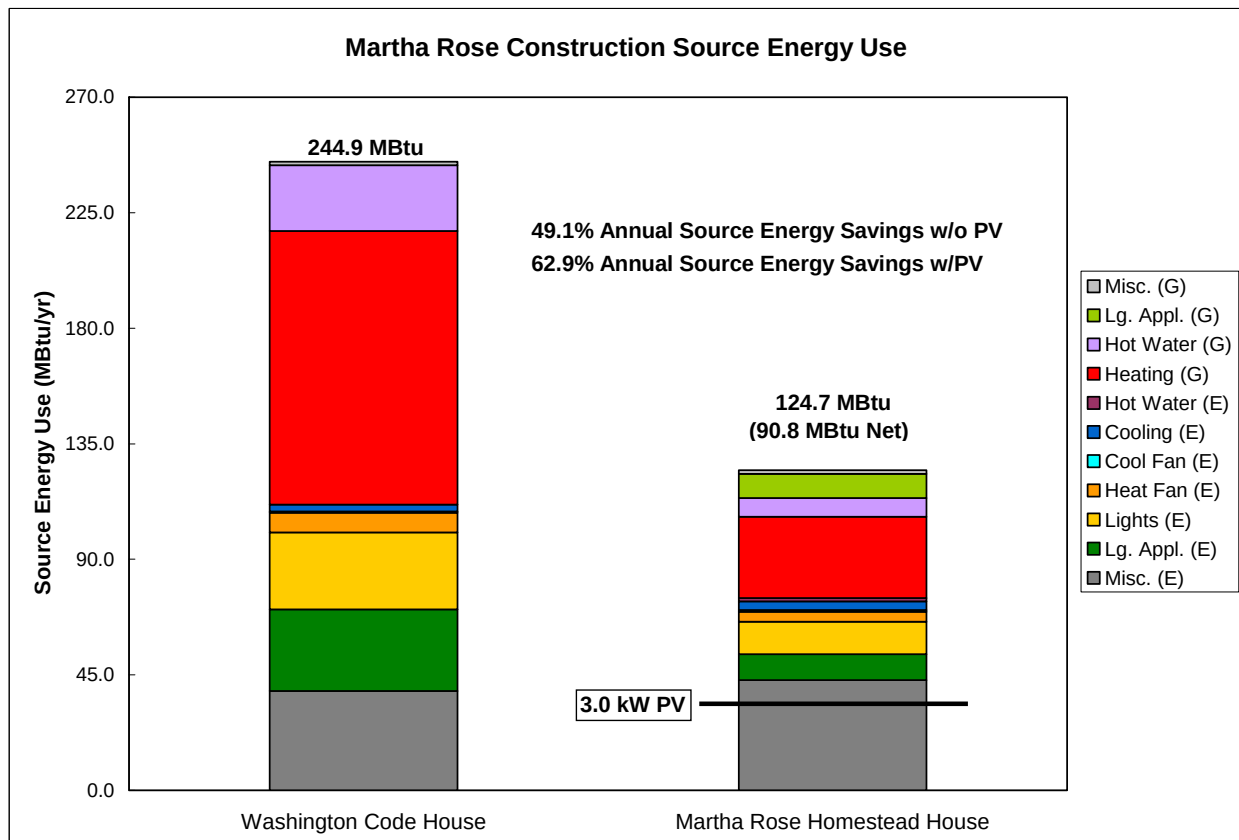


Figure 103: BEopt Source Energy Use
Martha Rose with Washington Code House as the Reference House

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Washington Code	15749 Greenwood	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	166.2	114.2	35.5	78.6%	68.9%	43.0%	32.2%
Space Cooling	13.2	3.2	4.1	68.7%	-30.6%	3.0%	-0.4%
DHW	28.0	25.6	8.6	69.4%	66.6%	6.4%	7.0%
Lighting	30.0	30.0	12.6	57.9%	57.9%	5.7%	7.1%
Appliances and MELS	66.7	71.9	63.9	4.2%	11.1%	0.9%	3.3%
Total Usage/ Savings	304.1	244.9	124.7	59.0%	49.1%	59.0%	49.1%
Site Generation	0.0	0.0	(33.9)	N/A	N/A	11.1%	13.8%
Net Usage/ Savings	304.1	244.9	90.8	70.1%	62.9%	70.1%	62.9%

Table 150: Source Energy Savings for the Martha Rose Homestead Plan

As shown in Table 150: Source Energy Savings for the Martha Rose Homestead Plan

, the MRC house exceeds the next Building America goal of 50% energy savings in the Marine Climate Zone with respect to the BA Benchmark. The critical above code energy reduction features implemented in order to reach this savings level are as follows:

- ENERGY STAR® refrigerator, dishwasher, and clothes washer
- 100% hardwired CFL lighting (70% ES fixtures)
- 92% EF gas tankless boiler (DHW + Space Heating)
- Solar Hot Water - Evacuated Tubes (DHW + Space Heating)
- 1.8 ACH₅₀ infiltration with blower door testing by HERS raters
- 2x6 walls with R23 blown-in fiberglass 16" oc + 1/2" R2.5 foam
- R60 blown-in fiberglass insulation in the attic
- No Ducts, zoned controlled hydronic radiators
- 0.25 U-value, 0.40 SHGC triple pane windows
- HRV 92% efficiency (dual core) for whole house and spot ventilation with filtration
- Gas cooking range and clothes dryer (gas dryer stub provided)
- 3 kW PV with SCL net metering

These features were selected prior to BIRA involvement, and refined with BIRA input during the design and construction stage. MRC's selections were based on Martha Rose's prior experience

as an energy efficient, sustainable, 'green' builder with the goal of exceeding ENERGY STAR® Northwest and Seattle Master Builder Built Green program specifications. During the design process, the most cost effective energy conservation measures were selected first, before adding renewable energy systems. Systems engineering principles were used to balance design goals of energy efficiency, health, safety and durability on a whole house basis. Design and system component selection attempted to leverage all utility, state and federal energy conservation and renewable energy incentives to both builder and the new homebuyer. The ability to provide comfortable zone controlled radiant heating also was selected as an upgrade from standard, ducted HVAC forced air systems. BIRA provided technical design and commissioning assistance on the HRV ventilation system, R-26 wall system, and integrated solar-thermal/DHW/space heating system.

Based on the BEopt simulation demonstrating a 59% energy savings before PV when compared to the BA Benchmark, MRC's Homestead prototype home passes the Source Energy Savings "Must Meet" criteria.

"Must Meet" Gate Criteria -- Prescriptive-Based Code Approval

The home far exceeds current minimum Washington State Energy Code (WSEC) and Washington State Ventilation and Indoor Air Quality Code (VIAQ) requirements. WSEC is slightly more stringent than current IECC code. The VIAQ code requires slightly higher minimum whole house ventilation rates than ASHRAE 62.2 for continuous operating systems. The higher VIAQ rates, however, produce less indoor air pollutant dilution because whole house ventilation system are required to operate for a minimum of eight (8) hours per day.

"Must Meet" Gate Criteria -- Quality Control Requirements

MRC has significant experience with energy efficient construction and technologies, and has been involved with years of training that focuses on QA practices. Efforts are underway to update the homeowner manuals to ensure adequate maintenance and operation of the systems.

Significant quality control procedures were implemented by MRC and by third-party inspectors, RESNET certified raters, state building departments, and WSU energy program staff. Blower doors and IR cameras were used to ensure a tight envelope. Flow hoods and flow grids were used to measure and balance HRV system flow rates (see Appendix G of the task report). HOBO data loggers and BTU meters were employed to evaluate operation of HRV system and solar thermal system performance. Utility data analysis was used to evaluate gas and electric energy use.

One QA challenge involved the poorly installed and never commissioned solar thermal system by Liquid Heating. Installation problems associated with panel sensor installation and solar loop piping to the storage tank caused solar pump short-cycling problems. These were found

during HOBO data logger monitoring of solar pump operation (Appendix J of the task report). Plastic piping leaked and required the system to be re-plumbed in copper. The system did not have anti-freeze, causing a concern about possible pipe freezing on the roof during power failures and a glycol solution was added to the storage tank. The system had no check valves installed which caused hot water from the storage tank to thermo-siphon to the panels on the roof at night.

“Should Meet” Gate Criteria - Neutral Cost Target

The 59% whole house energy savings provides substantial reduction in energy bills, albeit at a significant cost. Energy costs are based on the current utility rates in Shoreline, Washington, summarized in Table 151: Current Utility Rates for Shoreline, Washington

and include both electric and natural gas energy sources.

Electricity Rate	
Utility	Seattle City Light
Marginal	\$0.0614/kWh
Fixed	\$2.96/month
Natural Gas Rate	
Utility	Puget Sound Energy
Marginal	\$1.0858/therm
Fixed	\$8.25/month

Table 151: Current Utility Rates for Shoreline, Washington

Figure 104 shows the annual energy costs of the Martha Rose home as compared to the same home built to Washington’s energy code minimum.

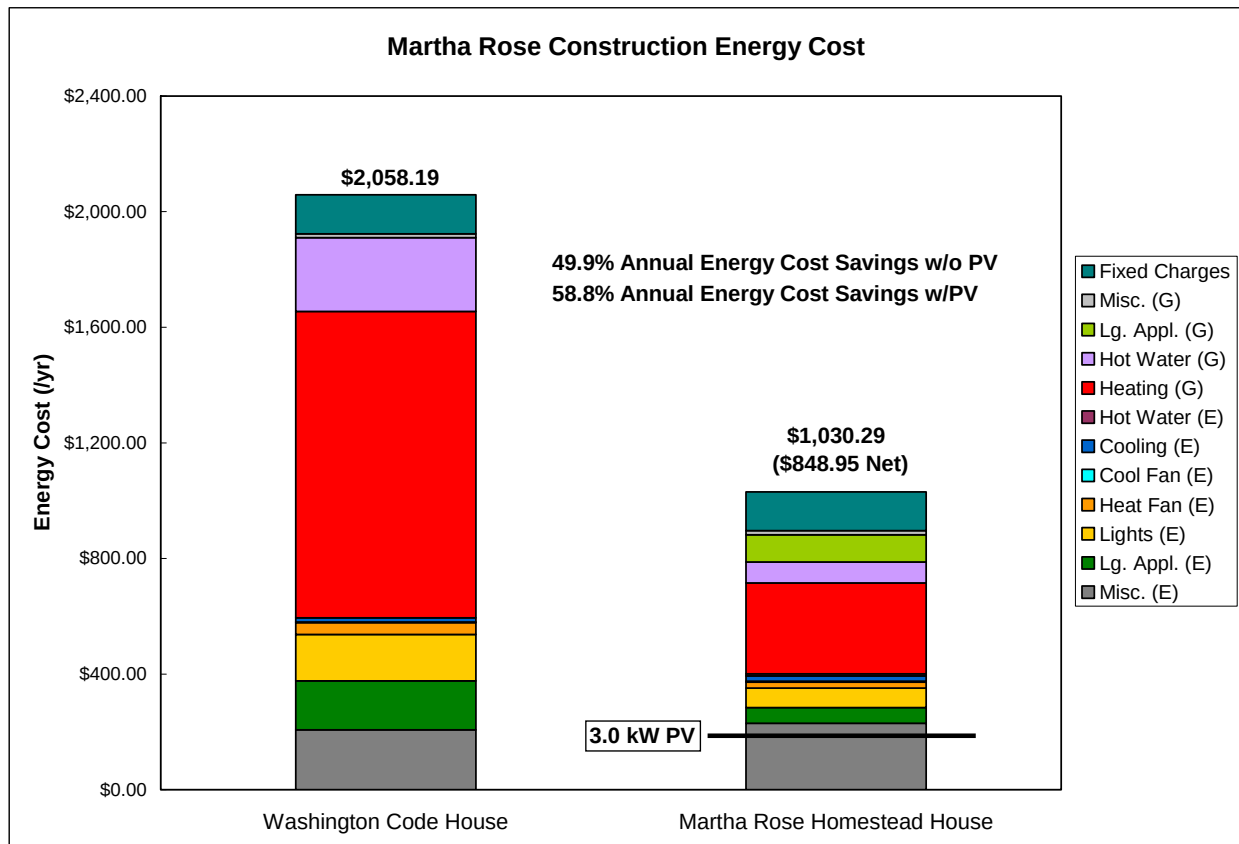


Figure 104: BEopt Energy Costs:
Martha Rose with Washington Code House as the Reference House

To calculate cost effectiveness relative to energy bill savings, it is important to have reliable cost information for all above code features. In this case cost information was gathered working directly with Martha Rose. Mike Lubliner, WSU Energy Extension, has worked very closely with MRC on this project as a member of the BIRA team. As a result, BIRA has very accurate cost information for this project. A 10% markup is assumed and the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation is not considered. Table 152: Energy Feature Incremental Cost Information for MRC Homestead Plan

provides a summary of the feature costs.

Energy Efficiency Feature	Builder Cost	10% Markup	Total	Monthly Cost	Annual Cost
Energy Star Appliances	\$50.00	\$5.00	\$55.00	(\$0.37)	(\$4.39)
Improved Triple Windows	\$1,640.00	\$164.00	\$1,804.00	(\$12.00)	(\$144.02)
100% CFL Lighting (2/3 fixtures)	\$1,400.00	\$140.00	\$1,540.00	(\$10.25)	(\$122.95)
92.5% EF Water Heater	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Envelope Seal, Thermal Bypass, testing & certification	\$2,000.00	\$200.00	\$2,200.00	(\$14.64)	(\$175.64)
R60 Attic Insulation	\$200.00	\$20.00	\$220.00	(\$1.46)	(\$17.56)
HRV 92% Fantech 3005R	\$3,700.00	\$370.00	\$4,070.00	(\$27.08)	(\$324.93)
92.5% AFUE boiler	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
R23 BIBs & 1/2" foam	\$4,400.00	\$440.00	\$4,840.00	(\$32.20)	(\$386.41)
R10 Under Slab	\$650.00	\$65.00	\$715.00	(\$4.76)	(\$57.08)
Solar Space/DHW	\$10,000.00	\$1,000.00	\$11,000.00	(\$73.18)	(\$878.20)
3 kW PV%	\$32,000.00	\$3,200.00	\$35,200.00	(\$234.19)	(\$2,810.24)
Totals	\$56,040.00	\$5,604.00	\$61,644.00	(\$410.12)	(\$4,921.43)

Table 152: Energy Feature Incremental Cost Information for MRC Homestead Plan

Some caveats regarding incremental costs include:

- Appliances: There were no additional costs for the ENERGY STAR® bottom-freezer refrigerator, because MRC selected a non-stainless unit and applied the savings to the improved efficiency. The ENERGY STAR® dishwasher was \$50 more than the comparable, non-ENERGY STAR unit. MRC did not consider the ENERGY STAR® front load washer as an upgrade cost because over 70% of new units in their market area are already front loading ENERGY STAR® units.
- Windows: Triple pane windows were used over double pane windows. MRC noted that this increased the window cost by approximately 20% (\$1020). In the Fish Singer Project, “right sizing” design session with WSU reduced the window areas to reduce the window package to \$440 over double pane.
- Lighting: MRC noted that 70% of the fixtures were dedicated ENERGY STAR® and that the total upgrade cost was approximately \$1400. This does not include utility incentives of \$20 per fixture. Future efforts to improve lighting design may reduce the fixture incremental costs.
- Space Heating & DHW System(s): MRC noted that the combination hydronic space and water heating system, using a 92.5% condensing tankless water heater, generated

comparable costs to installing a standard, non-condensing central forced air gas heating system and power vented gas storage tank. Therefore, no additional costs were assumed in the analysis.

- Air leakage Control, Testing and Certification: MRC assumed \$1440 for one extra day for two people to air seal all penetrations. Approximately \$560 was allocated for energy rating tests, including a blower door test.
- Ventilation: The fully ducted HRV costs were estimated to be \$4500. \$800 was deducted for the bathroom exhaust fans, ducting and electrical which were no longer needed, resulting in a net incremental cost of \$3700. This estimate also included a separate high efficiency filter, to ensure the home had exceptional indoor air quality.
- Insulation: MRC estimated an additional \$818 to add blown-in R60 fiberglass attic insulation over typical R38. An additional \$650 was included for the fully insulated slab (instead of only insulating the perimeter as required by WSEC). The eighty 4x8 sheets of ½" foam sheathing were estimated to cost an additional \$1600 (including labor). The blown in fiberglass wall system was assumed to cost roughly twice that of batt insulation, or approximately \$2800, for a combine wall cost of \$4400. In the future, cost reductions are possible if the sheathing can be used to replace OSB structural sheathing and other siding installation and structural issues are addressed.
- Solar: The installed solar thermal system cost was more than \$10,000. A complete redesign of the system is anticipated to reduce the cost to approximately \$7500 on future systems installed by more professional solar companies in the Seattle area. The PV system costs are expected to be reduced by \$5000 in new installations as the Washington state PV market becomes more competitive with new energy credits ranging from \$0.15-\$0.50 per kWh per year generated (See appendix H of the task report).

The top half of Table 153: Neutral Cost Analysis for the Homestead Floor Plan

adds a column to Table 150: Source Energy Savings for the Martha Rose Homestead Plan

that details the annual utility bill savings of each of the five main end use categories in comparison to the BA Benchmark. As shown in Table 153: Neutral Cost Analysis for the Homestead Floor Plan

the annual utility bill savings according to BEopt is \$1,776. It should be noted that this includes no fluctuations in utility rates or inflation. The bottom half of Table 153: Neutral Cost Analysis for the Homestead Floor Plan

is derived from the builder's first cost for each of the energy efficiency features listed.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	Washington Code	15749 Greenwood	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	166.2	114.2	35.5	78.6%	68.9%	43.0%	32.2%	\$1,224.97
Space Cooling	13.2	3.2	4.1	68.7%	-30.6%	3.0%	-0.4%	\$48.43
DHW	28.0	25.6	8.6	69.4%	66.6%	6.4%	7.0%	\$206.13
Lighting	30.0	30.0	12.6	57.9%	57.9%	5.7%	7.1%	\$93.02
Appliances and MELs	66.7	71.9	63.9	4.2%	11.1%	0.9%	3.3%	\$29.24
Total Usage/ Savings	304.1	244.9	124.7	59.0%	49.1%	59.0%	49.1%	\$1,594.91
Site Generation	0.0	0.0	(33.9)	N/A	N/A	11.1%	13.8%	\$181.33
Net Usage/ Savings	304.1	244.9	90.8	70.1%	62.9%	70.1%	62.9%	\$1,776.24

	Energy Efficiency Feature	Annual Mortgage Cost
		vs. Code
	Energy Star Appliances	(\$4.39)
	Improved Triple Windows	(\$144.02)
	100% CFL Lighting (2/3 fixtures)	(\$122.95)
	92.5% EF Water Heater	\$0.00
	Envelope Seal, Thermal Bypass, testing & cetification	(\$175.64)
	R60 Attic Insulation	(\$17.56)
	HRV 92% Fantech 3005R	(\$324.93)
	92.5% AFUE boiler	\$0.00
	R23 BIBs & 1/2" foam	(\$386.41)
	R10 Under Slab	(\$57.08)
	Solar Space/DHW	(\$878.20)
	3 kW PV%	(\$2,810.24)
	Total Annual Mortgage Cost	(\$4,921.43)
	Net Annual Cash Flow to Consumer	-\$3,145.19

Table 153: Neutral Cost Analysis for the Homestead Floor Plan

As shown in Table 153: Neutral Cost Analysis for the Homestead Floor Plan

the net annual cash flow to the homeowner is approximately <\$3,145>. This means that the incremental mortgaged cost of the energy features is more than the energy savings derived from those features. This analysis does not include the \$2,000 federal tax credit that MRC receives for each new home built that achieves 50% energy savings for heating and cooling over

the 2004 International Energy Conservation Code (IECC). This stems from the Building America goal of finding sustainable solutions. Since the tax credit that MRC utilizes expires at the end of 2009, it was not considered appropriate to include this credit. It is important to note, however, that the federal tax credit, along with ENERGY STAR®, provides a crucial framework and starting point for builders seeking to build energy efficiently, including MRC.

Based on this information, it is clear that the incremental annual cost of energy improvements is more than the annual reduction in utility bill costs and the MRC prototype fails to pass the Neutral Cost Target “Should Meet” criteria.

“Should Meet” Gate Criteria -- Quality Control Integration

Health, Safety, Durability, Comfort, and Energy related QA, QC, training are critical selling points for MRC, as discussed previously. On-going training and clear communications, specifications and commissioning are all required as new systems are incorporated in homes during design, installation, commissioning. Focus on training new homebuyers on how to best operate and maintain the home is also critical, requiring post -occupancy training and homeowner manuals.

“Should Meet” Gate Criteria -- Gaps Analysis

The MRC prototype identified critical a need for improvement in the selection of a well-trained and competent solar thermal installer. MRC plans to enclose commissioning and post-installation testing in the future to ensure that systems are performing as expected. WSU has installed a BTU meter that shows the consumer how much energy is saved by the solar thermal system. This is essential to ensuring solar thermal performance. Just as the PV inverter systems have energy metering built in, so should the solar thermal systems. WSU is proposing that BTU meters be incorporated into the next generation of differential thermostats to ensure that energy savings is apparent to all stakeholders. In addition, the solar thermal industry must develop guidelines to ensure training and certified systems, as is currently done in the state of Oregon. Without improved quality, the history of many failed solar thermal systems of the late 1970’s will repeat itself.

It will also be important to identify methods to introduce more rigid foam insulation into wall sheathing systems to provide additional thickness and increased R-value. This will increase options for use for a variety of siding products and facilitate approval for use in the higher Marine climate seismic zones. These systems, if designed with additional shear strength, hold promise for reducing the first cost of the foam by replacing OSB with foam throughout the home’s walls.

There are obviously cost reductions that must occur before this technology package would be feasible for a typical production builder. BIRA and MRC are working together to ensure MRC’s new project will optimize efficiency in the most cost-effective manner possible.

David Cohan 50% Marine Prototype - Portland, OR BP2 (2009)

During 2008-2009, David Cohan built a Building America (BA) prototype 50% whole house energy savings (WHES) home in Portland, Oregon. The house was the first in Portland approved for construction using SIPs for all elements of the building enclosure. Additional features of the project included:

- High efficiency ductless heat pump
- Heat recovery ventilation
- Solar thermal domestic hot water
- Advanced air leakage control
- LED and CFL lighting
- Beyond Code glazing

Key Results

The project attained 51.2% + WHES in the marine climate based on BEopt 0.8.7 modeling. Additional savings against the benchmark are believed to exist in the project but BEopt is unable to model the heat pumps HSPF of 10 and the floor assembly as constructed with SIPs.

Using construction costs supplied by the builder, the project meets the “should meet” cost neutrality criteria and shows a positive annual cash flow to the homeowner of \$474 without incentives. With the \$8750 in incentives, the project shows a positive annual cash flow to the homeowner of \$1,163.

Gate Status

The project was completed in the summer of 2009. Monitoring equipment has been installed to evaluate the performance of the solar hot water system; the ductless heat pump and overall energy use. The project has satisfied BA “must meet criteria” for source energy savings at the 50% WHES level, received prescriptive based code approval; and quality control requirements. “Should meet criteria” were met for cost neutrality.

Conclusions

David Cohan is not a production builder but his willingness to incorporate emerging technologies into his project at a time when other builders have been reluctant to explore innovations because of market conditions has afforded an excellent opportunity to evaluate a number of measures in a prototype environment. Challenges remain to the successful integration of SIPs construction and solar thermal DHW into a production environment especially in a market without incentives. High efficiency ductless heat pumps appear to be emerging as a significant alternative to conventional central forced air systems and are uniquely suited to the high performance environment of reduced loads found in BA homes.

During 2008-2009, David Cohan built a Building America prototype 50% whole house energy savings (WHES) home in Portland, Oregon. This “SIPs House” is the focus of this Building America Stage Gate 2 evaluation. The builder worked with BIRA through the design and construction process and assisted through the entire BA Stage Gate process with the goal of building an energy efficient, cost-effective and marketable home.

Background

In 2008, David Cohan announced plans for an innovative, highly efficient, and sustainable home. As the first approved single-family SIPs home in Portland, OR, David hopes to open a path to using SIPs in standard construction. The house is 2,089 square feet on a 5,500 square foot in-fill lot in the northeast side of Portland. (<http://www.sipshousepdx.com>)

David Cohan asked the BIRA team to assist him in building beyond the typical Energy Star® construction practices. BIRA’s contribution to the home design established a new level of energy efficiency, renewable energy, and sustainability. While helping the builder, BIRA achieved the BA goal of at least 50% WHES relative to the BA benchmark in the Marine Climate Zone.

For the home to meet the 50% WHES target, David Cohan incorporated features that produced savings above the 50% target. For example, the home incorporated increased insulation on the floor with the SIPs layer, solar water heating, high efficiency mini-split ductless heat pumps, a heat recovery ventilator, low U-value windows, and a green roof design. The green roof was left as an owner implementable option. There are no gas combustion appliances in this all-electric home.

“SIPs House” Location

The David Cohan prototype “SIPs House” is located at 6108 NE 45th Ave, Portland, OR. The immediate neighborhood includes a number of “green” sustainable homes reflecting the growing interest in high performance homes in the Portland market.

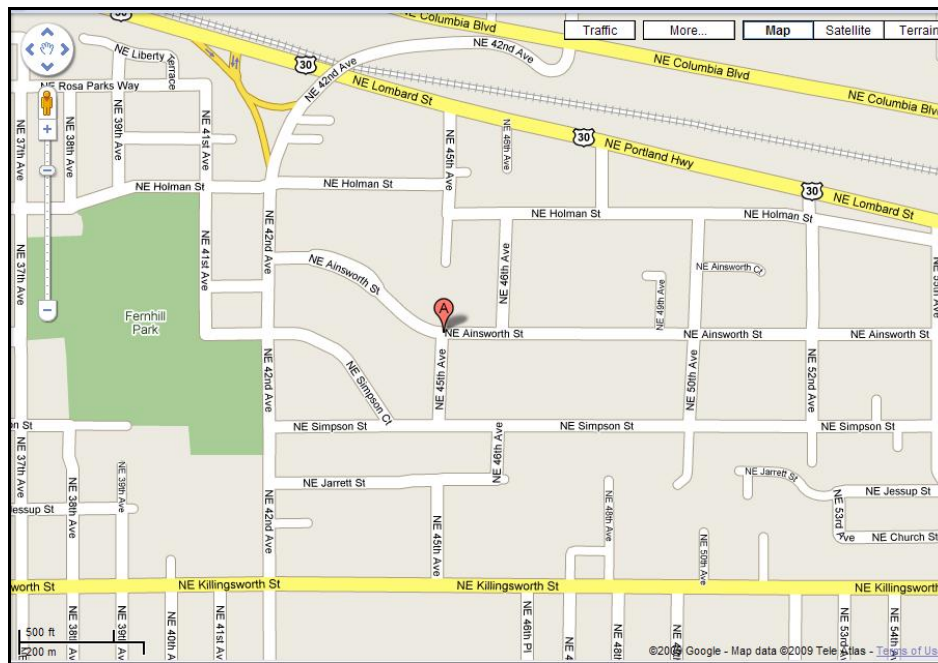


Figure 105: David Cohan's "SIPs House" Location

The Figure 106 below shows a rendering of the SIPs House. Floor plans can be found in Appendix C of the final report.



Figure 106: David Cohan "SIPs House"

Figure 107 shows the completed home, summer 2009.

Builder
David Cohan

Total sq. ft.
2,089

Bedrooms
4

Baths
2 1/2

Selling Price
\$500,000? Home For Sale



Figure 107: Completed Home

Climate

The average minimum temperature in the winter is 34.8°F and the average maximum summer temperature is 78.0°F with 4515 average HDD65. Average precipitation in Portland is 37.5 inches annually.

Annual Average Maximum Temperature	78.0°F
Annual Average Minimum Temperature	34.8°F
Annual Average Total Precipitation	37.5 inches

Table 154: Portland, OR Annual Climate Data

Average Temperatures			
Winter (°F)	Spring (°F)	Summer (°F)	Fall (°F)

Maximum: 47.2	Maximum: 61.1	Maximum: 78.0	Maximum: 63.3
Minimum: 34.8	Minimum: 42.2	Minimum: 55.4	Minimum: 45.4

Table 155: Portland, OR Temperature Data

Utility Providers

The electricity provider for this home is Portland General Electric. The following tables provide breakdowns of the time-of-use electricity rates and schedules.

On-peak (\$)	Mid-peak (\$)	Off-peak (\$)
0.12155	0.06899	0.04052

Table 156: Portland General Electric – Time of Use Electricity Rates

Time Period	Hours of the Day	Days of the Week
Summer Months – begins May 1 of each year		
On-peak	3-8 PM	Monday-Friday
Mid-peak	6 AM-3 PM	Monday-Friday
	8-10 PM	
	6 AM-10 PM	Saturday
Off-peak	10 PM-6 AM	Every day
	6 AM-10 PM	Sunday and specified holidays ²⁴
Winter Months – begins Nov. 1 of each year		
On-peak	6-10 AM	Monday-Friday
	5-8 PM	
Mid-peak	10 AM-5 PM	Monday-Friday
	8-10 PM	
	6 AM-10 PM	Saturday
Off-peak	10 PM-6 AM	Every day
	6 AM – 10 PM	Sunday and specified holidays ¹

Table 157: Portland General Electric – Time of Use Schedule

“Must Meet Criteria” -- Source Energy Savings

The Prototype home must provide targeted whole house source energy savings based on BA performance analysis procedures and energy performance measurements. BIRA used BEopt 0.8.7 to analyze the expected source energy savings. Utility bill data from Portland General

²⁴ Specified holidays include New Year’s Day, Memorial Day, Independence Day, Labor Day, Thanksgiving, and Christmas.

Electric will be used to determine actual energy use and will be compared to the Benchmark energy consumption. BIRA, with the help of the Washington State University (WSU) Energy Program, will be monitoring the indoor conditions of the home, the mini-split heat pump, and the solar thermal system to determine how effective the systems are in conditioning the interior space and providing domestic hot water, respectively. The table below lists the features for a 50% WHES relative to the Building America Benchmark.

50% WHES Features
8" R-30 SIP walls and floor
12" R-45 SIP roof
Green roof (ready)
0.00027 SLA infiltration (proposed) 0.00018 SLA (tested)
Slab on Grade with R-30 SIP
5/8" ceiling drywall
0.31 U-value/0.32 SHGC windows
ENERGY STAR® appliances
100% hardwired fluorescent or LED
18 SEER, 10 HSPF Mini-Split Heat Pump with backup electrical heaters
Heat Recovery Ventilator with filtration
Electric water heater
Flat plate solar thermal collectors

Table 158: 50% WHES "SIPs House" Base Case Features

As built, the home achieves a 51.2% + WHES level relative to the BA Benchmark. Because of BEOpt's inability to model several key features, the full value of some measures may not be fully realized in the analysis. The 18 SEER and 10 HSPF Fujitsu Mini-Split Heat Pump system was modeled as a standard 18 SEER and 9.2 HSPF heat pump. The duct system was modeled as ductless. The other feature that BEOpt was not capable of modeling was the SIPs floor on the slab foundation. The model was run with 0% exposed floor although that does not fully account for the benefit of the SIP floor on slab. The green roof was modeled as medium colored asphalt shingles. (See Appendix A of the final report for analysis details).

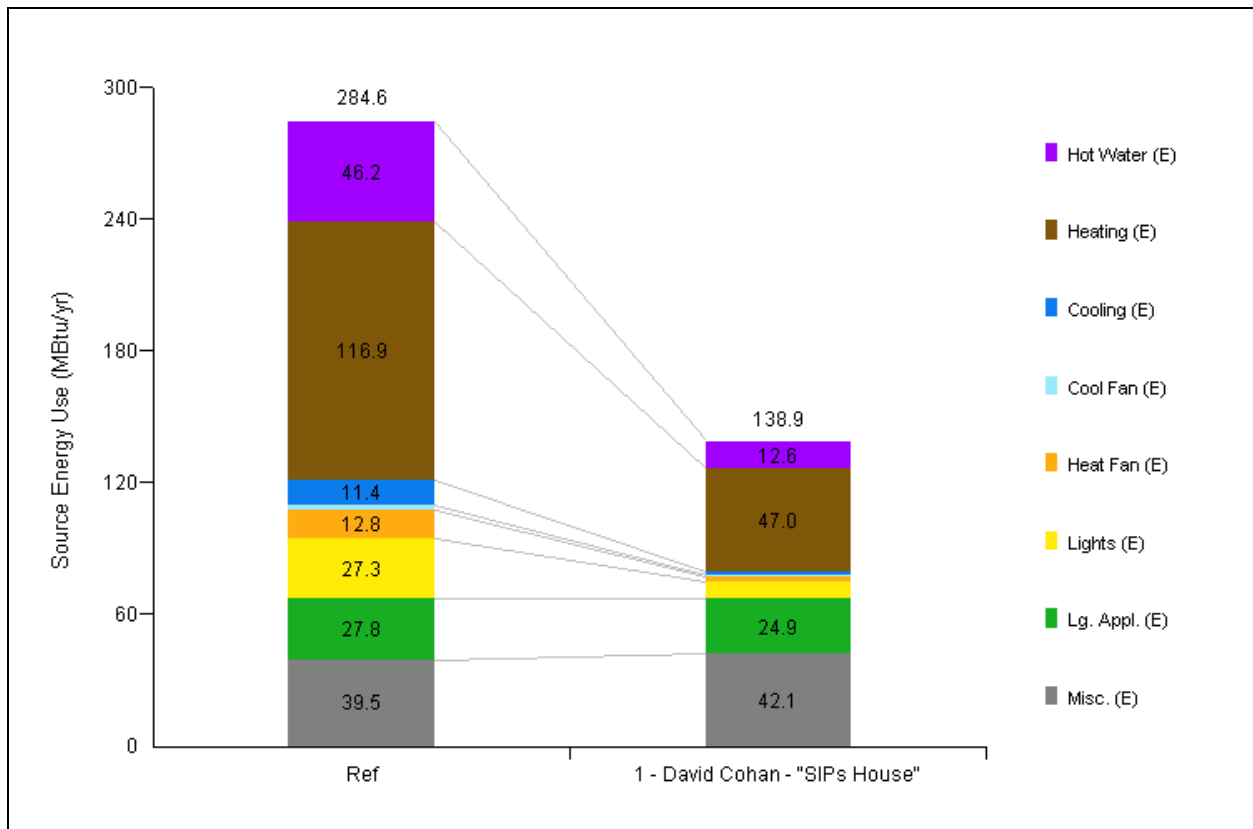


Figure 108: WHES versus Benchmark

"Must Meet Criteria" -- Prescriptive-Based Code Approval

Prior to the start of construction, construction documents, which include all systems incorporated into the home, were submitted and approved to ensure the structure and systems met applicable safety, health, and building code requirements. Typically, any code violation must be corrected and plans resubmitted until final approval is granted. Construction could only begin after final approval is received and a building permit granted.

The "SIPs House" was approved by the City of Portland; successfully passed all required inspections; and has received a certificate of occupancy.

"Must Meet Criteria" -- Quality Control Requirements

Earth Advantage has conducted LEED field testing and inspections. Final LEED certification is still pending.

Participation in independent third party certification programs based on on-site inspections such as LEED, Energy Star, Builder's Challenge, etc. provide significant assurances of quality control especially during the implementation of new building technologies.

The WSU Energy Program has completed third-party testing and inspections including air tightness testing and the installation of a data logging system to evaluate overall energy performance; performance of the solar hot water system; and energy performance and comfort impact of the ductless heat pump system.

The utility of in progress blower door testing was found to be very useful in meeting building tightness specifications. The assembly of SIPs panels can facilitate the air leakage control of the building enclosure but success is not automatic at least with crews inexperienced with the technology. Blower door testing after doors, windows and mechanical systems were installed but before interior finish provided guidance resulting in a final tested leakage rate 33% tighter than the original design specification. With further experience and design modifications additional significant reductions can be anticipated.

“Should Meet Criteria” -- Cost Neutrality

Cost effectiveness is key to determining whether the production builder and the homeowner will achieve an overall financial benefit from the use of these advanced features to achieve 50% WHES. BEopt 0.8.7 was used to perform an analysis of the advanced features’ incremental cost to the builder. The costs are used to determine whether the builder can maintain relatively low costs while implementing energy efficiency features. This preliminary analysis using BEopt will be used to determine whether the 50% WHES can be anticipated to provide sufficient reduction in energy bills to reach the neutral cost target.

Modeled energy performance, builder costs, and energy costs based on current utility rates were used to calculate the net annual cash flow to the homeowner. BEopt was not able to model the time of use rates used by Portland General Electric (Table 156 and Table 157) so the analysis was completed using an assume \$0.08/kWh. This data was used to predict whether, on a production basis, the incremental annual cost of energy improvements will be off-set by the annual reduction in utility bill costs.

The incremental costs of additional features were examined from the builder’s cost perspective as well as the impact on the homeowner’s monthly mortgage payments. The “cost-neutral” goal is for the homeowner to have utility bill savings greater than, or equal to, the increased monthly payment of the 30-year mortgage.

For this particular design, the following incentives were available through both the electric utility, Portland General Electric, as well as state and federal agencies.

Appliances	Description	Available Incentive Amount	Project Qualified Incentives
Portland General Electric			
Heat Pump Rebate	Energy efficient heat pump	\$200	\$200

Appliances	Description	Available Incentive Amount	Project Qualified Incentives
Portland General Electric			
Program	system installed by a PGE-approved contractor		
Solar Electric Incentive	\$2.25/watt _{DC} , up to \$20,000		
Additional Measures	Installation of an ENERGY STAR® clothes washer	\$100	
	Installation of an ENERGY STAR® Refrigerator	\$50	
	Lighting upgrade to 15 ENERGY STAR® Fixtures or CFLs	\$50	\$50
Total:		\$1,360	\$250
Energy Trust of Oregon, Oregon Department of Energy, & Federal Incentives			
Oregon High Performance Home Standard	Building Envelope and Mechanical Eligible Renewable Energy Systems	\$3,000, up to \$9,000	\$2000
Federal Tax Credit Home	50% reduction in heating and cooling when compared to 2004 IECC standards. 1/5 of the energy savings measures from improved enclosure	\$2,000	\$2000
H. Efficiency Heat Pump	HSPF of 9.0 or higher, EER or 12.0 or higher, valid AHRI Certification number	\$300-\$430	\$300
Solar DHW Tax Credit	Oregon certified by tax-credit technician, \$0.60/kWh up to \$1,500, SRCC certified	\$1,500	\$4200
	Federal	\$2000	
	Oregon Trust	\$880	
Total:		up to \$12,930	\$8500
Total Available Incentives:		up to \$14,290	\$8750

Table 159: Available Incentives

Incremental builder costs for the identified measures are included in [Table 160](#). Baseline costs for code minimum compliance were established using alternative bids when possible for alternative equipment. Other baseline construction costs were estimated based on the Economic Database in Support of ASHRAE 90.2 1481-RP as released by the NAHB Research Center, March 2009.

Energy Efficiency Feature	Builder Cost	Monthly Cost	Annual Cost
90% CFL Lighting	\$200.00	(\$1.33)	(\$15.97)
Solar w/Electric Tank Water Heater	\$7,700.00	(\$51.23)	(\$614.74)
Envelope Sealing, and Testing	\$650.00	(\$4.32)	(\$51.89)
SIPs panels	\$8,700.00	(\$57.88)	(\$694.58)
HRV	\$2,100.00	(\$13.97)	(\$167.66)
18 SEER (10 HSPF) HP	(\$2,000.00)	\$13.31	\$159.67
Highly Efficient Windows	\$0.00	\$0.00	\$0.00
Cost Markup to Customer	\$1,742.00	(\$11.59)	(\$139.07)
Rebates and Incentives	(\$8,750.00)	\$58.21	\$698.57
Totals	\$10,342.00	(\$68.81)	(\$825.67)

Table 160: Incremental Builder Cost

The top half of Table 161 adds details the annual utility bill savings of each of the five main end use categories in comparison to the BA Benchmark. These values are averaged over all four orientations. As shown in Table 161, the annual utility bill savings according to BEopt is \$1,938. It should be noted that this includes no fluctuations in utility rates or inflation.

The bottom half of Table 161 is derived from the builder's incremental first cost, detailed in Table 7, for each of the energy efficiency features listed. The builder costs were gathered from the builder. A 10% markup is assumed and the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation is not considered. For the 0.32 U-value windows, it is assumed that there are no additional costs. The net annual cash flow is calculated with and without incentive payments.

Description End Use	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings vs. Benchmark
	Benchmark	Oregon Code	Cohan SIPs House	Percent of End Use		Percent of Total		
	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	
Space Heating	129.7	78.6	49.7	61.7%	36.7%	28.1%	14.3%	\$950.09
Space Cooling	14.0	2.2	2.0	85.9%	9.4%	4.2%	0.1%	\$189.61
DHW	46.2	43.7	12.6	72.8%	71.1%	11.8%	15.3%	\$395.66
Lighting	27.3	7.6	7.6	72.1%	0.0%	6.9%	0.0%	\$228.88
Appliances and MELs	67.3	70.4	66.9	0.5%	4.9%	0.1%	1.7%	\$209.15
Total Usage/ Savings	284.6	202.5	138.9	51.2%	31.4%	51.2%	31.4%	\$1,988.39
					Energy Efficiency Feature			Annual Mortgage Cost vs. Code
					100% CFL Lighting (ES Requires 50%)			(\$15.97)
					Solar Hot Water w/ electric back-up			(\$614.74)
					Envelope Sealing, and Testing			(\$51.89)
					SIPs Construction			(\$694.58)
					HRV			(\$167.66)
					Ductless Heat Pump			\$159.67
					High Efficiency Windows			\$0.00
					Cost Markup to Customer			(\$138.52)
					Total Annual Mortgage Cost			(\$1523.68)
					Net Annual Cash Flow to Consumer			\$464.71
					Rebates and Incentives			\$698.57
Net Annual Cash Flow to Consumer after Incentives			\$1,162.72					

Table 161: Neutral Cost Analysis for the Cohan “SIPs House”

“Should Meet Criteria” -- Quality Control Integration

Incorporating new building features means that new building methods and procedures need to be addressed in the planning stages to ensure a smooth construction process and quality product. The plan to integrate the new methods and procedures should cover health, safety, durability, comfort, and energy related quality assurance. All trades should coordinate these features into their construction plans and should ensure that all plans necessary for city submittal are compliant with applicable building codes and jurisdictional requirements.

WSU worked with David Cohan to ensure that the design was followed. To ensure proper implementation, WSU met with the contractor for this home and discussed points on the construction schedule to assure that quality control mechanisms such as proper testing and inspections were included in their processes.

“Should Meet Criteria” -- Gap Analysis

An evaluation of the home building process was conducted to determine if there are extraneous circumstances that would prevent a production builder from using the methods and systems explored in this prototype. The gaps analysis provides the final information needed to determine how well the advanced systems integrate with production building practices and whether each process may be altered to achieve that goal.

A post-construction evaluation examined construction and installation issues gathered through questionnaires, interviews and reviews of installation documentation. Key information gathered during the gaps analysis included:

- Subcontractor Scopes of work and any related issues
- Training and/or certifications for advanced system, evidence of compliance with requirement for installation, any related issues
- Training issues
- Supply issues
- Code issues
- Design issues
- Installation issues
- Cost issues
- Labor issues

The project successfully demonstrated the integration of SIPs panel construction including floor assembly into a high performance home. Improved thermal performance with minimal thermal bridging and enhanced air leakage control offset added costs. Gaps in design integration and crew assembly experience remain challenges in a production environment. The SIPs system facilitates advanced air leakage control but training is required with new crews to assure

consistent outcomes. Feedback to assembly crews using a blower door is an effective instructional tool.

Solar thermal installation remains a maturing industry in the Pacific Northwest. Performance evaluation is on-going at the Cohan project and will be included in a broader analysis of the technology in a Stage Gate 1 system evaluation report in 2010.

Gold Medallion 50% Prototype – Completion Report BP3 (2010)

The report describes evaluation of the whole house energy use of a 50% prototype home through field-testing and energy simulation. The 50% prototype Gold Medallion Home is located in the cold, dry climate zone of Salt Lake Valley, Utah, in the Daybreak sustainable development community.

Key results

The actual performance of this near ZEH was compared to the simulated model of the benchmark house without any advanced energy saving features. The prototype used 47% less energy than the benchmark house in 2009. The electrical energy consumption was 50% lower and the thermal energy was lower by at least 16%, according to the simulated results. The total annual carbon dioxide emissions were reduced by 60% when compared to the standard practice prototype.

Gate Status

As reported in “*Task 3.2 Stage Gate 2 Prototype House Report: Performance Evaluations in Preproduction Prototypes*,” Deliverable Number 3.2.a, December 2008, the Gold Medallion home had been constructed and extensive monitoring equipment was installed. University of Utah (U of U) performed building monitoring and data evaluations for the PVT system and the two-stage OASys evaporative cooler. The U of U has continued to monitor and analyze the energy use through a full year of occupancy. Energy efficiency benefits and costs have been quantified and evaluated to verify that the house meets the goal of 50% whole house energy savings. All findings are documented in the completion report’s Appendix B.

Conclusions

The goal of 50% energy savings was met with a calculated 46% savings using EnergyPlus software to model the prototype and compare it to the benchmark house. The simulation results indicate that SIPs provide nearly 30% reduced energy use for the building in the heating season. The solar power generation unit, PVT, provides nearly 42% of the electrical energy consumed in summer and an average of 30% during the winter season. The thermal energy gain from PVT was nearly 50% of the total thermal energy use in summer but only 10% of the total thermal energy use in winter. The overall efficiency of PVT (total energy out / total solar energy

hitting the collector) was 35% in summer and at least 16% in winter (considering it provides a certain amount of space heating that could not be assessed accurately).

Introduction

The purpose of this report is to evaluate the prototype Gold Medallion in the Cold Climate Zone to determine if it meets Building America's 50% whole house energy savings (WHES) goal when compared to the Building America Benchmark. The prototype will be evaluated based on Building America's Stage Gate 2 "Must Meet" and "Should Meet" criteria (see Appendix A of the completion report).

This report documents the performance of the 50% prototype for a full year of occupancy (April 2009 to April 2010). Example performance data for individual devices on the Summer solstice (June 21, 2009), on a monthly basis and year-to-date totals are presented.

Project Overview

The 50% Cold Prototype House is located in the Salt Lake Valley, UT. The home was built by Gold Medallion in the Daybreak sustainable community.

The house contains a comprehensive network of sensors monitoring nearly every aspect of energy usage that occurs. Thermocouples are embedded in the walls, floors, ducts and plumbing; pulse meters track energy usage, water and gas flows. House performance data are collected on one minute, 15 minute, 60 minute and daily basis intervals. The data was utilized to analyze the energy usage, water usage, gas usage and for performing energy balance on the PVT system to measure its efficiency. Essential data patterns for any user-specified day are plotted in graphs which can be viewed from the 50% prototype house website at www.zeroenergyhome.utah.edu.

EnergyPlus (version 2.2.0) was employed to evaluate 2009 annual electrical energy consumption and the total energy use of the prototype house. The as-built home was compared to simulations that modeled a benchmark house using construction methods and materials commonly used by local builders in order to assess the Building America Gate 2 goal of 50% WHES.

Advanced Systems Overview

The overall energy performance of this house was improved by photovoltaic (PV) electrical energy production, decreased heat loss in the winter due to structurally insulated panels (SIPs), and the OASys evaporative cooling system during summer. The monthly cumulative energy data that was collected is similar to the values specified in the power and gas bills. The simulated results indicate that SIPs provide nearly 30% reduced energy use for the building in the heating season. However, SIPs have negligible impact on the cooling energy load in the

summer.

The OASys two-stage evaporative cooler reduces energy consumption by 60% when compared to a standard 13 SEER vapor-compression air conditioning system. Although the OASys evaporative cooler may reduce energy consumption, it does increase the amount of water consumption as water is the medium used to transfer energy. Because the SIPs wall system provides a tight house with very low air infiltration rates, the OASys system was an effective choice for zero energy home (ZEH) construction in Salt Lake City, UT as it also provides fresh air circulation.

The water heater is relatively energy efficient and has a time averaged efficiency of 83%. This is lower than the rated 96% efficiency, but includes heat loss to the air when heating. Heat loss to the building is recouped during times of heating but becomes counter-productive when cooling demands are high.

The solar power and hot water generation unit, PVT, provides nearly 42% of the electrical energy use in the ZEH in summer and an average of 30% during the winter heating season.

The thermal energy gain from PVT was nearly 50% of the total thermal energy use in summer and close to 10% of the total thermal energy use in winter. The overall efficiency of PVT (total energy out / total solar energy absorbed by the collector) was calculated as 35% during the summer and at least 16% efficiency during the winter (considering it provides a certain amount of space heating that could not be assessed accurately). The PVT system proved to provide additional benefits compared to a conventional PV system and seemed appropriate for this specific project. However, the actual performing efficiencies of the PVT system are much lower than the rated efficiency of 50-60%.

“Must Meet” Gate Criteria - Source Energy Savings

The 50% Cold prototype house incorporates many energy saving features, solar power generation and supplemental solar water heating. Major energy saving features include:

- Evaporative Cooler (OASys)
- Photovoltaic Thermal panels (PVT)
- On-demand tankless water heater
- Hydronic furnace
- Structurally Integrated Panels (SIPs) for walls

The house also incorporates additional energy saving features such as fluorescent lighting, radiant heat barrier in the attic, low emissivity windows, and ducts that run in conditioned space.

The EnergyPlus (version 2.2.0) simulation code was used to evaluate annual electrical energy

consumption and the total energy use of the prototype house using 2009 weather data. A comparison between simulations using actual weather data and measured energy use showed reasonable agreement. EnergyPlus was then used to evaluate the energy use in a similar benchmark house built with construction methods, appliances and materials commonly used by the local builders. The energy use of this 50% Cold Prototype house was 47% less than that of the benchmark house – nearly equal to the goal of a 50% reduction.

EnergyPlus calculations using 2009 weather data are presented in Appendix B.

“Must Meet” Gate Criteria - Prescriptive-Based Code Approval

As reported in *Task 3.2 Stage Gate 2 Prototype House Report: Performance Evaluations in Preproduction Prototypes*, Deliverable Number 3.2.a, December 2008, “By working with the City to educate them and address any issues prior to construction, the BIRA team was able to prevent code related issues in incorporating these advanced features.”

“Must Meet” Gate Criteria - Quality Control Requirements

As reported in *Task 3.2 Stage Gate 2 Prototype House Report: Performance Evaluations in Preproduction Prototypes*, Deliverable Number 3.2.a, December 2008:

“This home incorporated multiple advanced systems and insuring the systems were installed properly, as specified, required additional effort on BIRA’s part. Monthly meetings were conducted to address any issues in the incorporation of the BA design features. Although, the design required equipment and construction practices beyond the typical Gold Medallion building practices, they did not have any issues. BIRA worked with Gold Medallion in developing and meeting milestones to assure that progress was made and that designs were implemented properly. Monthly builder meetings were also used to incorporate and coordinate third-party testing and verification.”

“Should Meet” Gate Criteria - Neutral Cost Target

Cost Neutrality was addressed in *Task 3.2 Stage Gate 2 Prototype House Report: Performance Evaluations in Preproduction Prototypes*, Deliverable Number 3.2.a, December 2008. The Gold Medallion home’s cost of energy improvements is less than or equal to the annual reduction in utility bill costs, relative to the BA Benchmark analysis.

“Should Meet” Gate Criteria - Quality Control Integration

According to the *Task 3.2 Stage Gate 2 Prototype House Report: Performance Evaluations in Preproduction Prototypes*, Deliverable Number 3.2.a, December 2008,

“BIRA conducted monthly meetings to address any issues in the incorporation of the advanced

design elements. Since the Gold Medallion homes utilized PVT, OASys, hydronic heating, and SIPs, BIRA worked with them in developing and meeting milestones. This helped to assure that progress was being managed and provided a mechanism for information exchanged with the industry partners. PVT and OASys worked with the builder to ensure proper installation and commissioning of each system. Monthly builder meetings were used to incorporate and coordinate third-party and industry partner testing and verification. PVT worked with the builder to provide installation assistance and commissioned the system at completion.”

“Should Meet” Criteria - Gaps Analysis

The primary data gap was the quantity of thermal energy that was recovered from the PVT solar collectors. While the energy to the hot water storage tank could be quantified, the amount of directly heated air coming into the house or exhausted to the environment was not adequately quantified.

Task 4: Stage Gate 3 -- Community Scale Evaluations

The community scale evaluation process begins with identifying and characterizing candidate communities in the Marine, Hot-Humid and Hot/Mixed Dry climate zones that meet the needed performance target levels. The BIRA team identified six candidate communities in the Hot/Dry and Marine climates during BP1, six during BP2 and three communities in the hot/Mixed-Dry, Hot-Humid, and Marine climate zones during BP3. Plans were developed to evaluate each of these communities with respect to the Stage Gate 3 “Must Meet” and “Should Meet” criteria. Once the evaluation plans were established, a case study documenting each community’s performance was developed.

Subtask 4.1 Evaluation Plans for Initial Community Scale Projects of Ten or More Homes with 40-50% in Efficiency Savings

The BIRA team completed the evaluation plans for qualified initial community scale projects shown in the table below.

Community/Location	Builder	Number of Homes	% WHES/Climate Zone
O Bel! Sole Lancaster, CA	K Street LLC	58 completed	54% Hot/Dry
Landover Commons Vancouver, WA	New Traditions	94	44.1% Marine
Kentlake Highlands Kent, WA	Quadrant	9 completed 10 in process	41.7% Marine
Crescent Village Eugene, OR	Ruhoff	16 completed 8 in process	44.1% Marine
Village at Miller’s Creek Burien, WA	Schneider Family Homes	37	47.4% Marine
New Columbia Portland, OR	Tom Walsh and Co	22	43.5 % Marine
Snow Creek Park City, UT	Park City	13	50% Cold
Mololani Kaneohe, HI	Forest City Military Communities, LLC	244	50% Hot Humid
Mediterranean Villas Pasco, WA	Devoted Builders	200	40% Cold
Sage Green Portland, OR	Green One Construction	18	50% Marine
Artistic Homes NM / CO	Artistic Homes	12	50% Cold 50% Hot/Mixed Dry
Waikulu Kaneohe, HI	Forest City Military Communities, LLC	165	40% Hot Humid
DR Horton	DR Horton	10	50%+ Hot-Humid

Community/Location	Builder	Number of Homes	% WHES/Climate Zone
Oahu, HI			
Tierra del Sol Stockton, CA	Visionary Home Builders	22	50% Hot/Mixed-Dry

Table 162: Evaluation Plans – Initial Community Scale Projects

Subtask 4.2 Stage Gate 3 Case Studies: 40-50% Initial Community Scale Projects

The BIRA team completed the necessary case studies for qualified initial community scale projects required to completing the Building America 2008 – 2010 Joule Milestone. The communities are summarized in the table below.

Community/Location	Builder	Number of Homes	% WHES/Climate Zone
Landover Commons Vancouver, WA	New Traditions	94	44.1% Marine
Kentlake Highlands Kent, WA	Quadrant	10 completed 9 in process	41.7% Marine
Crescent Village Eugene, OR	Ruhoff	16 completed 8 in process	44.1% Marine
Village at Miller's Creek Burien, WA	Schneider Family Homes	37	47.4% Marine
New Columbia Portland, OR	Tom Walsh and Co	22	43.5 % Marine
Snow Creek Park City, UT	Park City	13	50% Cold
Mololani Kaneohe, HI	Forest City Military Communities, LLC	244	50% Hot Humid
Sage Green Portland, OR	Green One Construction	18	>50% Marine
Mediterranean Villas Pasco, WA	Devoted Builders	12	40% Cold
Artistic Homes NM / CO	Artistic Homes	165	50% Cold 50% Hot/Mixed Dry
Waikulu Kaneohe, HI	Forest City Military Communities, LLC	13	40% Hot Humid
DR Horton	DR Horton	10	50%+ Hot-Humid

Community/Location	Builder	Number of Homes	% WHES/Climate Zone
Oahu, HI			
Tierra del Sol Stockton, CA	Visionary Home Builders	22	50% Hot/Mixed-Dry

Table 163: 40-50% Initial Community Scale Project in the Multiple Climates

The following tables below summarize the Initial Community Scale Project findings during the contract period.

Community	Key Result	Gate Status BP1
Landover Commons	44.1% Marine	As of May 2008, New Tradition expects at least ten of these tax credit homes to be complete in the Landover Commons community by September. Based on the energy cost savings from BEopt and incremental costs from New Tradition Homes, it was determined that the homeowner can expect to see approximately \$700 per year net cost savings compared to the Building America Benchmark.
Kentlake Highlands	41.7% Marine	The Kentlake Highlands community meets Building America's 40% initial communities goal for the Marine Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria.
Crescent Village	44.1% Marine	There are at least 16 homes built at the 40% level, with another eight to be completed by the end of the year. Based on the energy cost savings from BEopt and incremental costs from Ruhoff Home Builders, it was determined that the homeowner can expect to see approximately \$319 per year net cost savings compared to the Building America Benchmark.
Village at Miller's Creek	47.4% Marine	All 37 of the homes in Village at Miller's Creek have been completed. Based on the energy cost savings from BEopt and incremental costs from Schneider Family Homes, it was determined that the homeowner should expect approximately \$830 per year net cost savings relative to the Building America Benchmark.

Community	Key Result	Gate Status BP1
New Columbia	43.5 % Marine	There are currently 22 homes of this level completed in the New Columbia community. Based on the energy cost savings from BEopt and incremental costs from Tom Walsh & Co., it was determined that the homeowner can expect to see approximately \$750 per year net cost savings compared to the Building America Benchmark.

Table 164: Summary of Initial Community Scale Projects

Community	Key Result	Gate Status BP2	Gate Status BP3
Snow Creek	>50% Cold Climate	Qualifies as a Building America 50% Community in the Cold Climate Zone with all plans averaging 54.8% WHES	This project fulfills all “must meet” and “should meet” criteria for Stage Gate 3.
Mololani	>50% Hot Humid Climate	Qualifies as a Building America 50% Community in the Hot-Humid Climate Zone with 52.9% WHES	This project fulfills all “must meet” and “should meet” criteria for Stage Gate 3.
Sage Green	>50% Marine Climate	Qualifies as a Building America 50% Community in the Marine Climate Zone with 50.1% WHES	This project fulfills all “must meet” and “should meet” criteria for Stage Gate 3.
Mediterranean Villas	40% Marine Climate	Qualifies as a Building America 40% Community in the Marine Climate Zone with 48.5% WHES	N/A
Artistic Homes	>50% Cold and Hot/Mixed-Dry Climate	Qualifies as a Building America 50% Community in the Cold and Hot/Mixed Dry Climate Zone with 55.7% WHES without PV	This project fulfills all “must meet” and “should meet” criteria for Stage Gate 3.
Waikulu	>50% Hot Humid Climate	Qualifies as a Building America 50% Community in the Hot-Humid Climate Zone with 51.4% WHES	This project fulfills all “must meet” and “should meet” criteria for Stage Gate 3.
DR Horton Oahu, HI	50%+ Hot-Humid N/A	N/A	Qualifies as a Building America 50% community in the Hot-Humid climate zone

Community	Key Result	Gate Status BP2	Gate Status BP3
			while satisfying stage Stage Gate 3 criteria.
Tierra del Sol Stockton, CA	50% Hot/Mixed-Dry	N/A	Qualifies as a Building America 50% Community in the Hot/Mixed-Dry climate zone. This community meets all Stage Gate 3 criteria.

Table 165: Summary of Initial Community Scale Projects

40% Case Study – Hot-Humid (Forest City)

The BIRA team has completed one (1) case study for 40% efficiency in the Hot-Humid climate zone satisfying stage gate 2 criteria. The report presents evaluation results of the Forest City Military Communities LLC – Naval Computer and Telecommunications Area Master Station (NCTAMS) Community. The community evaluation was based on the Building America Stage Gate 3 “Must Meet” and “Should Meet” criteria for Initial Community Scale Evaluations.

New Traditions - Community Overview BP1 (2008)

New Tradition Homes was started in 1987 by Alvar and Nancy Helmes and their family. The company has grown to be one of the largest homebuilding companies in the Clark County, Washington region. In 2006, New Tradition decided to build all of its homes to Northwest ENERGY STAR® and Earth Advantage standards and is currently participating in the Department of Energy’s Builders Challenge. In 2007, New Tradition won the Regional ENERGY STAR® Builder of the Year award from Northwest ENERGY STAR®. In addition, they have their own building science team that continues to strive for more energy efficient and higher quality homes.

The community described in this case study is New Tradition’s Landover Commons located in Vancouver, Washington. The city is located in Building America’s Marine Climate Zone and experiences an average annual precipitation of 41.3 inches, 4,399 annual heating degree days, and 291 annual cooling degree days. This climate provides the greatest opportunity for energy savings from reductions in space heating loads.

Landover Commons will consist of 94 homes when complete, at least ten meeting federal tax credit standards. The two-story, three bedroom homes are built with R21, 2x6, 16” o.c. construction, priced between \$229,900 and \$269,900, and are generally targeted at middle class homeowners or first time buyers looking for a high quality home. The community is provided electricity by Clark Public Utilities and natural gas by Northwest Natural.

This case study will show that the Landover Commons community meets Building America's 40% initial communities goal for the Marine Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria. It is important to note that New Tradition is constructing Building America homes across several communities and that the plan studied might not be built in each community.

For more information on the Landover Commons community, contact Steve Tapio, Quality Control Lead, New Tradition Homes, Steve.Tapio@NewTraditionHomes.com or visit the New Tradition Homes website, www.NewTraditionHomes.com.

"Must Meet" Gate Criteria -- Source Energy Savings

Using BEopt 0.8.6, an energy analysis was performed on New Tradition's Kent 2264 floor plan. Floor plans and elevations can be found in Appendix A of the task report. The Kent 2264 plan is a two-story house representative of a typical New Tradition house in Washington, with 2,250 square feet of finished floor area, three bedrooms, and two bathrooms. The plan was modeled as a federal tax credit home, an option offered by New Tradition for this floor plan. Two separate simulations were run, one with the BA Benchmark as the reference house, and one with a Washington code house as the reference house. Figure 109 shows the BEopt source energy use graph for the Kent 2264 floor plan with the BA Benchmark as the reference house. All four cardinal orientations were simulated for both reference homes. Table 166: Source Energy Savings for the Kent 2264 Floor Plan

summarizes the findings of both simulations. The energy savings for Kent 2264 are averaged over all four orientations and grouped into five main end use categories.

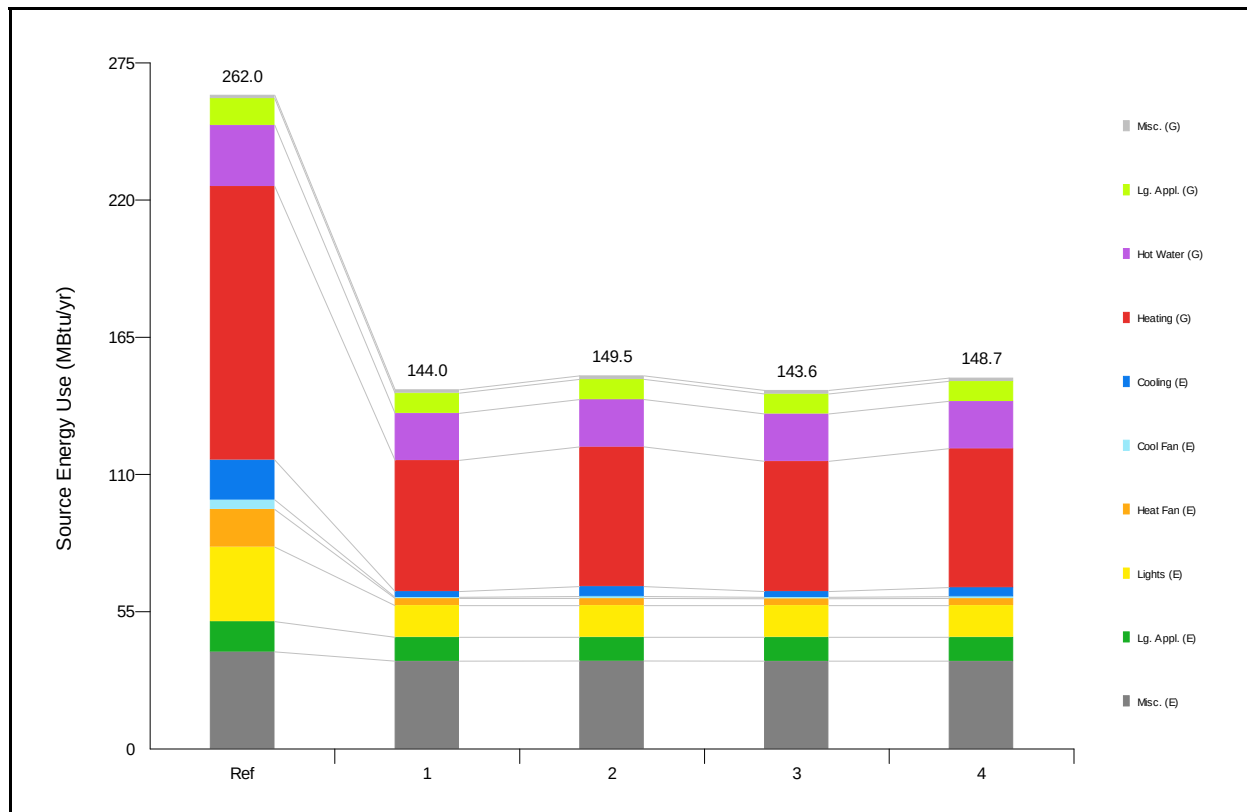


Figure 109: BEopt Source Energy Use
Kent 2264 with the BA Benchmark as the Reference House

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Washington Code	Kent 2264	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	124.7	77.5	57.0	54.3%	26.5%	25.9%	10.4%
Space Cooling	19.9	3.9	3.7	81.4%	5.3%	6.2%	0.1%
DHW	24.5	22.3	19.0	22.7%	15.1%	2.1%	1.7%
Lighting	29.9	29.9	12.7	57.5%	57.5%	6.6%	8.7%
Appliances and MELs	63.0	64.8	54.1	14.1%	16.5%	3.4%	5.4%
Total Usage/Savings	262.0	198.5	146.4	44.1%	26.2%	44.1%	26.2%

Table 166: Source Energy Savings for the Kent 2264 Floor Plan

As shown in Table 166: Source Energy Savings for the Kent 2264 Floor Plan

a typical New Tradition house with the federal tax credit package meets the Building America goal of 40% energy savings in the Marine Climate Zone with respect to the BA Benchmark. The critical above code energy reduction features implemented in order to reach this goal are as follows:

- ENERGY STAR® refrigerator, dishwasher, and clothes washer
- 70% hardwired CFL lighting
- 61% EF gas water heater
- 5.2 ACH₅₀ infiltration (typical New Tradition home)
- R49 blown-in cellulose insulation in the attic
- 92.5% AFUE furnace
- Ducts in conditioned space
- 0.32 U-value windows (worst case, most windows have 0.31 or 0.30 U-value)
- Gas cooking range and clothes dryer (gas dryer stub provided)

New Tradition Homes began with the features prescribed by Northwest ENERGY STAR®. By improving on these requirements, New Tradition was able to raise their homes to the federal tax credit level, which is equivalent to 40% whole house energy savings compared to the BA Benchmark. One additional feature that cannot be modeled in BEopt is a seasonal damper that New Tradition installs on its homes. The homeowner is instructed to use this feature when moving from the heating to the cooling season to deliver more comfortable and efficient space conditioning.

New Tradition also performed its own study of over 20 homes using customer energy bills to compare their Northwest ENERGY STAR® homes to a Washington code house. Their results showed a 20 - 23% whole house energy savings compared to code. This agrees favorably with the results shown in Table 166: Source Energy Savings for the Kent 2264 Floor Plan

The supplementary features of the federal tax credit home provide the additional 3 - 6% energy savings.

Based on the BEopt simulation providing 44.1% energy savings compared to the BA Benchmark, New Tradition Homes' Landover Commons community passes the Source Energy Savings "Must Meet" criteria.

"Must Meet" Gate Criteria - Market Coverage

Landover Commons will consist of 94 homes when completed. Within the at least 80% complete community are seven federal tax credit homes (40% above the BA Benchmark), more than ten tax credit homes were completed by September. For a site plan of the Landover Commons community, see Appendix E of the task report.

Based on this information, New Tradition Homes' Landover Commons community passes the Market Coverage "Must Meet" criteria.

"Must Meet" Gate Criteria - Neutral Cost Target

New Tradition Homes has been able to keep its costs relatively low while implementing energy efficiency features. They have done this by working with vendors to bring costs down, beginning with the most expensive elements. This effort is largely driven by the recent housing crunch - and it is definitely working. In addition, the 44.1% whole house energy savings provides substantial reduction in energy bills, resulting in few, if any, tradeoffs necessary to reach the neutral cost target. These costs are based on the current utility rates in Vancouver, Washington, summarized in Table 167: Current Utility Rates for Vancouver, Washington

, and include both electric and natural gas energy sources.

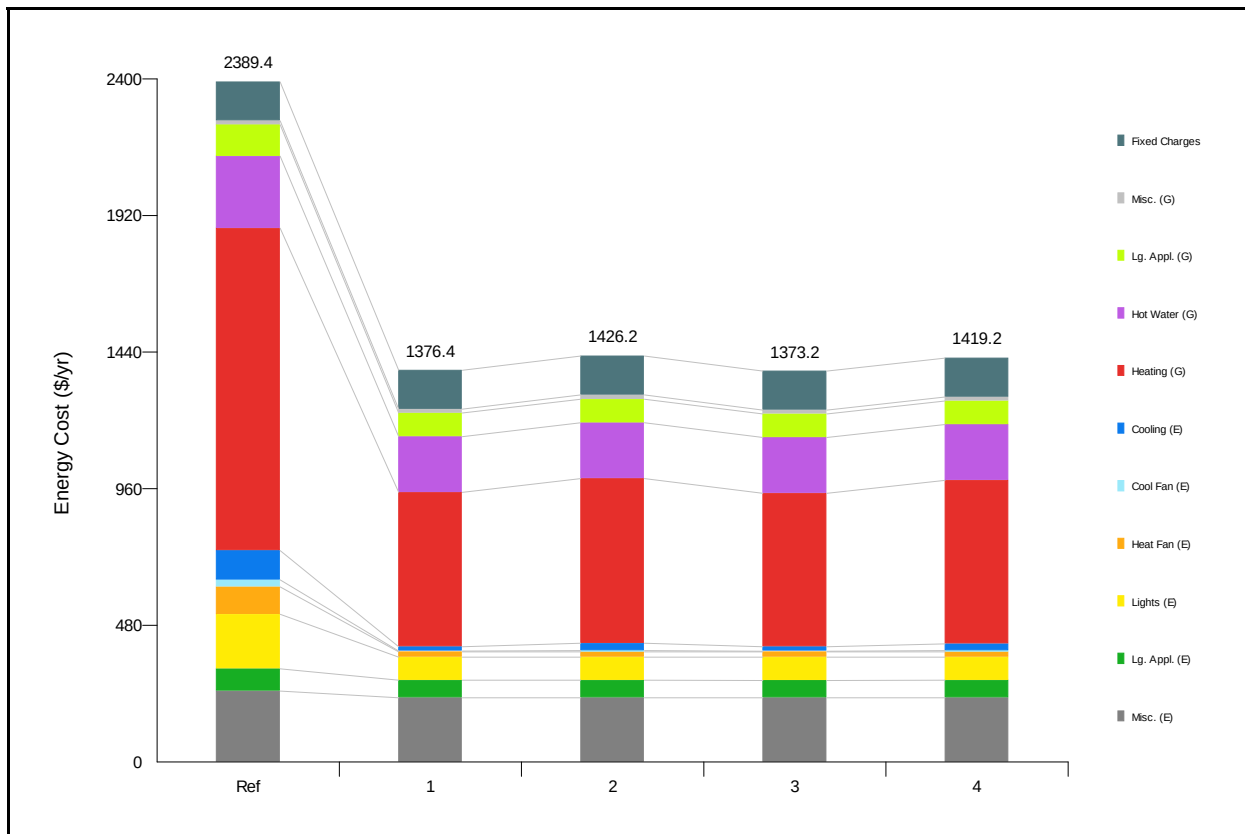


Figure 110: BEopt Energy Cost
Kent 2264 with the BA Benchmark as the Reference House

Electricity Rate	
Utility	Clark Public Utilities
Marginal	\$0.0736/kWh
Fixed	\$6.40/month
Natural Gas Rate	
Utility	Northwest Natural
Marginal	\$1.128/therm
Fixed	\$5.00/month

Table 167: Current Utility Rates for Vancouver, Washington

The top half of Table 168: Neutral Cost Analysis for the Kent 2264 Floor Plan

adds a column to Table 166: Source Energy Savings for the Kent 2264 Floor Plan

that details the annual utility bill savings of each of the five main end use categories in comparison to the BA Benchmark. Again, these values are averaged over all four orientations.

As shown in Table 168: Neutral Cost Analysis for the Kent 2264 Floor Plan

, the annual utility bill savings according to BEopt is \$990.61. It should be noted that this includes no fluctuations in utility rates or inflation.

The bottom half of Table 168: Neutral Cost Analysis for the Kent 2264 Floor Plan

is derived from the builder's first for each of the energy efficiency features listed. The builder costs were gathered from a meeting between BIRA representatives and New Tradition's purchasing agent, quality control lead, and vice president of operations. A 10% markup is assumed and the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation is not considered. For the 0.32 U-value windows and the gas cooking range and clothes dryer, it is assumed that there are no additional costs.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	Washington Code	Kent 2264	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	124.7	77.5	57.0	54.3%	26.5%	25.9%	10.4%	\$651.96
Space Cooling	19.9	3.9	3.7	81.4%	5.3%	6.2%	0.1%	\$103.69
DHW	24.5	22.3	19.0	22.7%	15.1%	2.1%	1.7%	\$57.45
Lighting	29.9	29.9	12.7	57.5%	57.5%	6.6%	8.7%	\$110.25
Appliances and MELs	63.0	64.8	54.1	14.1%	16.5%	3.4%	5.4%	\$67.26
Total Usage/ Savings	262.0	198.5	146.4	44.1%	26.2%	44.1%	26.2%	\$990.61
					Energy Efficiency Feature			Annual Mortgage Cost
								vs. Code
					ENERGY STAR Appliances			(\$21.08)
					70% CFL Lighting			(\$10.54)

61% EF Water Heater	(\$13.17)
Improved Duct Sealing, Envelope Sealing, and Testing	(\$118.56)
R49 Attic Insulation	(\$28.10)
92.5% AFUE Furnace	(\$39.52)
Moving Ducts Into Conditioned Space	(\$59.28)
Total Annual Mortgage Cost	(\$290.24)
Net Annual Cash Flow to Consumer	\$700.37

Table 168: Neutral Cost Analysis for the Kent 2264 Floor Plan

As shown in Table 168: Neutral Cost Analysis for the Kent 2264 Floor Plan

, the net annual cash flow to the homeowner is approximately \$700. Based on this information, it is clear that the incremental annual cost of energy improvements is much less than the annual reduction in utility bill costs and New Tradition Homes' Landover Commons community passes the Neutral Cost Target "Must Meet" criteria.

This analysis does not include the \$2,000 federal tax credit that New Tradition receives for each new home built that achieves 50% energy savings for heating and cooling over the 2004 International Energy Conservation Code (IECC). This stems from Building America's goal of finding sustainable solutions. Since the tax credit that New Tradition Homes utilizes expires at the end of 2008, it was not considered appropriate to include this credit. It is important to note, however, that the federal tax credit, along with ENERGY STAR®, provides a crucial framework and starting point for builders seeking to build energy efficiently, including New Tradition Homes.

"Should Meet" Gate Criteria -- Marketability

Keeping homes marketable in the current housing crisis has been a real challenge for New Tradition Homes. The main focus has been faster turnarounds for installation and adoption of energy efficiency/healthy home features as opposed to higher margins. New Tradition believes that their differentiation is helping to keep them afloat during this market downswing. To support this belief, they conducted their own survey which indicated that 95% of homebuyers show at least some desire to have high performing homes and that energy efficiency is the second most desirable feature among energy and non-energy features. With this information in

hand, New Tradition continues to build energy efficient homes at a price comparable to code homes. Although they have smaller margins than their competitors, New Tradition is selling more units.

All of New Tradition's homes for 2008 include their 20th Anniversary Special package. This package includes Northwest ENERGY STAR® and Earth Advantage certification as well as stainless steel appliances and granite countertops. One sales associate made the comment that customers seem to come back for the Northwest ENERGY STAR® and Earth Advantage certification and that the biggest draw is the cost savings. New Tradition has also participated in the Department of Energy's Builders Challenge. A press release can be found in Appendix G of the task report.

Based on current sales and marketing information, New Tradition Homes' Landover Commons community passes the Marketability "Should Meet" criteria.

In future marketing efforts using information from this Building America study, New Tradition would like to be able to quantitatively show homebuyers the energy savings that their house provides compared to a typical Washington code house.

For more information on New Tradition Homes sales and marketing strategy, contact Mandi Kostman, (360) 606-4080 or Robin Ramos (360) 721-1858, Sales Agents, New Tradition Homes.

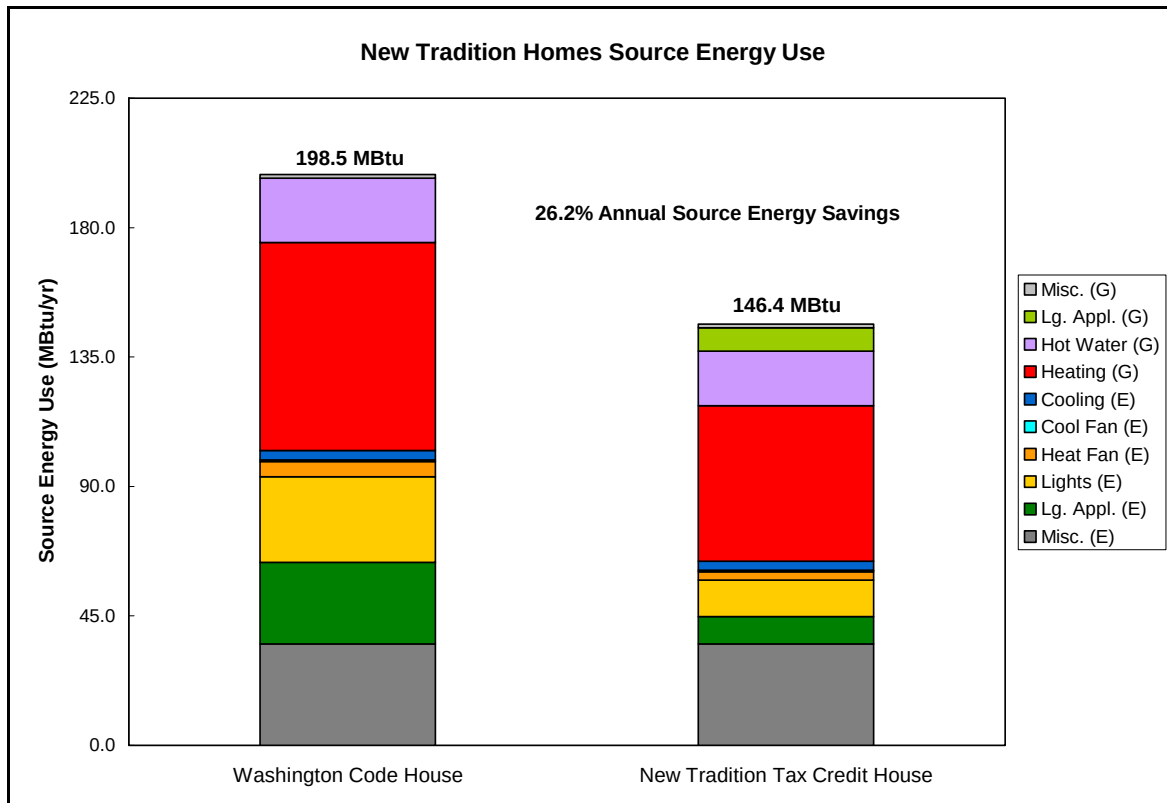


Figure 111: Source Energy Use Marketing Material for New Tradition Homes

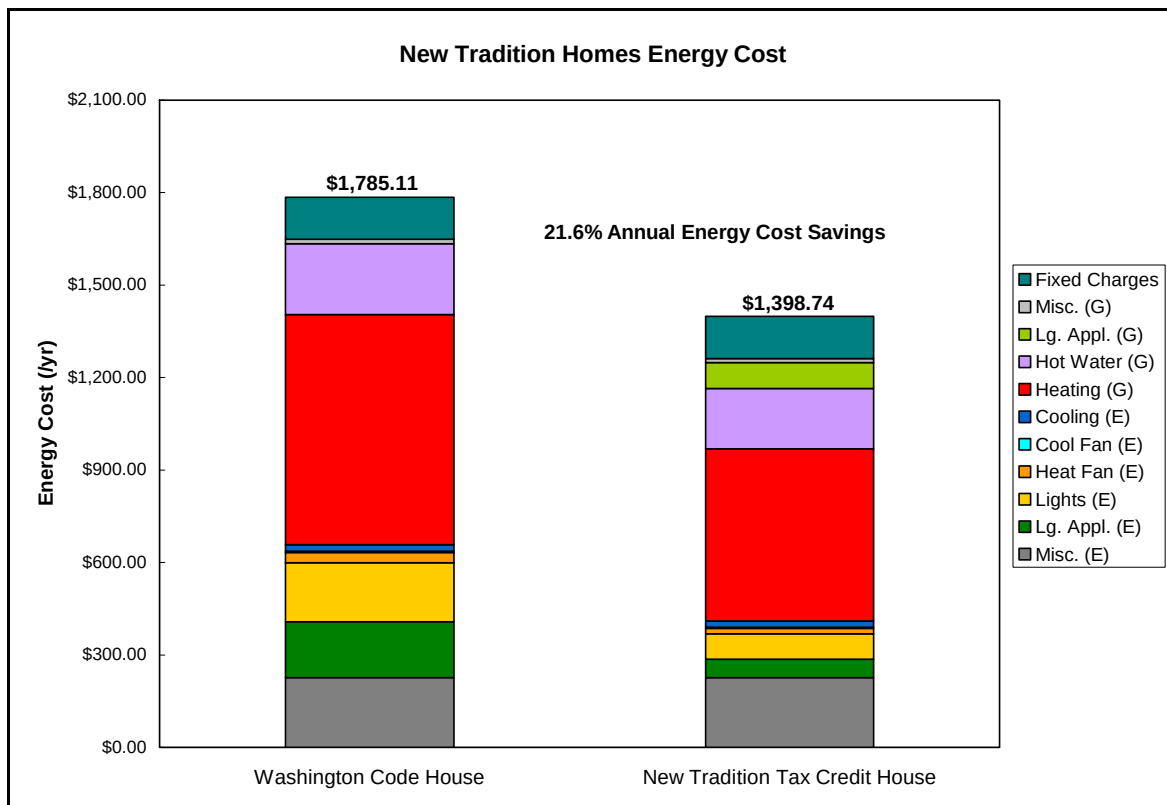


Figure 112: Energy Cost Marketing Material for New Tradition Homes

“Should Meet” Gate Criteria -- Builder Commitment

In 2006 New Tradition Homes made a commitment to build all of their homes to Northwest ENERGY STAR and Earth Advantage standards. They are the only southwest Washington production builder that does this. Earth Advantage has been certifying homes with New Tradition Homes for two and a half years and has certified more than 350 of their homes. In that time, New Tradition Homes has continued to build better quality and more energy efficient houses.

New Tradition Homes has committed significant resources of time and money to educate their staff, subcontractors, and customers about the benefits of building high performance homes. Their commitment to energy efficiency is evident by the amount of building science training that New Tradition staff has attended. Their goal is to have the entire staff understand what makes a quality-built home and how to explain that to potential buyers. Representatives from the company attend workshops on energy efficient construction, indoor air quality, green building techniques, and marketing high performance homes. New Tradition continuously builds, tests, trains, and fine-tunes all facets of their company. This team commitment helps separate New Tradition Homes from the rest of the production builders in Clark County. According to Mark LaLiberte, President of Building Knowledge Consulting, Inc., New Tradition’s “commitments to building homes that represent the best technology, performance, and quality

is unmatched.”

New Tradition Homes is one of very few builders to have their own building science team, a fact that demonstrates a true dedication to continuously building more energy efficient homes. They continually work with local and national experts to research and test new methods of building homes that exceed traditional performance measures. New Tradition is always looking to implement “cutting edge” energy savings technologies and sustainable building systems. Mike Lubliner, a Building Science Specialist working for the Washington State University Energy Program and a member of the BIRA team, believes that New Tradition is “one of the best, because of their 100% commitment to building cost effective, quality, healthy, durable, and energy efficient homes in Washington State.”

New Tradition is also committed to involving the industry at large. They have integrated suppliers, consultants, researchers, and code officials into their efforts and shared their experiences with other builders. They have also trained their sales agents to help them turn technical information into benefits that empower homeowners to make better decisions with respect to energy efficiency. New Tradition understands that energy efficiency is not just about individual features but rather an integrated process and commitment to continual improvement.

Based on this builder’s proactive energy efficiency practices at the Landover Commons community, New Tradition Homes passes the Builder Commitment “Should Meet” criteria.

“Should Meet” Gate Criteria -- Gaps Analysis

New Tradition’s current strategy for moving ducts inside conditioned space involves the use of drop-downs and soffits. This method is three times more expensive than using bio-spray foam, including labor and materials, and is largely driven by scheduling with subcontractors. For example, using drop-downs requires the framer to return a second time. In one case, the framer actually framed the drop-downs when he first framed the house. This caused a problem when the HVAC installers arrived and had to work around the drop-down framing in order to install the ducts. This led to a very high cost for labor as well as a lower quality installation.

Bio-spray foam is much cheaper and involves placing the ducts in the attic and covering them with spray foam while keeping the furnace in conditioned space. Interestingly, even when New Traditions doesn’t put the ducts inside for their Kent floor plan, they still use drop-downs and soffits because they are architecturally pleasing and define the spaces and transitions between rooms.

In the future, New Tradition hopes to implement open-web trusses between the first and second floors to facilitate moving ducts inside. This design allows subcontractors the flexibility to run plumbing, electrical, and ductwork easily between floors, with little to no “trade damage” or “trade fighting.” Additional costs for this new truss design can be offset by cost

savings in the HVAC system equipment and installation. These cost savings can be made possible through shorter, un-insulated duct runs and the purchase of smaller, less expensive furnaces due to reduced heating loads.

Another aspect New Tradition hopes to improve is further tightening of the house envelope. In the future, New Tradition plans to caulk and/or foam ceiling penetrations before installing attic insulation. This includes such ceiling penetrations as can lights, and is the one element of sealing New Traditions is not currently addressing.

New Tradition is also strongly considering moving to 100% CFL lighting using screw-in CFLs for the remaining fixtures. Although not a long term solution, this would certainly increase the energy savings at a small cost. New Traditions currently estimates a cost of only \$24 per home, including a \$2 per bulb rebate from Clark Public Utilities.

“Should Meet” Gate Criteria -- Quality Assurance

New Tradition Homes has demonstrated a strong commitment to quality assurance. They have aggressive weatherization protocols and a separate, third-party weatherization contractor to ensure that sealing is done independently of the window installers and other subcontractors. This subcontractor caulks around the house’s bottom plate and other penetrations where typical builders might not. New Tradition Homes’ enclosed crawlspace foundations have exceptional drainage, including a sloped floor with a drain and gravel underneath for optimal water management. Superintendents have pre-drywall inspection protocols that must be adhered to before construction can continue. In addition, to qualify for Northwest ENERGY

STAR® and Earth Advantage, the homes must meet prescriptive quality assurance and quality control protocols. As a result of these practices, New Tradition has very few call backs.

One area of quality control that New Tradition has exceptional control over is their HVAC installation. The long-term relationship they have with their HVAC subcontractor, Area Heating, and the high quality of their installations have allowed HVAC system call backs to avoid the Top-Ten call back categories.

Based on this information, New Tradition Homes’ Landover Commons community passes the Quality Assurance “Should Meet” criteria.

Quadrant - Community Overview BP1 (2008)

Weyerhaeuser Real Estate Company (WRECO) is the fifteenth largest homebuilding company in the United States. It was formed in 1969 and is composed of six separate homebuilding companies that operate in different regions of the United States: [Maracay Homes](#) (Arizona), [Winchester Homes](#) (Maryland and Virginia), [Pardee Homes](#) (California and Nevada), [Trendmaker Homes](#) (Texas), and [Quadrant Homes](#) (Washington). These homebuilders operate

with their own brands and local marketing strategies.

Quadrant Homes began building houses and residential communities in the Seattle area in 1960. In its early years, it built between 150 and 200 houses annually. In 2003, Quadrant sold over 1,000 houses, producing over \$250 million in revenue. Within its industry, the company is in the top percentile of net income as a percent of revenue. Quadrant Homes uses a 54-day lean building process to maintain their position as the largest builder in the Puget Sound region.

The community that will be described in this case study is Quadrant's Kentlake Highlands community located in Kent, Washington. The city is located in Building America's Marine Climate Zone and experiences average annual precipitation of 39.4 inches, 4,834 annual heating degree days, and 154 annual cooling degree days. This climate provides the greatest opportunity for energy savings from reductions in space heating loads.

Kentlake Highlands is a representative Quadrant Homes community, consisting of homes built specifically to homeowners' needs. When complete, Kentlake Highlands will feature over 300 homes, at least ten of which will be built with Quadrant's "Energy Sound" package, which brings the homes to the federal tax credit level. It is also important to note that all of Quadrant's homes are built with a tight envelope and feature the furnace and ducts inside conditioned space. This provides significant energy savings for the heating load compared to standard homes in the region. The two-story, four bedroom homes are built with R21, 2x6, 16"o.c. construction, priced in the high \$200,000s, and are generally targeted at middle-class homeowners or first time buyers looking for a high quality home. The community is provided electricity and gas by Puget Sound Energy.

This case study will show that the Kentlake Highlands community meets Building America's 40% initial communities goal for the Marine Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria.

For more information on the Kentlake Highlands community, contact Tien Peng, Director of Design, (425) 646-8371, Tien.Peng@QuadrantHomes.com or visit the Quadrant Homes website, www.QuadrantHomes.com.

"Must Meet" Gate Criteria -- Source Energy Savings

Using BEopt 0.8.6, an energy analysis was performed on Quadrant's Olympic 2011 floor plan. (Floor plans and elevations can be found in the task report.) The Olympic 2011 plan is a two-story house representative of a typical Quadrant house in Washington, with 2,082 square feet of finished floor area, four bedrooms, and two and a half bathrooms. The plan was modeled as an Energy Sound house, an option package offered by Quadrant that achieves the federal tax credit level. Two separate simulations were run, one with the BA Benchmark as the reference

house, and one with a Washington code house as the reference house. All four cardinal orientations were simulated for both reference homes. Table 169: Source Energy Savings for the Olympic 2011 Floor Plan

summarizes the findings of both simulations. The energy savings for Olympic 2011 are averaged over all four orientations and grouped into five main end-use categories.

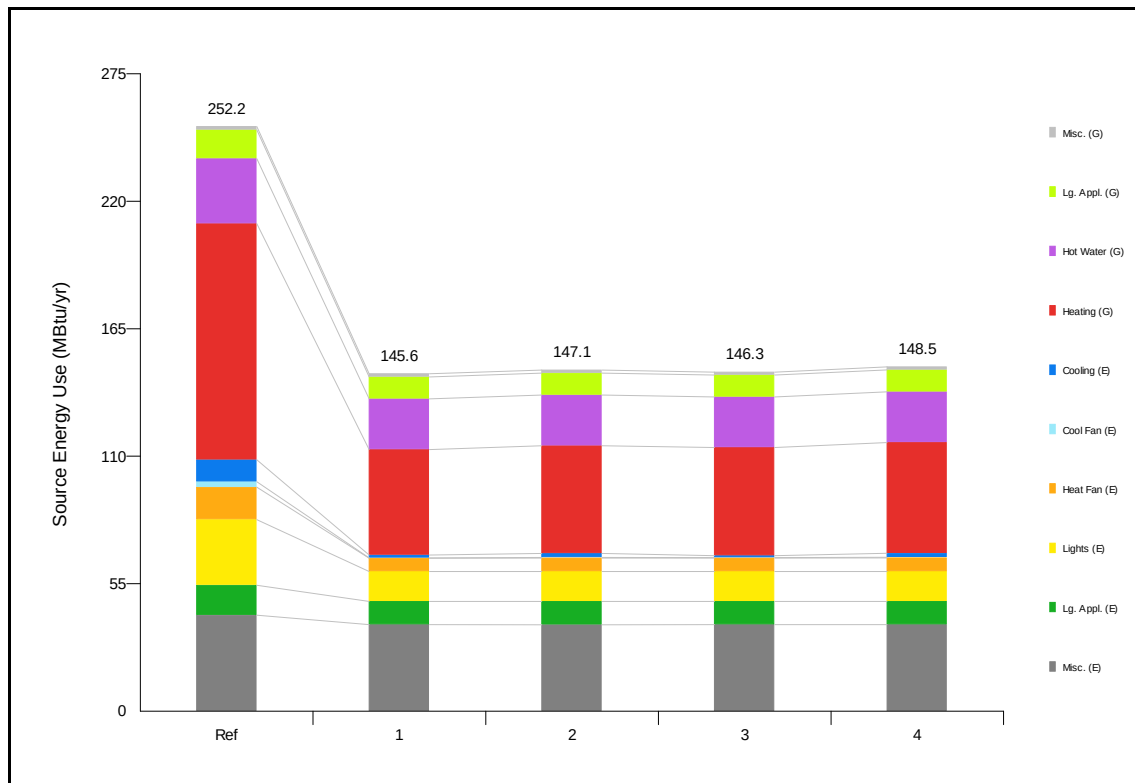


Figure 113: BEopt Source Energy Use
Olympic 2011 with the BA Benchmark as the Reference House.

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Washington Code	Olympic 2011	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	115.9	76.3	52.4	54.8%	31.3%	25.2%	11.8%
Space Cooling	11.9	2.0	1.6	86.2%	19.4%	4.1%	0.2%
DHW	28.0	25.6	21.8	22.0%	14.7%	2.4%	1.9%
Lighting	28.4	28.4	12.9	54.5%	54.5%	6.1%	7.6%
Appliances and MELs	68.1	70.5	58.1	14.7%	17.6%	4.0%	6.1%
Total Usage/ Savings	252.2	202.8	146.9	41.7%	27.5%	41.7%	27.5%

Table 169: Source Energy Savings for the Olympic 2011 Floor Plan

As shown in Table 169: Source Energy Savings for the Olympic 2011 Floor Plan

a typical Quadrant house with the federal tax credit package meets the Building America goal of 40% energy savings in the Marine Climate Zone with respect to the BA Benchmark. The critical above-code energy reduction features implemented in order to reach this goal are as follows:

- ENERGY STAR® refrigerator, dishwasher, and clothes washer
- 50% hardwired CFL lighting
- 3.4 ACH₅₀ infiltration (typical Quadrant home)
- R49 blown-in cellulose insulation in the attic
- 94% AFUE furnace
- Ducts in conditioned space
- 0.29 U-value windows
- Gas cooking range and clothes dryer

Quadrant Homes began with the features prescribed by Northwest ENERGY STAR®. By improving upon these requirements, Quadrant was able to raise their Energy Sound homes to the federal tax credit level, which is equivalent to 40% whole house energy savings compared to the BA Benchmark. For a complete list of BEopt inputs for both the Olympic 2011 plan and the code house used as a reference house, see Appendix B of the task report.

To confirm that the energy savings produced by the BEopt simulation was correct, a similar

simulation was performed using Energy Gauge USA 2.7. In each software, a simulation was performed for a typical Washington code house, a typical Quadrant Homes code house, a Northwest ENERGY STAR® certified Quadrant Homes house, and a Quadrant Energy Sound house. A summary of this comparison can be found in Table 170: Simulation Comparison for Quadrant Homes

BEopt 0.8.6 / Energy Gauge USA 2.7

. As shown, the BEopt simulation and the Energy Gauge simulation are very comparable, both in nominal values given for energy use in MBtu/yr, as well as in the incremental percent savings. Overall, BEopt was more conservative in its estimates of both energy use and percent savings. For the Quadrant Energy Sound house in this study, both BEopt and Energy Gauge predict a savings level of at least 40% above the Building America Benchmark.

Description	Annual Source Energy			
	BEopt		Energy Gauge	
House	(MBtu/yr)	Percent Savings	(MBtu/yr)	Percent Savings
Benchmark	252.2	0.0%	244.0	0.0%
Washington Code	202.8	19.6%	195.1	20.0%
Quadrant Code	177.1	29.8%	171.8	29.6%
Quadrant Northwest ENERGY STAR	149.2	40.9%	140.8	42.3%
Quadrant Energy Sound	146.9	41.7%	138.1	43.4%

Table 170: Simulation Comparison for Quadrant Homes

BEopt 0.8.6 / Energy Gauge USA 2.7

Based on the BEopt simulation providing 41.7% energy savings compared to the BA Benchmark, Quadrant Homes' Kentlake Highlands community passes the Source Energy Savings "Must Meet" criteria.

"Must Meet" Gate Criteria -- Market Coverage

Kentlake Highlands consists of over 300 lots. Of the 242 homes currently under construction, nine of these homes feature Quadrant's Energy Sound package. This package corresponds to 40% energy efficiency savings over the Building America Benchmark as well as qualifying for the federal tax credit. By September 2008, Quadrant had ten Energy Sound homes built in the Kentlake Highlands community. As of June 2008, Quadrant had begun construction on 86 Energy Sound homes across all communities, representing 10% of all homes currently under construction.

Based on this information, Quadrant Homes' Kentlake Highlands community passes the Market Coverage "Must Meet" criteria.

"Must Meet" Gate Criteria -- Neutral Cost Target

Quadrant Homes has been able to keep its costs relatively low while implementing energy efficiency features. In addition, the 41.7% whole house energy savings provides substantial reduction in energy bills, resulting in little to no tradeoffs necessary to reach the neutral cost target. Figure 114 shows the BEopt energy cost graph for the Olympic 2011 floor plan with the BA Benchmark as the reference house. These costs are based on the current utility rates in Kent, Washington, summarized in Table 171: Current Utility rates for Kent, Washington

, and include both electric and natural gas energy sources.

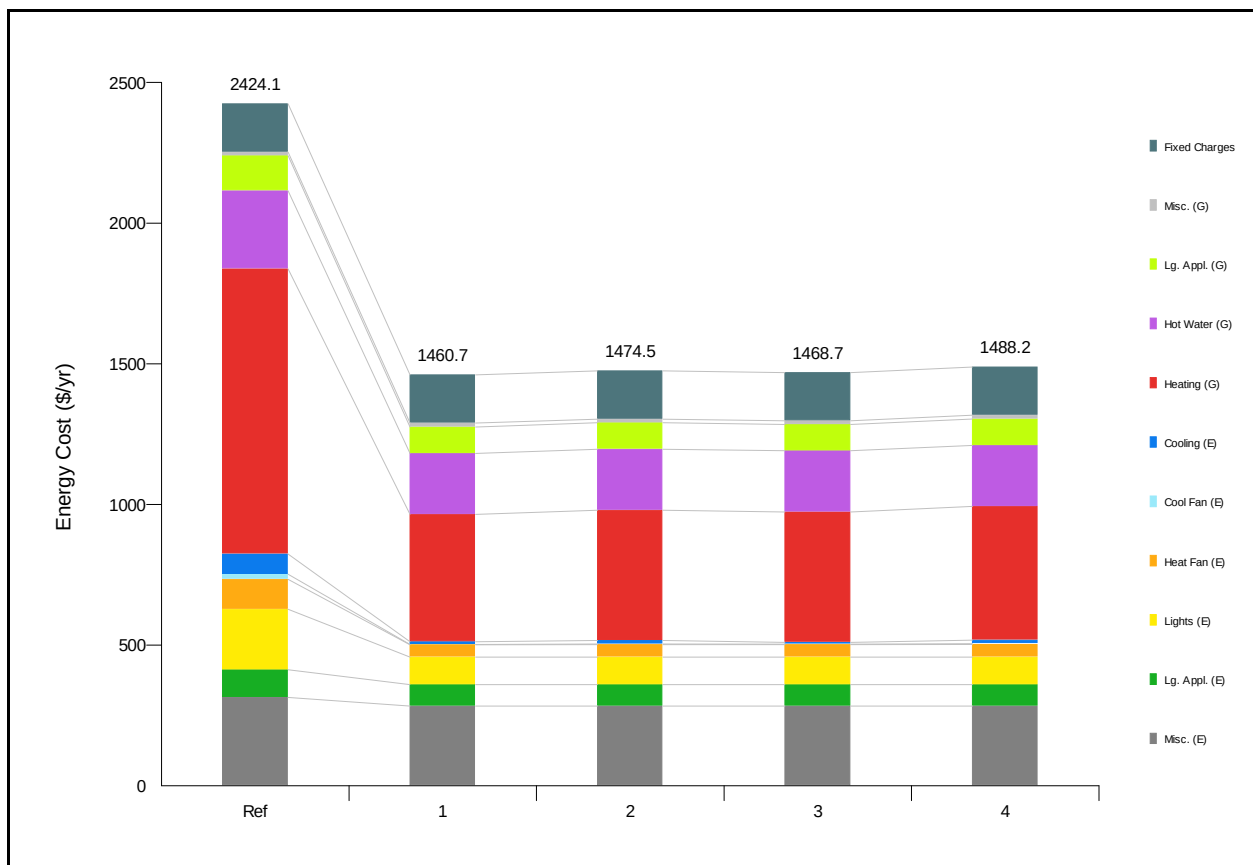


Figure 114: BEopt Energy Cost
Olympic 2011 with the BA Benchmark as the Reference House

Electricity Rate	
Utility	Puget Sound Energy

	Marginal	\$0.0872/kWh
	Fixed	\$6.02/month
Natural Gas Rate		
	Utility	Puget Sound Energy
	Marginal	\$1.0858/therm
	Fixed	\$8.25/month

Table 171: Current Utility rates for Kent, Washington

The top half of Table 172: Neutral Cost Analysis for the Olympic 2011 Floor Plan

adds a column to Table 169: Source Energy Savings for the Olympic 2011 Floor Plan

that details the annual utility bill savings of each of the five main end-use categories in comparison to the BA Benchmark. Again, these values are averaged over all four orientations. As shown in Table 172: Neutral Cost Analysis for the Olympic 2011 Floor Plan

, the annual utility bill savings according to BEopt is \$951.02. It should be noted that this includes no fluctuations in utility rates or inflation.

The bottom half of Table 172: Neutral Cost Analysis for the Olympic 2011 Floor Plan

is derived from the builder's first cost, available in Appendix D of the task report, for each of the energy efficiency features listed. The builder cost comes from a meeting between BIRA representatives and representatives from Quadrant Homes. A 10% markup is assumed and the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation is not considered. For the 0.29 U-value windows and the gas cooking range and clothes dryer, it is assumed that there are no additional costs.

In addition, ducts inside conditioned space are not considered because they are a standard feature that Quadrant includes on all of their homes. Quadrant Homes has been able to move the HVAC system into conditioned space without increasing costs. Moving ducts inside conditioned space decreases some HVAC costs by allowing shorter un-insulated duct runs and the purchase of smaller furnaces. Northwest ENERGY STAR® requires ducts outside conditioned space be sealed and tested. However, ducts inside conditioned space are not required to be tested or sealed. Quadrant Homes seals all inside duct seams and joints with tape or mastic. On ENERGY STAR® and Energy Sound (Building America) homes, all seams and joints are sealed with mastic. BIRA recommends sealing inside ducts to ensure effective delivery of conditioned air and to promote indoor air quality (IAQ).²⁵

²⁵ More information about Quadrant Homes' evolution toward moving the HVAC system inside can be found in the Builder Commitment and Gaps section of the final report..

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	Washington Code	Olympic 2011	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	115.9	76.3	52.4	54.8%	31.3%	25.2%	11.8%	\$611.57
Space Cooling	11.9	2.0	1.6	86.2%	19.4%	4.1%	0.2%	\$77.70
DHW	28.0	25.6	21.8	22.0%	14.7%	2.4%	1.9%	\$61.37
Lighting	28.4	28.4	12.9	54.5%	54.5%	6.1%	7.6%	\$117.28
Appliances and MELs	68.1	70.5	58.1	14.7%	17.6%	4.0%	6.1%	\$83.09
Total Usage/ Savings	252.2	202.8	146.9	41.7%	27.5%	41.7%	27.5%	\$951.02
					Energy Efficiency Feature			Annual Mortgage Cost
								vs. Code
					ENERGY STAR Appliances			(\$21.24)
					50% CFL Lighting			(\$10.70)
					Duct Testing and Third Party Verification			(\$31.93)
					R49 Attic Insulation			(\$28.10)
					94% AFUE Furnace			(\$67.70)
					Total Annual Mortgage Cost			(\$159.67)
					Net Annual Cash Flow to Consumer			\$791.34

Table 172: Neutral Cost Analysis for the Olympic 2011 Floor Plan

As shown in Table 172: Neutral Cost Analysis for the Olympic 2011 Floor Plan

, the net annual cash flow to the homeowner is approximately \$790. Based on this information, it is clear that the incremental annual cost of energy improvements is much less than the annual reduction in utility bill costs and Quadrant Homes' Kentlake Highlands community passes the Neutral Cost Target "Must Meet" criteria.

The above analysis does not include the \$2,000 federal tax credit that Quadrant receives for each new home they build that achieves 50% energy savings for heating and cooling over the 2004 International Energy Conservation Code (IECC). This stems from Building America's goal of finding sustainable solutions. Since the tax credit that Quadrant Homes utilizes expires at the end of 2008, it was not considered appropriate to include it here. This analysis also does not include rebates received from Puget Sound Energy for building to Northwest ENERGY STAR® standards. It is important to note, however, that the federal tax credit, along with ENERGY STAR®, provides a crucial framework and starting point for builders seeking to build energy efficiently, including Quadrant Homes.

"Should Meet" Gate Criteria -- Marketability

Quadrant Homes builds approximately 1,000 homes per year almost exclusively in the Puget Sound region. In order to build so many homes in such a short period of time, Quadrant has had to develop an extremely efficient building process that takes only 54 days from the time framing begins to the time the keys are given to the homeowner. This requires extremely careful planning with subcontractors as well as "controlled volume building." This means that Quadrant carefully monitors their resources to find the optimum number of homes to construct at one time. In addition, Quadrant markets the fact that they plan their communities far in advance to ensure the best use of resources.

With their efficient planning and building process, Quadrant markets the idea that they can provide "More House, Less Money." This refers not only to the size of the home, but also to the quality and features. Quadrant believes that because their employees do not have to constantly "reinvent the wheel" every time they build a home, they can focus on providing homeowners with the perfect home at a reduced cost. This starts with Quadrant's floor plans, which they market as functional, open, and customizable to fit anyone's needs. Next, Quadrant allows customers to visit one of their two, 12,000 square foot showrooms that allow homeowners to make selections on features ranging from carpeting to bathroom accessories. Customers can also select energy efficiency features at these showrooms, which Quadrant successfully markets as the only features that pay the customer back. After leaving the showroom, homeowners can visit Quadrant's website and log in with a secure username and password to select the features they would like to use from the comfort of their own home.

In addition, Quadrant makes sure that homeowners receive exceptional customer service throughout the course of construction. The homeowner is provided with several points of contact, including community sales managers, home mortgage consultants, and superintendents. Homeowners are also provided with a personal service representative who can help them with any problems they face after they move in. This includes managing the warranty that Quadrant provides with every home.

Based on current sales and marketing information, Quadrant Homes' Kentlake Highlands community passes the Marketability "Should Meet" criteria.

In future marketing efforts, Quadrant would like to use information from this Building America study to quantitatively show homebuyers the energy savings that their Energy Sound house provides compared to a typical Washington code house. Figure 115 and Figure 116 are example graphs that BIRA provided Quadrant Homes to help with this marketing effort. In addition, Figure 117 shows a comparison of energy cost between a Washington code house, a Quadrant code house, a Quadrant Northwest ENERGY STAR® house, and a Quadrant Energy Sound house. Figure 118 shows that not only is the Quadrant Energy Sound house cost-effective compared to the Building America Benchmark; it is also cost-effective compared to a Quadrant code house. As shown in Figure 117, the energy savings of a Quadrant Code house compared to a Washington Code house is similar to the savings provided by a Quadrant Energy Sound House compared to a Quadrant Code House. It is clear that even Quadrant's base design is a very energy efficient home. This displays the value of having a tight envelope and moving the furnace and ducts inside conditioned space.

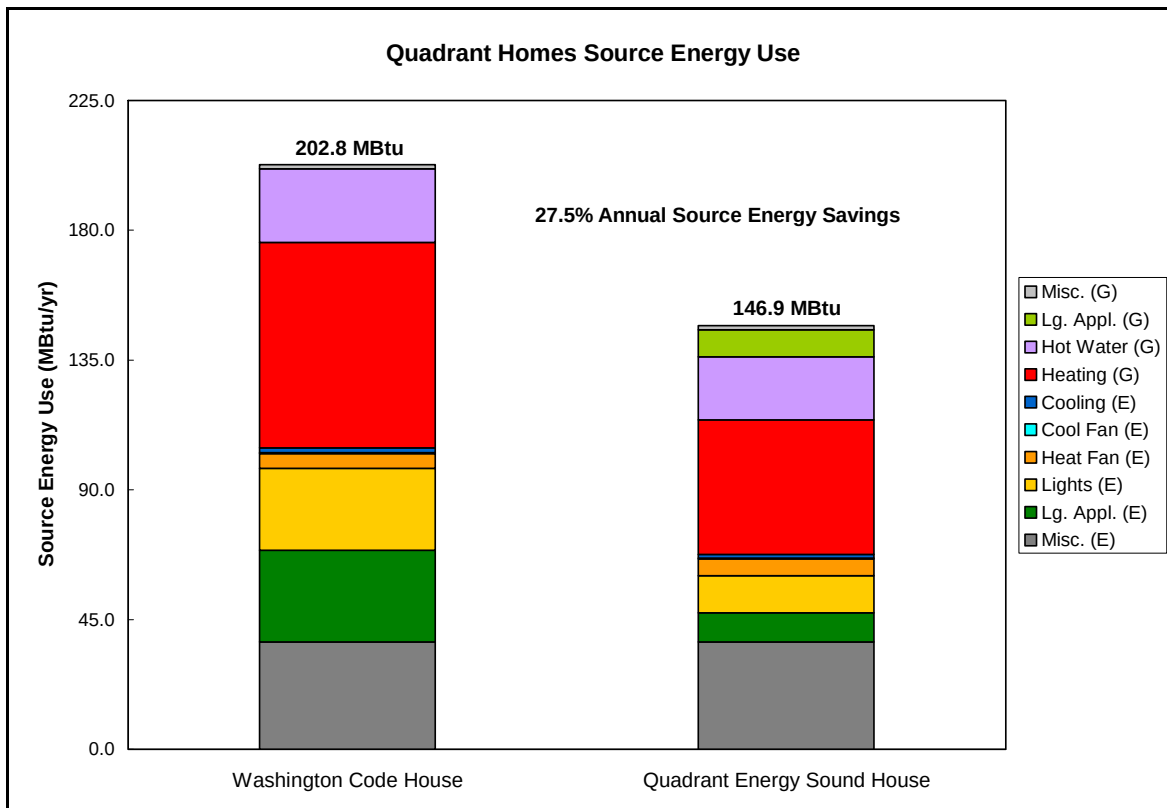


Figure 115: Source Energy Use Marketing Material for Quadrant Homes

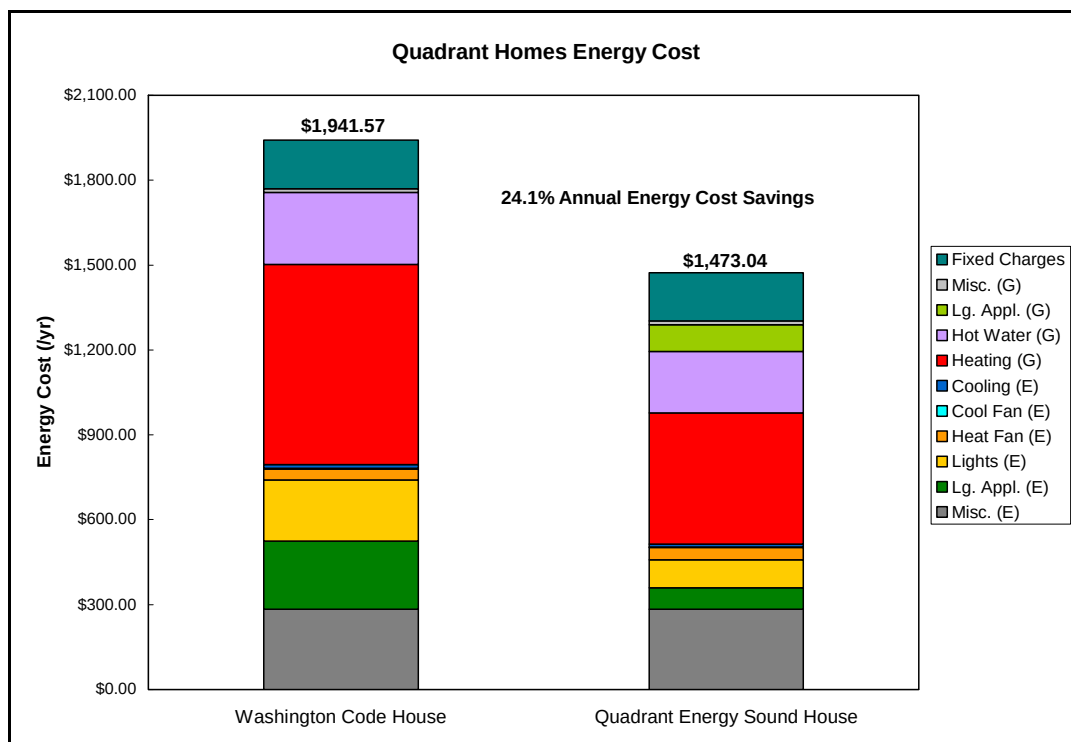


Figure 116: Energy Cost Marketing Material for Quadrant Homes

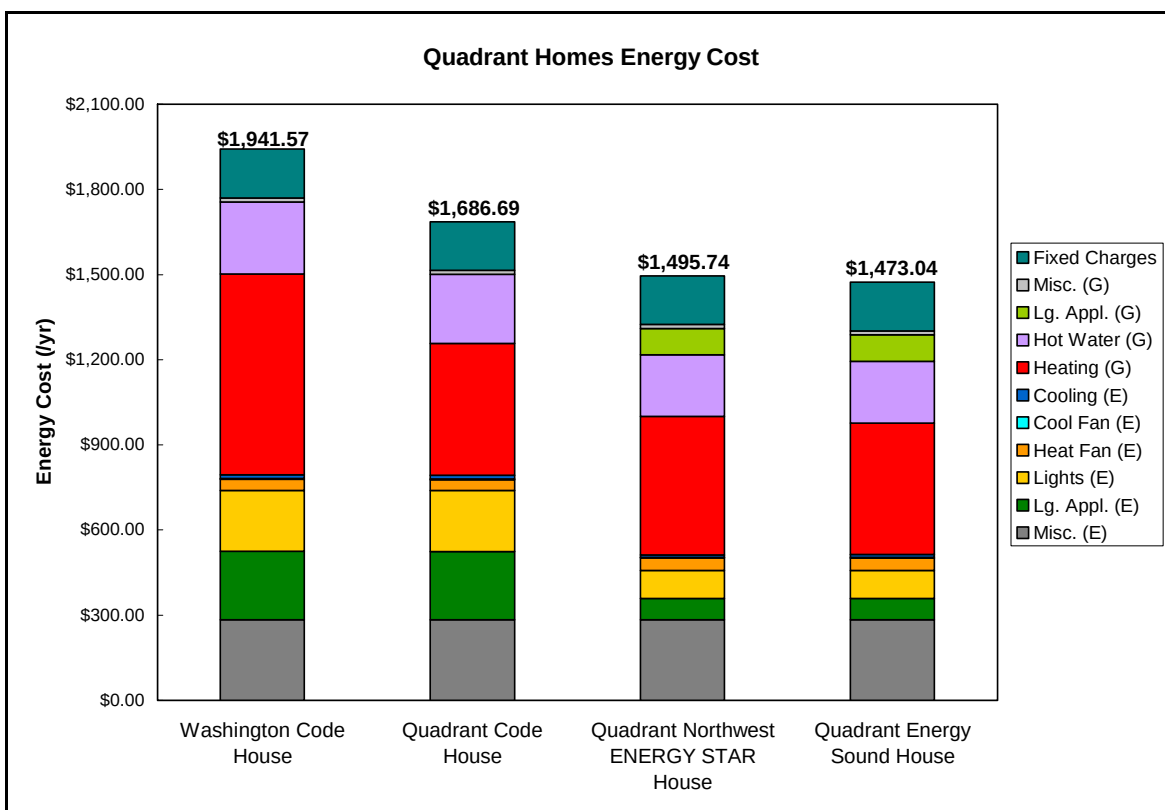


Figure 117: Energy Cost Comparison Marketing Material for Quadrant Homes

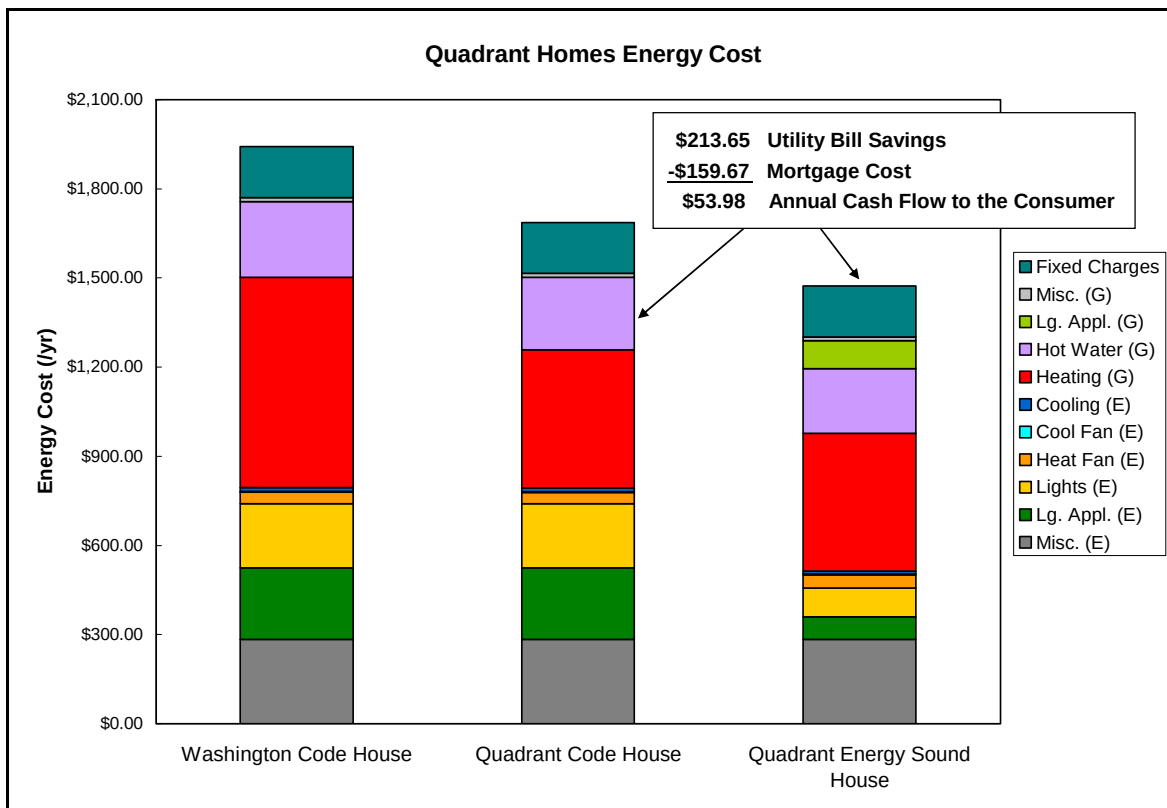


Figure 118: Cost Effectiveness Marketing Materials for Quadrant Homes

“Should Meet” Gate Criteria -- Builder Commitment

As a builder, Quadrant Homes is committed to efficient, process-driven construction. Whereas Building America is focused on a whole-building approach to energy efficiency, Quadrant Homes is focused on a whole-business approach in every decision they make. With such a well-defined construction process, Quadrant is able to focus on their high turnaround rate and financial bottom line. Any energy efficiency measure that they implement must be able to fit within this framework. In order to successfully continue to work with Quadrant Homes, BIRA must continue to work with and understand Quadrant’s business model. In order for Quadrant to continue to build to Building America standards, Building America’s values must continue to align with Quadrant’s. In addition, buyers must continue to select energy efficiency options for Quadrant to keep these options on the shelf.

One example of Quadrant’s willingness to adopt Building America practices is the process they took to bring ducts inside conditioned space for all of their 1,000 homes per year. While working with the WSU Energy Program to redesign their homes and achieve the \$2,000 federal tax credit level, it became evident to Quadrant that moving ducts inside conditioned space was the best option. Following this conclusion, Quadrant representatives met with their HVAC subcontractor, Bob’s Heating, to design a new system. Quadrant was able to bring their supply ducts within the building envelope while also putting the furnace in a mechanical closet on the

second floor. Although the return ductwork is still in the attic, the ducts have R-8 insulation and are then buried in insulation.

Quadrant was able to successfully bring ducts inside conditioned space for several reasons. One major reason was the fact that Quadrant was already using open-web trusses between the first and second floors. Although slightly more expensive, open-web trusses allow streamlined construction when buyers choose optional floor plans that require longer truss spans. In addition, they provide ample room for plumbing, electrical, and ductwork without trade fighting or trade damage. It also increases quality by getting subcontractors out of the crawlspace and into a work environment that is not only easier to work in but also much more easily inspected. In this way, bringing ducts inside conditioned space was a move that not only made sense in energy efficiency, but also in terms of Quadrant's business model.

Other factors contributing to the success of Quadrant bringing ducts inside conditioned space include their dedicated subcontractor, Bob's Heating, and Quadrant's direct involvement in the redesign. Since Quadrant decided to make this feature standard, they have been able to standardize their methods and implement them even more effectively. If Quadrant can be shown the all-around benefits of energy efficiency measures, it is clear that they will take the steps necessary to implement these features into their designs.

Based on this builder's proactive energy efficiency practices at the Kentlake Highlands community, Quadrant Homes passes the Builder Commitment "Should Meet" criteria.

"Should Meet" Gate Criteria -- Gaps Analysis

Quadrant currently has several issues that it is attempting to address. In all of their homes, Quadrant has brought the furnace inside a mechanical closet on the second floor. This closet is built to outside-space code requirements with insulated walls and a weather-stripped door. This design is required to accommodate an 80% AFUE furnace with non-direct venting (the standard furnace Quadrant offers). However, this insulation is not required when the homeowner opts to upgrade to a 90+% AFUE furnace (Northwest ENERGY STAR®), but it is installed nonetheless as a part of Quadrant's uniform 54-day build-out schedule. This is an additional cost that Quadrant is unnecessarily incurring due to their streamlined construction process. WSU and ConSol has been working with Quadrant to encourage them to upgrade all their homes with 90+ furnaces at an approximate incremental cost of \$770 per home. This cost includes the furnace, labor, pump and plumbing required for the condensate drain. The cost of building the mechanical closet to outside code specifications is significantly less than the \$770 per home to improve the furnace but this number would "buy-down" the cost of the improved furnace. Beyond cost, Quadrant has yet to make this wholesale change because their marketing approach is centered around upgraded features. An improved furnace would be a significant upgrade in standard equipment.

Quadrant Homes uses open-web trusses between floors in all of their 2-story homes. This

allows plenty of room to bring supply ducts inside conditioned space and also accommodates for other trades' work, such as plumbing. Quadrant did run into an issue while implementing this design that involved the placement of insulation. According to Washington code, insulation must be in contact with the surface it is insulating. In Quadrant's design, insulation between the conditioned bonus room and the garage sometimes wraps around the ducts and other objects in the open-web trusses, resulting in a code violation. WSU Energy Program staff is currently working to identify both air sealing details and code language prohibitions to this approach.

Another issue Quadrant faced involved moving the furnace into conditioned space. When the mechanical room was being built, the furnace was installed before the drywall was completed. This caused an issue for the drywall installers who had to work around the furnace. Instead, the drywall coordination was done with the water heater installation. In future efforts, Quadrant will work with their subcontractors to install both the furnace and the water heater after the drywall has been completely installed.

A very important issue that Quadrant Homes faced involved the federal tax credit. As Quadrant Homes continued to refine their building process, they discovered that implementing energy efficiency measures as standard features was more cost-effective than implementing them as options (as with bringing ducts inside conditioned space). Realizing this, Quadrant considered building all of their homes to the Energy Sound level. This would result in approximately 1,000 homes per year being built at the 40% level in the Marine Climate Zone. Two problems arose with this scenario:

- In current Energy Sound homes, Quadrant has to pay the costs to implement the advanced features, including the time required to apply for the federal tax credit, but Weyerhaeuser receives the tax credit. This provides little to no incentive for Quadrant to convert all of their homes to Energy Sound.
- Even if Quadrant did see the tax credit themselves, they would incur the costs in one year and not receive the tax credit until the following year. This results in additional carrying costs for Quadrant.

Based on these issues, Quadrant Homes made the decision to keep the Energy Sound package as an option, rather than part of their standard package. BIRA has seen this issue with several large builders and feels strongly that this market barrier must be addressed.

"Should Meet" Gate Criteria -- Quality Assurance

With Quadrant Homes' extremely fast construction process, it would be very easy for problems to arise if they didn't have strict quality control protocols. These protocols include all of Building America's quality control protocols as well as the protocols specified by Northwest ENERGY STAR®. All subcontractor coordination and scheduling is done through the central office. Because of this, the superintendent's main focus is to ensure that schedules are kept and that Quadrant's quality control protocols are followed.

Quality assurance occurs after the home is complete and is performed by a representative of the State Certifying Organization (SCO) from the WSU Energy Program. WSU samples between 5% and 10% of homes for quality assurance. The following tasks are performed for quality assurance: blower door test; duct blaster test; verification of fluorescent lighting; confirmation of window and insulation values; and checking of the furnace, water heater, and dishwasher for compliance.

Based on this information, Quadrant Homes' Kentlake Highlands community passes the Quality Assurance "Should Meet" criteria.

Ruhoff Homes BP1 (2008)

Community Overview

Ruhoff Home Builders was founded in 1998 by Chad and Katy Ruhoff. Aaron Solbeck is their Construction Manager and Jason Bosch serves as their Field Superintendent. Chad Ruhoff followed in the footsteps of his father, also a homebuilder, who retired in 1997. The small company has built over 100 homes in the Eugene, Oregon area, building about 50% custom homes and 50% speculative projects. Chad Ruhoff is extremely well-versed in building quality, high-performance homes and believes that keeping potential homebuyers informed on energy efficiency measures is extremely important.

The community described in this case study is Crescent Village, located in Eugene, Oregon. The city is located in Building America's Marine Climate Zone and experiences average annual precipitation of 49.4 inches, 4,505 annual heating degree days, and 248 annual cooling degree days. This climate provides the greatest opportunity for energy savings from reductions in space heating loads.

Crescent Village, designated Eugene's first "urban village," was designed using the concept of New Urbanism, featuring mixed housing, shops, restaurants, and a town center. The project is the ninth largest construction project in the state of Oregon. Ruhoff Home Builders took part in building a portion of the community consisting of single-family, detached homes. The first phase of construction, set to be complete this year, will consist of 24 townhomes, all of which meet the federal tax credit standards. The three-story, three bedroom homes are built with R23 BIBS, 2x6, 24" o.c. panelized walls, priced between \$470,000 and \$550,000, and are generally targeted at middle-class homeowners or first time buyers looking for a high quality home. The homes feature ducts inside conditioned space through the use of open-web trusses. The community is provided electricity through the Eugene Water and Electric Board and gas through Northwest Natural.

This case study will show that the Crescent Village community meets Building America's 40% initial communities goal for the Marine Climate Zone while addressing all of Stage Gate 3 "Must Meet" and "Should Meet" criteria.

For more information on the Crescent Village community, contact Chad Ruhoff, Owner, Ruhoff Home Builders, Chad@RuhoffHomeBuilders.com or visit the Ruhoff Home Builders website, www.RuhoffHomeBuilders.com.

“Must Meet” Gate Criteria -- Source Energy Savings

Using BEopt 0.8.6, an energy analysis was performed on Ruhoff’s Fidalgo Townhome floor plan. Floor plans and elevations can be found in Appendix A of the task report. The Fidalgo Townhome plan is a three-story house representative of a typical Ruhoff house in Crescent Village, with 2,350 square feet of finished floor area, three bedrooms, and two and a half bathrooms. The plan was modeled as a federal tax credit home, a standard package at Crescent Village. Two separate simulations were run, one with the BA Benchmark as the reference house, and one with an Oregon code house as the reference house. Figure 119 shows the BEopt source energy use graph for the Fidalgo Townhome floor plan with the BA Benchmark as the reference house. Since all of the homes in the Crescent Village community have the garage on the east side of the home, this was the only orientation simulated. Table 173: Source Energy Savings for the Fidalgo Townhome Floor Plan

summarizes the findings of both simulations. The energy savings for Fidalgo Townhome are grouped into five main end-use categories.

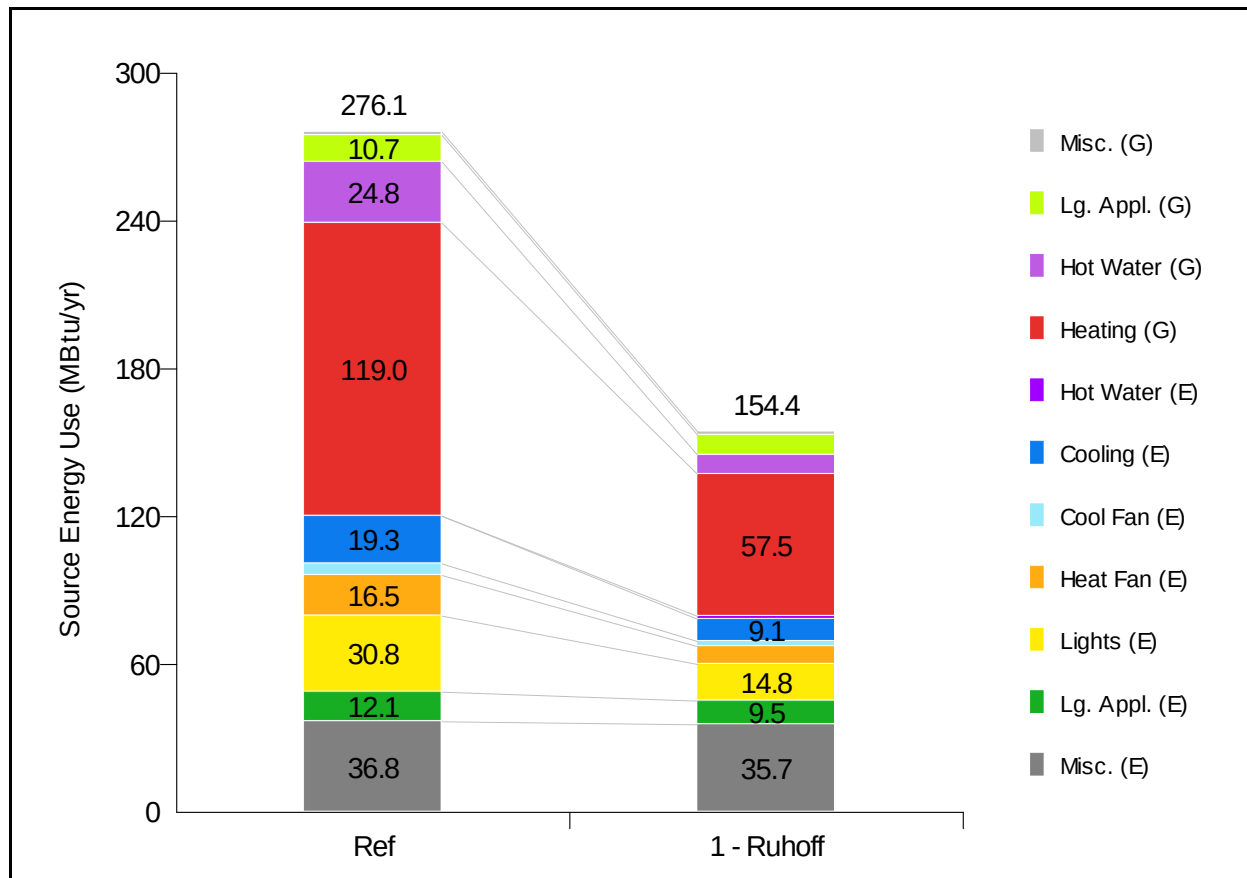


Figure 119: BEopt Source Energy Use
Fidalgo Townhome with the BA Benchmark as the Reference House

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Oregon Code	Fidalgo Townhome	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	135.5	116.8	64.7	52.3%	44.6%	25.6%	22.2%
Space Cooling	24.0	12.2	11.2	53.3%	0.4%	4.6%	0.4%
DHW	24.8	20.3	9.1	63.3%	55.2%	5.7%	4.8%
Lighting	30.8	30.8	14.8	52.0%	52.0%	5.8%	6.8%
Appliances and MELs	61.0	54.5	54.6	10.6%	-0.2%	2.3%	0.0%
Total Usage/ Savings	276.1	234.6	154.4	44.1%	34.2%	44.1%	34.2%

Table 173: Source Energy Savings for the Fidalgo Townhome Floor Plan

As shown in Table 173: Source Energy Savings for the Fidalgo Townhome Floor Plan

, a typical Ruhoff house with the federal tax credit package meets the Building America goal of 40% energy savings in the Marine Climate Zone with respect to the BA Benchmark. The critical above code energy reduction features implemented in order to reach this goal are as follows:

- ENERGY STAR® refrigerator, dishwasher, and clothes washer
- 50% hardwired CFL lighting
- R40 blown-in cellulose insulation in the attic
- 3.8 ACH₅₀ infiltration (typical Ruhoff home)
- 64 sq. ft. closed loop solar DHW
- 94% AFUE furnace
- R37 crawl space ceiling
- R23 BIBS, 2x6, 24" o.c. walls
- Ducts in conditioned space
- SEER 14 air conditioner
- 0.32 U-value windows
- Gas cooking range and clothes dryer

Ruhoff Home Builders began with the features prescribed by Northwest ENERGY STAR®. By improving on these requirements, Ruhoff was able to raise their homes to the federal tax credit level, which is also equivalent to 40% whole house energy savings when compared to the BA Benchmark.

Based on the BEopt simulation providing 44.1% energy savings compared to the BA Benchmark,

Ruhoff Home Builders' Crescent Village community passes the Source Energy Savings "Must Meet" criteria.

"Must Meet" Gate Criteria -- Market Coverage

Ruhoff Home Builders will be completing 24 Crescent Village homes in this year's phase of construction. Currently, at least 16 of these homes are built, with at least eight sold and occupied. All 24 of these homes will meet the 40% source energy savings level. Based on this information, Ruhoff Home Builders' Crescent Village community passes the Market Coverage "Must Meet" criteria.

"Must Meet" Gate Criteria -- Neutral Cost Target

Ruhoff Home Builders has been able to keep its costs relatively low while implementing energy efficiency features. In addition, the 44.1% whole house energy savings provides substantial reduction in energy bills, resulting in little to no tradeoffs necessary to reach the neutral cost target. Figure 120 shows the BEopt energy cost graph for the Fidalgo Townhome floor plan with the BA Benchmark as the reference house. These costs are based on the current utility rates in Eugene, Oregon, summarized in Table 174: Current Utility rates for Eugene, Oregon

, and include both electric and natural gas energy sources.

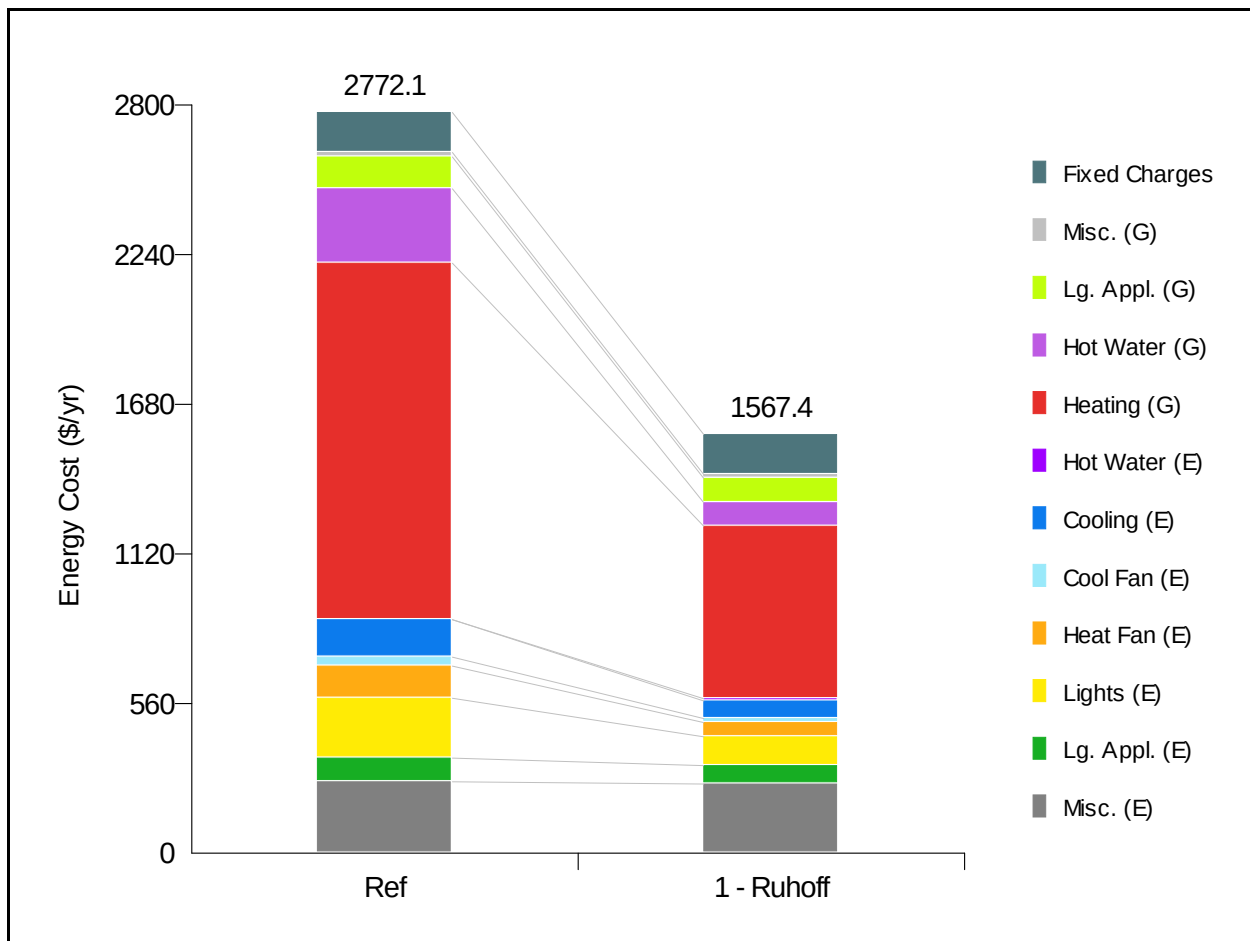


Figure 120: BEopt Energy Cost
Fidalgo Townhome with the BA Benchmark as the Reference House

Electricity Rate		
	Utility	Eugene Water and Electric Board
	Marginal	\$0.0835/kWh
	Fixed	\$6.50/month
Natural Gas Rate		
	Utility	Northwest Natural
	Marginal	\$1.2245/therm
	Fixed	\$6.00/month

Table 174: Current Utility rates for Eugene, Oregon

The top half of Table 175: Neutral Cost Analysis for the Fidalgo Townhome Floor Plan
 adds a column to Table 173: Source Energy Savings for the Fidalgo Townhome Floor Plan
 that details the annual utility bill savings of each of the five main end use categories in

comparison to the BA Benchmark. As shown in Table 175: Neutral Cost Analysis for the Fidalgo Townhome Floor Plan

, the annual utility bill savings according to BEopt is \$1,204.69. It should be noted that this includes no fluctuations in utility rates or inflation.

The bottom half of Table 175: Neutral Cost Analysis for the Fidalgo Townhome Floor Plan

is derived from the builder's first cost, detailed in Appendix D of the task report, for each of the energy efficiency features listed. The builder cost comes from a meeting between BIRA representatives and representatives from Ruhoff Home Builders. A 10% markup is assumed and the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation is not considered. For the 0.32 U-value windows and the gas cooking range and dryer, it is assumed that there is no additional cost.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	Oregon Code	Fidalgo Townhome	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	135.5	116.8	64.7	52.3%	44.6%	25.6%	22.2%	\$757.16
Space Cooling	24.0	12.2	11.2	53.3%	0.4%	4.6%	0.4%	\$92.87
DHW	24.8	20.3	9.1	63.3%	55.2%	5.7%	4.8%	\$180.46
Lighting	30.8	30.8	14.8	52.0%	52.0%	5.8%	6.8%	\$116.65
Appliances and MELs	61.0	54.5	54.6	10.6%	-0.2%	2.3%	0.0%	\$57.55
Total Usage/ Savings	276.1	234.6	154.4	44.1%	34.2%	44.1%	34.2%	\$1,204.69
					Energy Efficiency Feature		Annual Mortgage Cost	
							vs. Code	
					ENERGY STAR Appliances		(\$21.08)	
					50% CFL Lighting		(\$10.54)	
					R40 Attic Insulation (Vaulted)		(\$28.10)	
					Improved Duct Sealing, Envelope Sealing, and Testing		(\$105.38)	
					64 sq. ft. Closed Loop Solar DHW		(\$570.83)	
					94% AFUE Furnace		(\$70.26)	
					R37 Crawl Space Ceiling		(\$8.78)	
					R23 BIBS, 2x6, 24"o.c.		(\$70.26)	
					Total Annual Mortgage Cost		(\$885.22)	
					Net Annual Cash Flow to Consumer		\$319.47	

Table 175: Neutral Cost Analysis for the Fidalgo Townhome Floor Plan

As shown in Table 175: Neutral Cost Analysis for the Fidalgo Townhome Floor Plan

, the net annual cash flow to the homeowner is approximately \$319. Based on this information, it is clear that the incremental annual cost of energy improvements is much less than the annual reduction in utility bill costs and Ruhoff Home Builders' Crescent Village community passes the Neutral Cost Target "Must Meet" criteria.

The above analysis does not include the \$2,000 federal tax credit that Ruhoff receives for each new home they build that achieves 50% energy savings for heating and cooling over the 2004 International Energy Conservation Code (IECC). This stems from Building America's goal of finding sustainable solutions. Since the tax credit that Ruhoff Home Builders utilizes expires at the end of 2008, it was not considered appropriate to include it here. The analysis also does not include incentives that Ruhoff receives from the Energy Trust of Oregon and the ODOE. It is important to note, however, that the federal tax credit, Northwest ENERGY STAR®, and other incentive programs provide a crucial framework and starting point for builders seeking to build energy efficiently, including Ruhoff Home Builders.

"Should Meet" Gate Criteria --Marketability

Ruhoff Home Builders has taken several different steps to keep the homes in Crescent Village marketable. Their ultimate goal is to make sure that potential buyers are well-informed on energy efficiency measures. Most potential buyers do not know about these features until the builder or realtor informs them, but Chad Ruhoff says that once they know, buyers are impressed by these features and value them. This fact is very important with the current state of the market.

One way that Ruhoff informs potential buyers is through the use of flyers, signs, and informational plaques in model homes at Crescent Village. In addition, features such as low U-value windows are labeled and their benefits are explained. Based on current sales and marketing information, Ruhoff Home Builders' Crescent Village community passes the Marketability "Should Meet" criteria.

In future marketing efforts using information from this Building America study, Ruhoff Home Builders would like to quantitatively show homebuyers the energy savings that their house provides compared to a typical Oregon code house. Figure 121 and Figure 122 are example graphs that BIRA provided Ruhoff Home Builders in order to help with this marketing effort.

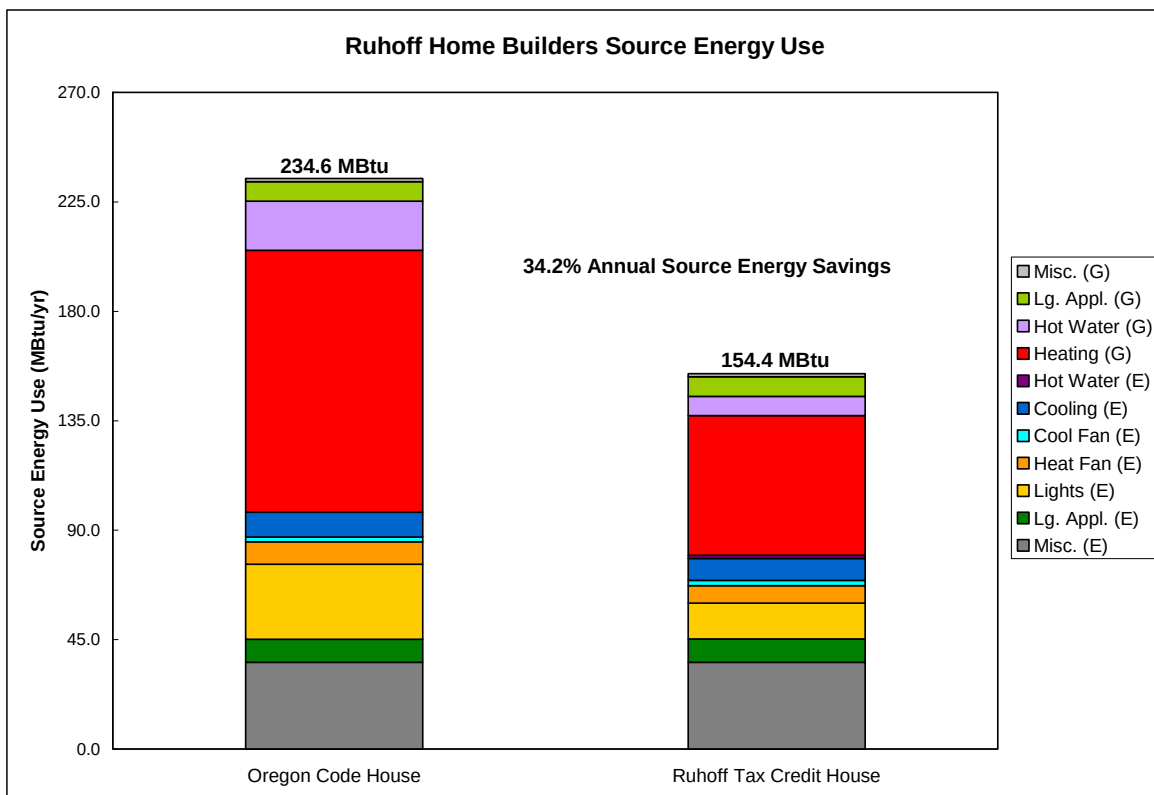


Figure 121: Source Energy Use Marketing Material for Ruhoff Home Builders

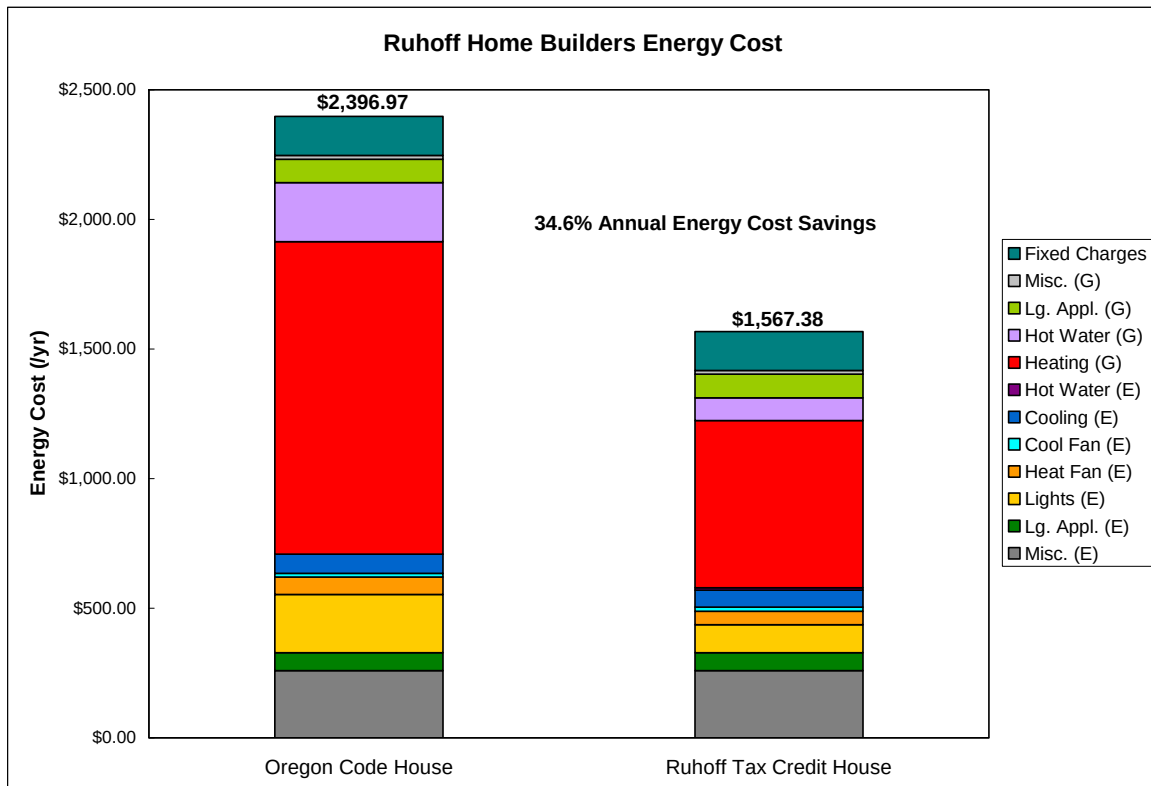


Figure 122: Energy Cost Marketing Material for Ruhoff Home Builders

“Should Meet” Gate Criteria -- Builder Commitment

Chad Ruhoff is completely committed to building homes to current and future Building America levels. Ruhoff recognizes that his company has five areas that it does exceedingly well and that contribute to their green building practices. These areas include energy efficiency (ENERGY STAR®, ductwork leakage, envelope leakage, energy efficient windows, and solar installations), healthy indoor air quality, right-sizing of HVAC equipment, durability, and environmentally-responsible products and practices. In addition, Ruhoff Home Builders actively works to reduce construction waste and recycle as much as possible. Chad Ruhoff realizes that these practices have upfront costs, but he also understands that these costs will be recouped through utility bill savings.

Ultimately, if Chad Ruhoff can convey his knowledge and commitment to the rest of his employees and subcontractors, Ruhoff Home Builders will continue to be a successful Building America partner. Based on this builder’s proactive energy efficiency practices at the Crescent Village community, Ruhoff Home Builders passes the Builder Commitment “Should Meet” criteria.

“Should Meet” Gate Criteria -- Gaps Analysis

Ruhoff Home Builders currently constructs their homes using panelized, 2x6, 24” o.c. walls. These walls have R23 BIBS insulation and are covered in 1/2” OSB, Tyvek housewrap, and a three-coat stucco system. Already a very good wall system, Chad Ruhoff says they are looking to improve. One way of doing this is by adding external foam insulation over the OSB, but Chad says they are nervous about water issues between the foam and the rest of the wall system. BIRA is looking to leverage our relationship with another builder, Schneider Family Homes, to help teach builders such as Ruhoff how external foam insulation can be installed successfully in the Marine Climate Zone. Schneider Family Homes has already successfully implemented external foam on a community they built in Washington.

Ruhoff has also experienced issues with quality installation of insulation. Although not seen as a very desirable task, properly installed insulation is a key component of any energy efficient home. Chad Ruhoff believes that site supervision for this task is extremely important.

Another issue affecting Ruhoff Home Builders is the 2008 expiration of the \$2,000 federal tax credit they received for each of the homes in Crescent Village. Although policymakers are currently being lobbied to extend this tax credit, the uncertainty causes problems. Many Northwest builders feel that they cannot count on tax credits such as these and build energy efficiently for other reasons. However, incentives such as the federal tax credit can entice builders that wouldn’t normally change their building practices to do so.

“Should Meet” Gate Criteria -- Quality Assurance

Ruhoff Home Builders take several steps to ensure that quality homes are built in Crescent Village. All superintendents are provided air sealing training. Part of this training involves making sure that subcontractors do not drill excessive holes in the OSB on external walls. Ruhoff also provides training on their special window flashing protocols using Wet-Flash. Chad Ruhoff believes that it is important to help subcontractors understand the importance of building practices such as these, rather than just providing unqualified rules. In addition, Ruhoff Home Builders generally uses subcontractors at Crescent Village that they have successfully used on past projects and have already learned Ruhoff’s preferred practices.

Just in case subcontractors decide not to follow the correct building practices, the Construction Manager is on-site every day. Not only does he help subcontractors by providing training and guidance, he also attends quality assurance and energy training himself on a regular basis.

Lastly, the Parr panelized wall system used to frame the homes in Crescent Village provides an extra level of quality assurance. The walls are prefabricated before arriving on-site and fit together extremely well. In addition, using this system allows framing time to be reduced to only nine days.

Based on this information, Ruhoff Home Builders' Crescent Village community passes the Quality Assurance "Should Meet" criteria.

Schneider Family Homes BP1 (2008)

Community Overview

Schneider Family Homes was founded in 1974 and continues to be family owned and operated. Many of their on-site supervisors are senior project managers that have been with the company for years. Although Schneider focuses on the greater Seattle area, they also have communities in Oregon and other parts of Washington. All of their current and future communities are Northwest ENERGY STAR® certified and the community studied is Built Green certified as well. Schneider Family Homes is especially interested in energy efficiency programs that can provide value to them through marketing efforts. Schneider's main focus is to provide the most house and the best value for the price while also providing exceptional customer service.

This case study will examine Schneider's Village at Miller's Creek community located in Burien, Washington. The city is located in Building America's Marine Climate Zone and experiences average annual precipitation of 37.2 inches, 4,834 annual heating degree days, and 154 annual cooling degree days. This climate provides the greatest opportunity for energy savings from reductions in space heating loads.

Village at Miller's Creek is a gated community with homes designed to resemble European townhomes. It consists of 37 completed homes, 28 of which meet the federal tax credit standards. The two-story, three bedroom homes are built with R23 BIBS, 2x6, 24" o.c. construction, priced in the mid \$300,000's, and are generally targeted at middle class homeowners or first time buyers looking for a high quality home. The community is provided electricity and gas by Puget Sound Energy.

This case study will show that the Village at Miller's Creek community meets Building America's 40% initial communities goal for the Marine Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria.

For more information on the Village at Miller's Creek community, contact Tom Balderston, Building Performance Consultant, Conservation Services Group, Tom.Balderston@csgroup.com or visit the Schneider Family Homes website, www.SchneiderHomes.com.

"Must Meet" Gate Criteria -- Source Energy Savings

Using BEopt 0.8.6, an energy analysis was performed on Schneider's E381 floor plan. Floor plans and elevations can be found in Appendix A of the task report. The E381 plan is a two-story house representative of a typical Schneider house in Washington, with 2,019 square feet of finished floor area, three bedrooms, and two and a half bathrooms. The plan was modeled as a

federal tax credit home, a standard package at Village at Miller's Creek. Two separate simulations were run, one with the BA Benchmark as the reference house, and one with a Washington code house as the reference house. Figure 123 shows the BEopt source energy use graph for the E381 floor plan with the BA Benchmark as the reference house. All four cardinal orientations were simulated for both reference homes. Table 176: Source Energy Savings for the E381 Floor Plan

summarizes the findings of both simulations. The energy savings for E381 are averaged over all four orientations and grouped into five main end-use categories.

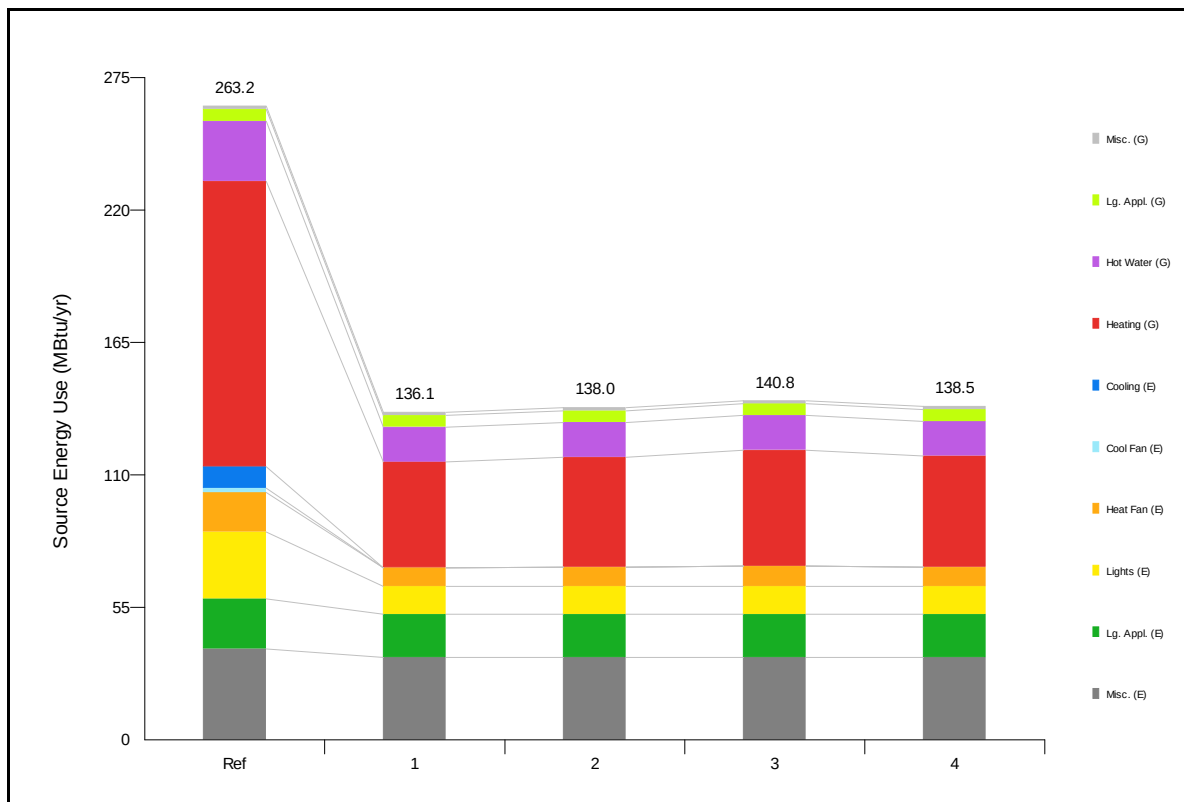


Figure 123: BEopt Source Energy Use
E381 with the BA Benchmark as the Reference House

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Washington Code	E381	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	134.8	99.0	54.0	59.9%	45.5%	30.7%	21.1%
Space Cooling	10.7	0.0	0.0	100.0%	0.0%	4.1%	0.0%
DHW	25.1	22.8	14.4	42.5%	36.9%	4.0%	3.9%
Lighting	27.8	27.8	11.6	58.3%	58.3%	6.2%	7.6%
Appliances and MELs	64.8	63.9	58.3	10.0%	8.6%	2.5%	2.6%
Total Usage/ Savings	263.2	213.5	138.3	47.4%	35.2%	47.4%	35.2%

Table 176: Source Energy Savings for the E381 Floor Plan

As shown in Table 176: Source Energy Savings for the E381 Floor Plan

, a typical Schneider house with the federal tax credit package meets the Building America goal of 40% energy savings in the Marine Climate Zone with respect to the BA Benchmark. The critical above-code energy reduction features implemented in order to reach this goal are as follows:

- ENERGY STAR® refrigerator, dishwasher, and clothes washer
- 80% hardwired CFL lighting
- R40 blown-in cellulose insulation in the attic
- 4.6 ACH₅₀ infiltration (typical Schneider home)
- 81% EF gas tankless water heater
- 92.5% AFUE furnace
- Ducts in conditioned space
- R23 BIBS, 2x6, 24" o.c. walls
- 0.34 U-value windows
- Gas cooking range

Schneider Family Homes began with the features prescribed by Northwest ENERGY STAR®. By improving on these requirements, Schneider was able to raise their homes to the federal tax credit level, which is equivalent to 40% whole house energy savings compared to the BA Benchmark.

Based on the BEopt simulation providing 47.4% energy savings compared to the BA Benchmark, Schneider Family Homes' Village at Miller's Creek community passes the Source Energy Savings "Must Meet" criteria.

"Must Meet" Gate Criteria -- Market Coverage

Village at Miller's Creek consists of 37 completed homes. Of these homes, 28 meet the 40% source energy savings level. At least 25 of the 40% homes are currently sold and occupied. Based on this information, Schneider Family Homes' Village at Miller's Creek community passes the Market Coverage "Must Meet" criteria.

"Must Meet" Gate Criteria -- Neutral Cost Target

Schneider Family Homes has been able to maintain relatively low costs while implementing energy efficiency features. In addition, the 47.4% whole house energy savings provides substantial reduction in energy bills, resulting in little to no tradeoffs necessary to reach the neutral cost target. Figure 124 shows the BEopt energy cost graph for the E381 floor plan with the BA Benchmark as the reference house. These costs are based on the current utility rates in Burien, Washington, summarized in Table 177: Current Utility Rates for Burien, Washington

, and include both electric and natural gas energy sources.

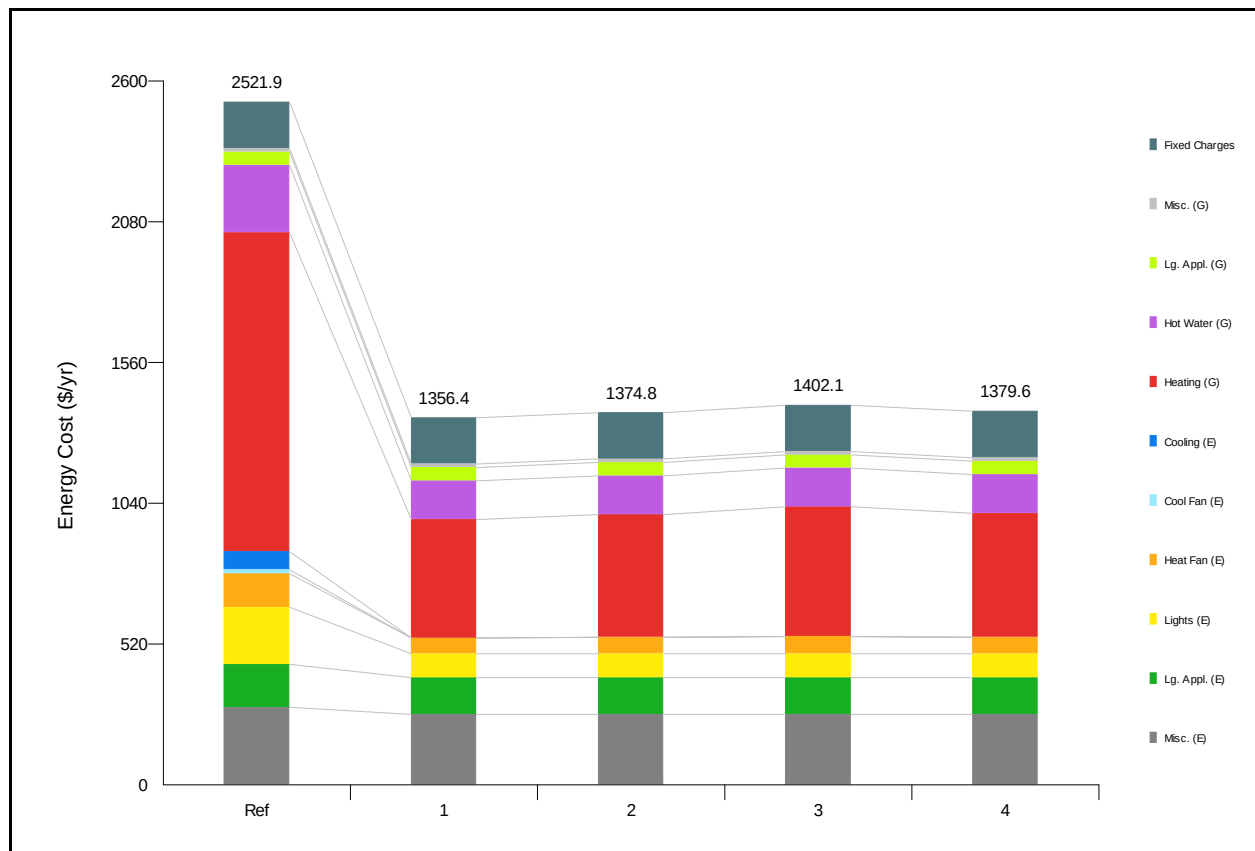


Figure 124: BEopt Energy Cost
E381 with the BA Benchmark as the Reference House

Electricity Rate		
	Utility	Puget Sound Energy
	Marginal	\$0.0872/kWh
	Fixed	\$6.02/month
Natural Gas Rate		
	Utility	Puget Sound Energy
	Marginal	\$1.0858/therm
	Fixed	\$8.25/month

Table 177: Current Utility Rates for Burien, Washington

The top half of Table 178: Neutral Cost Analysis for the E381 Floor Plan

adds a column to Table 176 that details the annual utility bill savings of each of the five main end-use categories in comparison to the BA Benchmark. Again, these values are averaged over all four orientations. As shown in Table 178, the annual utility bill savings according to BEopt is \$1,143.68. It should be noted that this includes no fluctuations in utility rates or inflation.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	Washington Code	E381	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	134.8	99.0	54.0	59.9%	45.5%	30.7%	21.1%	\$784.00
Space Cooling	10.7	0.0	0.0	100.0%	0.0%	4.1%	0.0%	\$81.45
DHW	25.1	22.8	14.4	42.5%	36.9%	4.0%	3.9%	\$105.92
Lighting	27.8	27.8	11.6	58.3%	58.3%	6.2%	7.6%	\$123.13
Appliances and MELs	64.8	63.9	58.3	10.0%	8.6%	2.5%	2.6%	\$49.18
Total Usage/ Savings	263.2	213.5	138.3	47.4%	35.2%	47.4%	35.2%	\$1,143.68
					Energy Efficiency Feature			Annual Mortgage Cost
								vs. Code
					ENERGY STAR Appliances			(\$21.08)
					80% CFL Lighting			(\$10.54)
					R40 Attic Insulation (Vaulted)			(\$14.05)
					Improved Duct Sealing, Envelope Sealing, and Testing			(\$50.06)
					81% EF Tankless Water Heater			(\$48.30)
					92.5% AFUE Furnace			(\$39.52)
					Moving Ducts Into Conditioned Space			(\$59.28)
					R23 BIBS, 2x6, 24"o.c.			(\$70.26)
					Total Annual Mortgage Cost			(\$313.08)
					Net Annual Cash Flow to Consumer			\$830.60

Table 178: Neutral Cost Analysis for the E381 Floor Plan

As shown in Table 178: Neutral Cost Analysis for the E381 Floor Plan

, the net annual cash flow to the homeowner is approximately \$830. Based on this information, it is clear that the incremental annual cost of energy improvements is much less than the annual reduction in utility bill costs and Schneider Family Homes' Village at Miller's Creek community passes the Neutral Cost Target "Must Meet" criteria.

This analysis does not include the \$2,000 federal tax credit that Schneider receives for each new home built that achieves 50% energy savings for heating and cooling over the 2004 International Energy Conservation Code (IECC). This stems from Building America's goal of finding sustainable solutions. Since the tax credit that Schneider Family Homes utilizes expires at the end of 2008, it was not considered appropriate to include it here. The analysis also does not include several rebates that Schneider receives from Puget Sound Energy for building to Northwest ENERGY STAR® standards. It is important to note, however, that the federal tax credit, along with ENERGY STAR®, provides a crucial framework and starting point for builders seeking to build energy efficiently, including Schneider Family Homes.

"Should Meet" Gate Criteria -- Marketability

Schneider Family Homes chose to use the Built Green Program for their marketing efforts at an incremental cost of approximately \$60 per home. All of the homes at Village at Miller's Creek are constructed to three-star Built Green standards. Pat Shea, superintendent for the community, remarked that the Built Green Program is a "marketing machine." He believes that not only does the program do an excellent job at promoting the Built Green features of the community, it also does a good job promoting the Schneider Family Homes' name.

Village at Miller's Creek began selling when the market downturn began. Pat Shea believes that its good location, energy efficient features, and townhome design allowed the community to outpace the competition even as the market declined. Schneider provides exceptional customer service to keep their homes marketable as well. One example of this comes from a customer testimonial on the Schneider website. "Having an interested and attentive Schneider Homes' agent/representative on site during the buying and 'settling in' process is a great service from the builder." Overall, Schneider Family Homes has been very happy with sales. Pat Shea believes sales may have been even better had Schneider focused on selling "green" as opposed to energy efficiency features.

In spite of the market downturn, at least 34 of the 37 homes in this community are currently sold and occupied. Based on current sales and marketing information, Schneider Family Homes' Village at Miller's Creek community passes the Marketability "Should Meet" criteria.

In future marketing efforts using information from this Building America study, Schneider would like to be able to quantitatively show homebuyers the energy savings that their house provides

when compared to a typical Washington code house. Figure 125 and Figure 126 are example material that BIRA provided to Schneider Family Homes to assist with this marketing effort. Originally, Schneider Homes had hoped to receive graphs such as these from Northwest ENERGY STAR®.

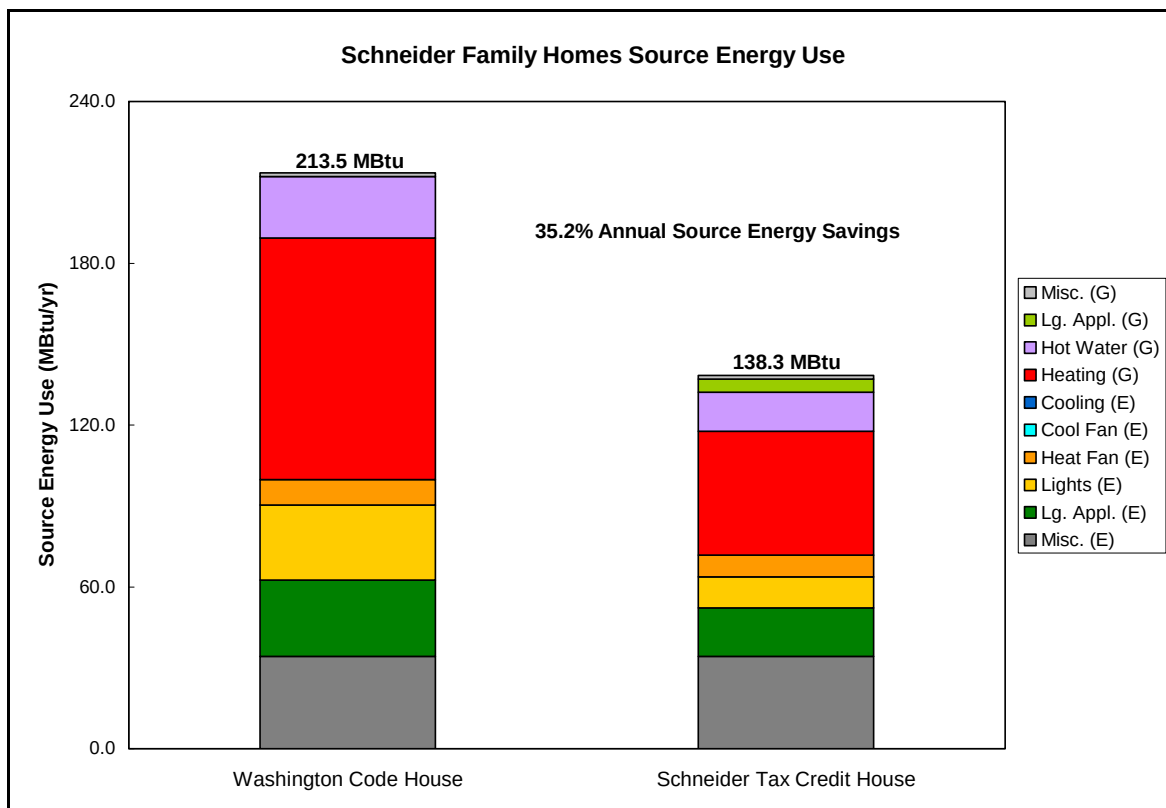


Figure 125: Source Energy Use Marketing Material for Schneider Family Homes

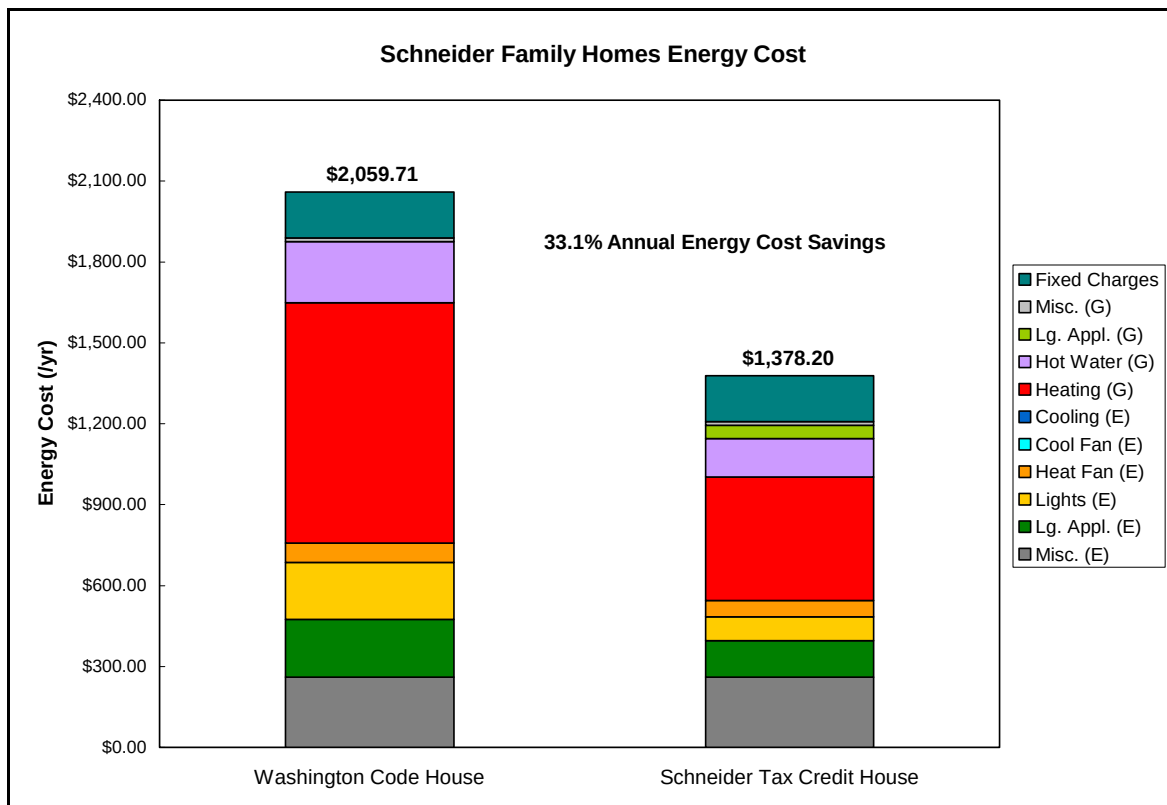


Figure 126: Energy Cost Marketing Material for Schneider Family Homes

“Should Meet” Gate Criteria -- Builder Commitment

The owners of Schneider Family Homes believe that energy efficiency is one of their biggest selling tools. Schneider is committed to finding energy efficiency programs that also provide value to the builder. They were the first major production builder in the Puget Sound area to make a 100% commitment to Northwest ENERGY STAR® homes in late 2004. Originally, Schneider Family Homes thought that Northwest ENERGY STAR® was going to be a marketing driver and that real performance in Built Green was unclear. However, Schneider began to express periodic disappointment in the direct consumer marketing effort from Northwest ENERGY STAR®. In 2007, Schneider added the Built Green three-star program to Village at Miller’s Creek. In addition, many current projects are being certified at the four-star level. Schneider feels that Built Green will have more influence on their buyers, but will continue with Northwest ENERGY STAR®, which Pat Shea believes is a relatively easy program for them to participate in.

Based on this builder’s proactive energy efficiency practices at the Village at Miller’s Creek community, Schneider Family Homes passes the Builder Commitment “Should Meet” criteria.

“Should Meet” Gate Criteria -- Gaps Analysis

Schneider Family Homes used open-web trusses for long spans in between floors in all of the homes in Village at Miller’s Creek. This allowed plenty of room to bring ducts inside conditioned space and also accommodated for other trade’s work, such as plumbing. Schneider did run into an issue while implementing this design that involved the placement of insulation. According to Washington code, insulation must be in contact with the surface it is insulating. In Schneider’s design, insulation between conditioned space and the garage would, in some cases, go around the ducts and other objects in the open-web trusses, resulting in a code violation. WSU Energy Program staff is currently working to identify both air sealing details and code language prohibitions to this approach.

Schneider believes that it was easier for the homes in Village at Miller’s Creek to reach the federal tax credit level due to the smaller footprint they produce as a result of their three-story design. This allowed both the ducts and the plumbing to have shorter spans.

Some owners of homes in the Village at Miller’s Creek community have complained that if they switch hot water applications (i.e. from the clothes washer to the shower) in a short period of time, a short burst of cold water is felt. This is mostly due to the design of traditional tankless water heaters and is an issue being solved through the use of small tanks on newer tankless water heater designs. Other homeowner complaints, especially from older demographics, included a dislike for having the furnace inside conditioned space due to the additional noise.

Another issue that Schneider Family Homes found with tankless water heaters involved a disconnect in communication between themselves, the developer, and the utility. When the builder and the developer are not one in the same, as in this project, the developer may have the gas line put in before discussions have begun on what features the homes will have. When the utility, Puget Sound Energy (PSE), asks the developer if tankless water heaters will be included in the homes, the developer may not know and will have the smallest lines possible installed to save costs. Because of this issue, Schneider had to remove a few tankless units to appease the utility and ensure that there would be adequate gas flow.

Pat Shea has recently instituted precut framing on all single family homes. A local truss plant provides wall packages with all plates, studs, headers, and cripples premade and marked. The computer driven cutting equipment aligns stud layout from floor to floor and reduces jobsite labor and lumber costs.

On some of their other projects, Schneider Family Homes has used 2x4 construction with R15 high-density batts and 1” of external foam on normal walls or ½” of foam on shear walls. This approach is cost neutral compared to a typical code housing using 2x6 construction with R21 batts and provides equal, if not greater, insulation value. Pat Shea commented that the extra foam was easy and inexpensive to add to the project. The critical pathway to Zero Energy Homes in the Marine Climate Zone includes a push towards the use of external foam insulation.

Many builders are hesitant to use this approach due to concerns about water infiltration in the Marine Climate.

In future efforts, BIRA would like to leverage our relationship with Schneider Family Homes to teach other builders how to use external foam effectively. Pat Shea is an excellent resource for technical assistance in this area. He says that the foam actually helps make the sealing of the homes easier. After installing the foam, Schneider installs an external house wrap for a continuous drainage plan, believing that the foam should be treated as a *second* water barrier. Pat Shea also believes that walls stay straighter with foam installed. Schneider has run into issues with warped OSB causing bowed walls when using 24" o.c. or OVE construction.

"Should Meet" Gate Criteria -- Quality Assurance

Training and quality control for Village at Miller's Creek involved strict adherence to Northwest ENERGY STAR® guidelines. The Northwest ENERGY STAR verifier, Dan Wildenhaus of Atmosphere IEM, worked with the site crews to teach air sealing and thermal bypass checklist details. Schneider is interested in continued training for issues such as air leakage at partition wall top plates in upcoming four-star Built Green homes. In addition, all of Schneider Family Homes' superintendents have a long association with the family-run company, including Pat Shea.

Lastly, Schneider has a full warranty on all of their homes through the Residential Warranty Corporation to ensure that any defects within their homes are not the responsibility of the homeowners.

Based on this information, Schneider Family Homes' Village at Miller's Creek community passes the Quality Assurance "Should Meet" criteria.

Tom Walsh & Co. BP1 (2008)

Community Overview

Originally a multifamily homebuilder, Tom Walsh & Co. began focusing on single family homes in 1999 under the leadership of Ben Walsh. This provided them the opportunity to bring their production line building process from multifamily housing to a new market.

In 2003, a Housing Opportunities for People Everywhere (HOPE VI) project began, designed to renovate the Columbia Villa public housing community in northern Portland, Oregon. This project was originally funded by a \$35 million grant given to the Housing Authority of Portland (HAP) by the U.S. Department of Housing and Urban Development (HUD) that served as an anchor for the \$153 million final project. In December 2003, after relocating 382 households, demolition began on Columbia Villa.

New Columbia was designed to replace Columbia Villa's 462 public housing units, originally built

in 1942, with a mix of 854 homeownership units, affordable rental housing units, senior rental units, and replacement public housing units. The ambitious project, with a design centered on New Urbanism, required at least 20% of construction and service contracts to go to qualified disadvantaged, minority-owned, women-owned, and emerging small businesses. In addition, builders were required to use sustainable practices during both the demolition and construction stages.

Tom Walsh & Co. came onto the scene in October 2005, beginning construction on 24 Northwest ENERGY STAR® and Earth Advantage single family homes. After completing these homes, Tom Walsh & Co. learned about the \$2,000 federal tax credit through independent research. After consulting with Earth Advantage and their HVAC contractor, Ben Walsh was able to refine the designs for the next phase of construction in order to qualify for this credit. In October 2006, the second phase of construction began.

In addition to qualifying for the Northwest ENERGY STAR® and Earth Advantage programs, these 22 homes include R30 insulated floors, R49 insulated ceilings, and ducts in conditioned space. These are the homes in New Columbia that meet Building America's 40% goal in the Marine Climate Zone. The two-story, three bedroom homes are built with R21, 2x6, 24" o.c. construction, priced between \$274,900 and \$299,900, and are generally targeted at entry-level homebuyers looking for a traditional, high-quality home.

The community is provided electricity by Portland General Electric and natural gas by Northwest Natural. Portland experiences average annual precipitation of 36.3 inches, 4,399 annual heating degree days, and 291 annual cooling degree days. This climate provides the greatest opportunity for energy savings from reductions in space heating loads.

This case study will show that the New Columbia community meets Building America's 40% initial communities goal for the Marine Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria.

For more information on Tom Walsh & Co.'s involvement in the New Columbia community, contact Tom Walsh, (503) 973-5001 ext. 12, Partners@TomWalsh.com or visit the Tom Walsh & Co. website, www.TomWalsh.commailto:Partners@TomWalsh.com.

For more information on the New Columbia community as a whole, contact Steve Rudman, Housing Authority of Portland, (503) 802-8455.

"Must Meet" Gate Criteria -- Source Energy Savings

Using BEopt 0.8.6, an energy analysis was performed on Tom Walsh's Roseburg 1884 floor plan. The Roseburg plan is a two-story house representative of a typical Tom Walsh house in New Columbia, with 1,884 square feet of finished floor area, three bedrooms, and two and a half bathrooms. Two separate simulations were run, one with the BA Benchmark as the reference

house, and one with an Oregon code house as the reference house. Figure 127 shows the BEopt source energy use graph for the Roseburg 1884 floor plan with the BA Benchmark as the reference house. All four cardinal orientations were simulated for both reference homes. Table 179: Source Energy Savings for the Roseburg 1884 Floor Plan

summarizes the findings of both simulations. The energy savings for Roseburg 1884 are averaged over all four orientations and grouped into five main end-use categories.

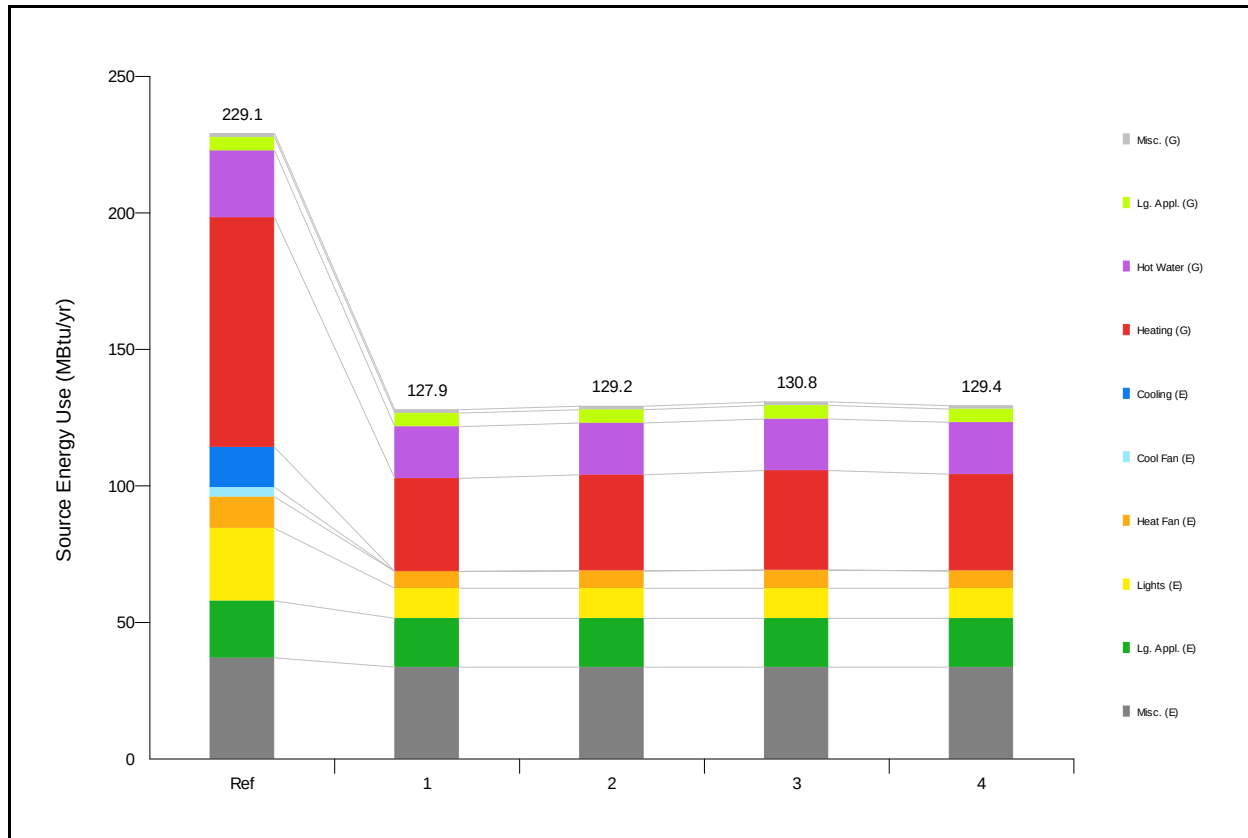


Figure 127: BEopt Source Energy Use
Roseburg 1884 with the BA Benchmark as the Reference House

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Oregon Code	Roseburg 1884	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	95.7	63.3	41.7	56.4%	34.1%	23.6%	12.3%
Space Cooling	18.2	0.0	0.0	100.0%	0.0%	7.9%	0.0%
DHW	24.5	22.3	19.0	22.7%	15.1%	2.4%	1.9%
Lighting	26.5	26.5	11.0	58.7%	58.7%	6.8%	8.9%
Appliances and MELs	64.1	63.1	57.7	9.9%	8.6%	2.8%	3.1%
Total Usage/ Savings	229.1	175.3	129.3	43.5%	26.2%	43.5%	26.2%

Table 179: Source Energy Savings for the Roseburg 1884 Floor Plan

As shown in Table 179: Source Energy Savings for the Roseburg 1884 Floor Plan

, a typical Tom Walsh house in the New Columbia community meets the Building America goal of 40% energy savings in the Marine Climate Zone with respect to the BA Benchmark. The critical above code energy reduction features implemented in order to reach this goal are as follows:

- ENERGY STAR® refrigerator, dishwasher, and clothes washer
- 100% hardwired CFL lighting
- 62% EF gas water heater
- 4.4 ACH₅₀ infiltration (typical Tom Walsh home)
- R49 blown-in cellulose insulation in the attic
- 94% AFUE furnace
- Ducts in conditioned space
- 0.29 U-value windows
- Gas cooking range

Tom Walsh & Co. began with the features prescribed by Northwest ENERGY STAR®. By improving upon these requirements, Tom Walsh was able to raise their homes to the federal tax credit level, which is equivalent to 40% whole house energy savings compared to the BA Benchmark.

Based on the BEopt simulation providing 43.5% energy savings compared to the BA Benchmark,

Tom Walsh & Co.'s New Columbia community passes the Source Energy Savings "Must Meet" criteria.

"Must Meet" Gate Criteria -- Market Coverage

The portion of New Columbia built by Tom Walsh & Co. consists of 46 homes. Within the currently complete community are 22 homes reaching 40% energy efficiency savings above the BA Benchmark. At least 20 of these homes are sold. It is also important to note that two homes in the 22 home community feature solar domestic hot water (SDHW). Although these two homes do not meet the Market Coverage criteria, data collected from them will be used by HAP in future projects. For a site plan of the New Columbia community, see Appendix E of the task report.

Based on this information, Tom Walsh & Co.'s New Columbia community passes the Market Coverage "Must Meet" criteria.

"Must Meet" Gate Criteria -- Neutral Cost Target

Figure 128 shows the BEopt energy cost graph for the Roseburg 1884 floor plan with the BA Benchmark as the reference house. These costs are based on the current utility rates in Portland, Oregon, summarized in Table 180: Current Utility Rates for Portland, Oregon

, and include both electric and natural gas energy sources.

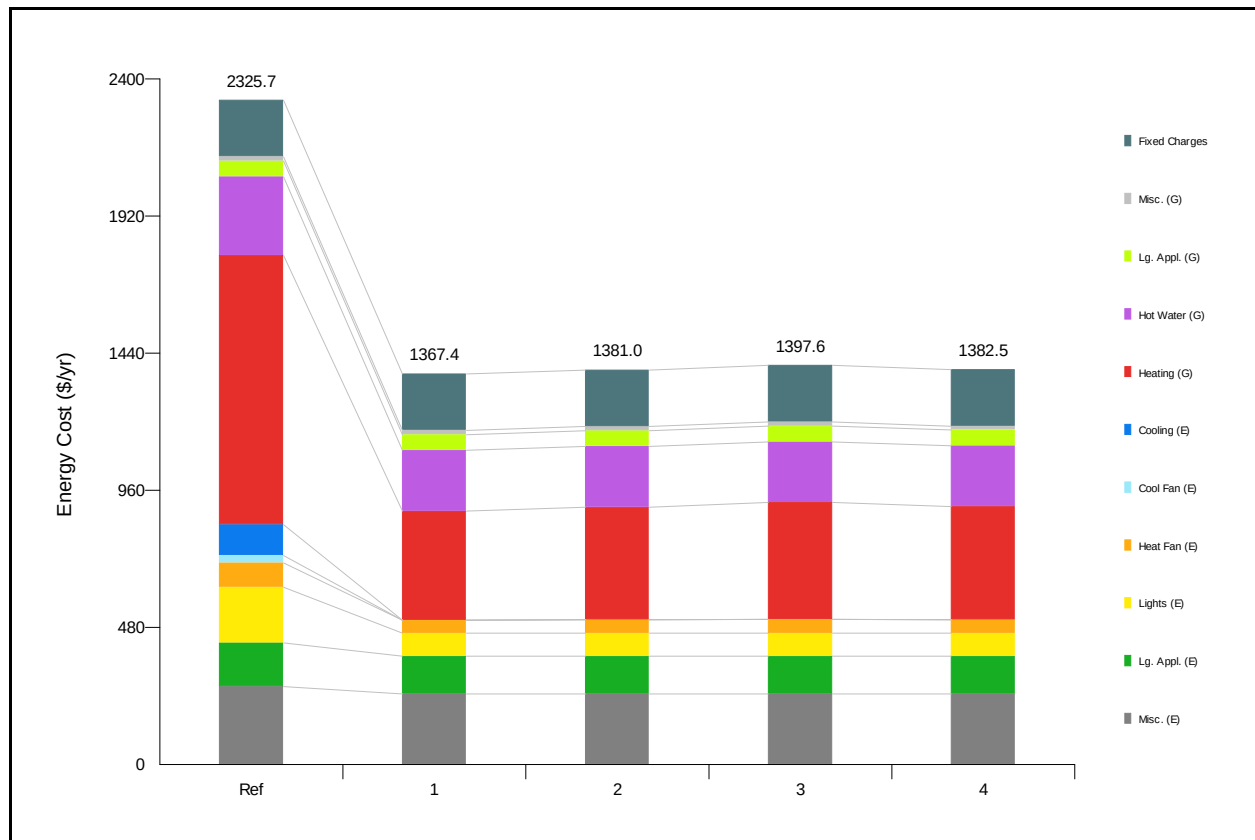


Figure 128: BEopt Energy Cost
Roseburg 1884 with the BA Benchmark as the Reference House

Electricity Rate	
Utility	Portland General Electric
Marginal	\$0.0844/kWh
Fixed	\$10.50/month
Natural Gas Rate	
Utility	Northwest Natural
Marginal	\$1.2245/therm
Fixed	\$6.00/month

Table 180: Current Utility Rates for Portland, Oregon

The top half of Table 181: Neutral Cost Analysis for the Roseburg 1884 Floor Plan

adds a column to Table 179 that details the annual utility bill savings of each of the five main end-use categories in comparison to the BA Benchmark. Again, these values are averaged over all four orientations. As shown in Table 181: Neutral Cost Analysis for the Roseburg 1884 Floor Plan

, the annual utility bill savings according to BEopt is \$943.60. It should be noted that this includes no fluctuations in utility rates or inflation.

The bottom half of Table 181: Neutral Cost Analysis for the Roseburg 1884 Floor Plan

is derived from the builder's first cost, for each of the energy efficiency features listed. The builder costs come from a meeting between BIRA representatives and representatives from Tom Walsh & Co. A 10% markup is assumed, the cost is converted into an annuity assuming a 7% loan over 30 years, and inflation is not considered. For the 0.29 U-value windows and the gas cooking range, it is assumed that there is no additional cost. Tom Walsh & Co. works with a small regional window manufacturer that keeps prices low with little advertising or marketing of any kind. Tom Walsh & Co. was able to keep other costs low by working with their current subcontractors and simply providing training and support to improve their processes.

It is also important to note that Tom Walsh & Co. actually saved money by moving ducts into conditioned space (approximately \$250 per house). The only cost associated with adding the drop-downs and soffits to implement space for the duct work was a small amount for materials. The framer did not charge extra for labor because it was seen as just another part of the house. Tom Walsh & Co. saved money because they were able to use 35% less ductwork and install a smaller HVAC system.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	Oregon Code	Roseburg 1884	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	95.7	63.3	41.7	56.4%	34.1%	23.6%	12.3%	\$586.13
Space Cooling	18.2	0.0	0.0	100.0%	0.0%	7.9%	0.0%	\$133.59
DHW	24.5	22.3	19.0	22.7%	15.1%	2.4%	1.9%	\$62.37
Lighting	26.5	26.5	11.0	58.7%	58.7%	6.8%	8.9%	\$114.53
Appliances and MELs	64.1	63.1	57.7	9.9%	8.6%	2.8%	3.1%	\$46.99
Total Usage/ Savings	229.1	175.3	129.3	43.5%	26.2%	43.5%	26.2%	\$943.60
					Energy Efficiency Feature			Annual Mortgage Cost
								vs. Code
					ENERGY STAR Appliances			(\$21.08)
					100% CFL Lighting			(\$10.54)
					62% EF Water Heater			(\$13.17)
					Improved Duct Sealing, Envelope Sealing, and Testing			(\$70.26)
					R49 Attic Insulation			(\$28.10)
					94% AFUE Furnace			(\$70.26)
					Moving Ducts Into Conditioned Space			\$21.95
					Total Annual Mortgage Cost			(\$191.45)
					Net Annual Cash Flow to Consumer			\$752.15

Table 181: Neutral Cost Analysis for the Roseburg 1884 Floor Plan

As shown in Table 181: Neutral Cost Analysis for the Roseburg 1884 Floor Plan

, the net annual cash flow to the homeowner is approximately \$750. Based on this information,

it is clear that the incremental annual cost of energy improvements is much less than the annual reduction in

utility bill costs and Tom Walsh & Co.'s New Columbia community passes the Neutral Cost Target "Must Meet" criteria.

The above analysis does not include the \$2,000 federal tax credit that Tom Walsh receives for each new home they build that achieves 50% energy savings for heating and cooling over the 2004 International Energy Conservation Code (IECC). This stems from Building America's goal of finding sustainable solutions. Since the tax credit that Tom Walsh & Co. utilizes expires at the end of 2008, it was not considered appropriate to include here.

This analysis also does not include \$1,000 per home that Tom Walsh & Co. received from the Energy Trust of Oregon for reaching the federal tax credit level. Ben Walsh says that rebates have a lot of issues surrounding them. Many of them are not advertised and are hard to apply for once the builder learns of them. Ben Walsh sees this as the price he pays for being ahead of the curve, but he feels that it's worth it. It is important to note, however, that the federal tax credit, Northwest ENERGY STAR, and other incentive programs provide a crucial framework and starting point for builders seeking to build energy efficiently, including Tom Walsh and Co.

"Should Meet" Gate Criteria -- Marketability

For help with their marketing efforts, Tom Walsh & Co. hired an independent realtor, Chris Bonner of Hasson Company. She provided marketing materials and sales support that promoted the energy efficient features of New Columbia. In addition, HAP provided copious amounts of marketing for the entire New Columbia project, and several articles were written in local publications. These materials are available in the case study report.

Tom Walsh himself believes that New Columbia was an ideal place to build energy efficient homes because it was designed to provide affordable housing. By keeping the cost of the home low and providing lower energy bills, Walsh believes that younger, budget-conscious, entry-level buyers were drawn to the community. Ultimately, Tom Walsh says the main focus of Tom Walsh & Co. is to sell high quality homes that provide the best customer satisfaction possible, creating positive marketing through word of mouth.

Based on current sales and marketing information, Tom Walsh & Co.'s New Columbia community passes the Marketability "Should Meet" criteria.

In future marketing efforts using information from this Building America study, Tom Walsh would like to be able to quantitatively show homebuyers the energy savings that their house provides compared to a typical Oregon code house. Figure 129 and Figure 130 are example graphs that BIRA provided Tom Walsh & Co. in order to help with this marketing effort.

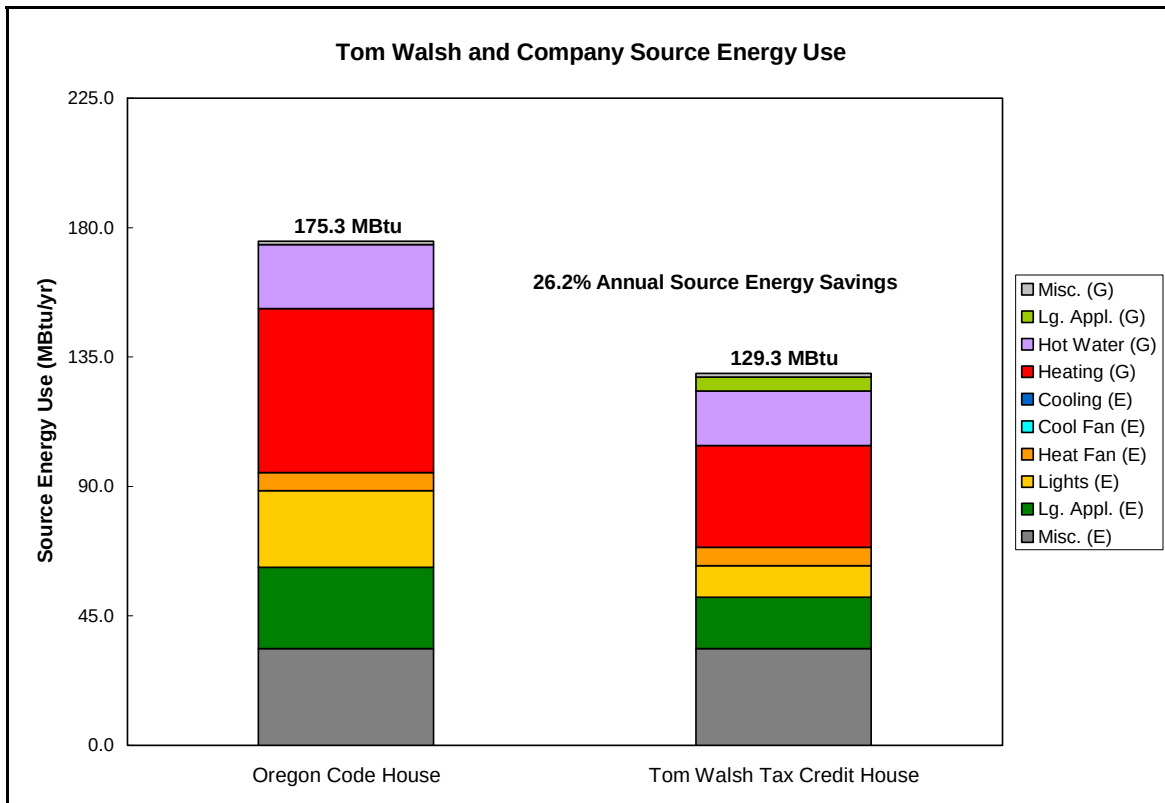


Figure 129: Source Energy Use Marketing Material for Tom Walsh & Co.

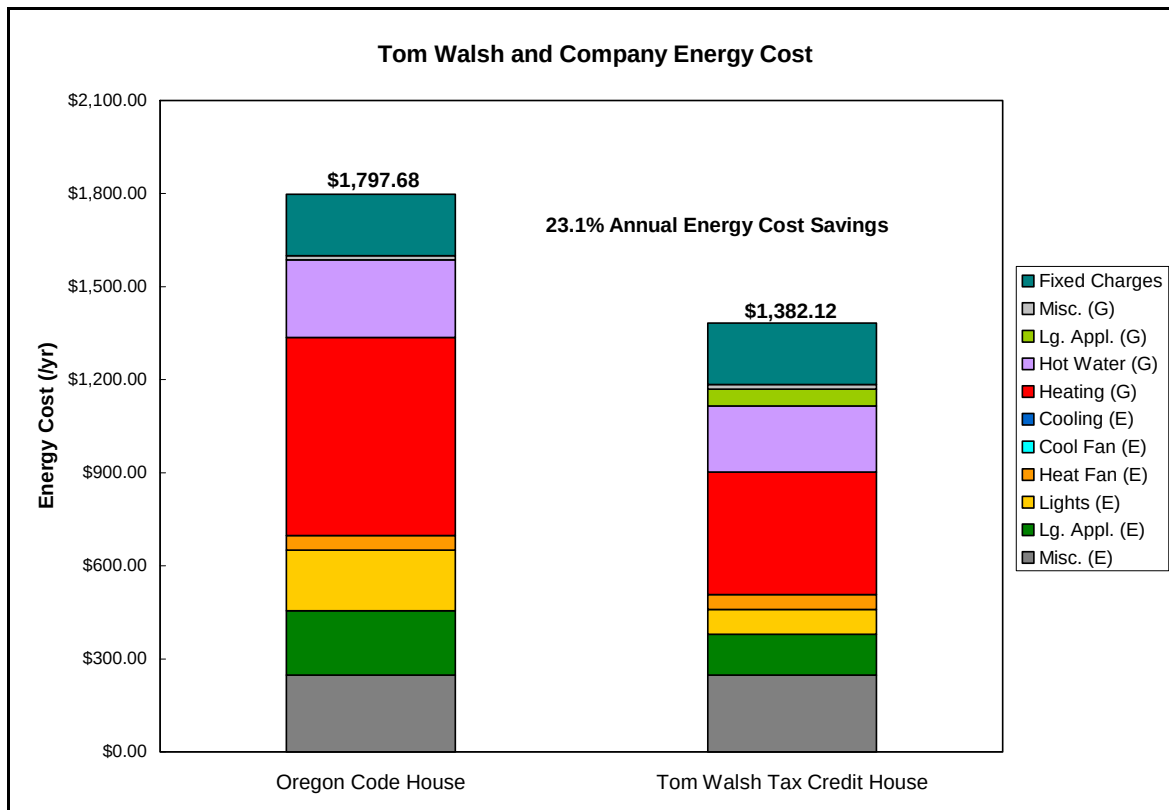


Figure 130: Energy Cost Marketing Material for Tom Walsh & Co.

“Should Meet” Gate Criteria -- Builder Commitment

Tom Walsh & Co. is dedicated to continually building energy efficiently. Tom Walsh says that he is willing to incorporate more designs improvements in the future, as long as they don’t involve too much risk. Early in the first phase of construction at New Columbia, Tom Walsh & Co. quickly learned to use features such as HardiePlank Lap Siding, a cost-effective measure to improve the quality and look of a home. In addition, I-joists were used to save money and allow easier installation of trades work such as plumbing (a technique Tom Walsh & Co. picked up in multifamily building). In the second phase of construction, the designs of all the homes were improved with better construction practices and features (see Gaps Analysis below). In the future, Walsh is open to improvements such as the use of open-web trusses to bring ducts into conditioned space more effectively.

Ben Walsh, project manager for the New Columbia project, has taken the building practices he learned from the project and created his own company that is focused on energy efficient, single family homes. The company, Ben Walsh Co., is also known by the name Green One. Their next project consists of 18 three-story homes with many of the same features used at New Columbia. These homes will also feature half-inch external foam insulation on the walls as well as insulated slab foundations. BIRA will be working with Ben Walsh in future Building America endeavors.

Based on this builder's proactive energy efficiency practices at the New Columbia community, Tom Walsh & Co. passes the Builder Commitment "Should Meet" criteria.

"Should Meet" Gate Criteria - Gaps Analysis

Many of the gaps that Tom Walsh & Co. experienced during the first phase of construction at New Columbia were corrected during the second phase. For example, in the first phase of construction, many of the homes were experiencing infiltration of around 7.0 ACH₅₀. By the end of the second phase, some homes were coming in as low as 3.0 ACH₅₀ as a result of more careful foaming, more careful caulking, super-insulated outlets, sealed bottom plates, and the use of Building America sealing protocols. The estimated incremental time to implement these improvements was only one and a half hours per home. Additional improvements included bringing ducts inside conditioned space through the use of drop-downs and additional insulation in the ceiling and floors. Other issues Tom Walsh & Co. faced involved installation problems with whole house fans and butterfly dampers.

Ben Walsh believes that drop-downs and soffits are an effective way of bringing ducts inside conditioned space. This method is made easier in homes with nine foot first floor ceilings, which are featured in all Tom Walsh & Co. homes. Ben Walsh believes that nine foot ceilings are valued by buyers because they make rooms appear bigger. Drop-downs and soffits also have the added benefit of defining rooms,

Tom Walsh & Co. is considering using open-web trusses as a method of bringing ducts inside the building envelope in future projects. One issue that Ben Walsh foresees is that open-web trusses typically raise the height of the house. This results in the need for an extra riser on the stairs, which can cause a problem with the floor plans if open-web trusses were not in the original blueprints. To alleviate this, Ben Walsh believes he can implement open web trusses by lowering the ceiling on the first floor from nine feet to eight feet, eight inches. Most homebuyers see nine foot ceilings as a luxury and can see the difference between nine foot and eight foot ceilings. However, most will not be able to see the four inch difference between nine feet and eight feet, eight inches.

Tom Walsh also suggested to BIRA team members that incentive programs are too complex and not well integrated. Walsh believes incentives are a good idea, but that qualification requirements should be simpler if agencies are looking to promote energy efficiency. As a result, Tom Walsh & Co. obtains as many incentives as they can qualify for, but they don't count on them.

"Should Meet" Gate Criteria - Quality Assurance

Tom Walsh & Co. is a multifamily builder who entered the single family building market in 1999.

Ben Walsh, Tom Walsh's nephew, is currently leading the single family work. By bringing their production-line oriented building style to single family homes, Tom Walsh believes that they have a much better building process than many of their competitors. One "trade fighting" mitigation process that Tom Walsh & Co. uses is to have only one subcontractor working on a home at a time. Each subcontractor is given their allotted time to complete their task and when they are done, the next subcontractor arrives. Using this process, Tom Walsh & Co. was able to finish each home in New Columbia in 27 weeks.

Other quality assurance measures taken by Tom Walsh & Co. at New Columbia include the supervisor, Paul Johnson, keeping a daily log of the project's progress. These logs were then reviewed to assure that a quality installation was performed. Tom Walsh had a lot of faith in Johnson with regards to New Columbia. When asked about quality control, Walsh asserted, "Paul is my quality control."

Tom Walsh & Co. also hired a separate subcontractor to perform the window sealing and flashing. This allowed the framers or window installers to perform their work while a separate, professional subcontractor maintained the quality focus on sealing and flashing. Both FortiFlash Waterproof Flashing Membrane and window wrap were used on all windows.

Based on this information, Tom Walsh & Co.'s New Columbia community passes the Quality Assurance "Should Meet" criteria.

Snow Creek Cottages – Park City, UT – 50% Cold BP2 (2009)

This report describes the evaluation of Park City's Snow Creek Cottages development to determine if it meets the Building America 50% whole house energy savings goal when compared to the Building America Benchmark in the Cold Climate Zone. The community will be evaluated based on Building America's Stage Gate 3 "Must Meet" and "Should Meet" criteria. A key research partner in this endeavor is the University of Utah (U of U) led by Professor Kent Udell.

Key Results

Initial analysis indicates the Snow Creek Cottages community qualifies as a Building America 50% Community in the Cold Climate Zone. All plans in this community are above 50% below the BA benchmark in energy use. This assessment is based on an energy analysis performed using EnergyGauge® USA v.2.8.02, incremental costs based on builder estimates, and additional information acquired by the U of U.

Gate Status

An energy analysis was performed on all four floor plans in the Snow Creek Cottages community. All plans average energy savings of 54.8% when compared to the Building America

Benchmark. All of the thirteen homes currently under construction will be built to this energy savings. Based on the energy cost savings from EnergyGauge and incremental costs from Park City, it has been determined that the homeowner expects to see approximately \$224 to \$570 per year (dependent on floor plan) net cost savings compared to the Building America Benchmark.

Conclusions

The Snow Creek Cottage community by Park City exceeds the 50% Cold Climate Zone community requirements. This community is currently under construction; the U of U is documenting construction, costs, and implementation of key systems within community. BIRA will report on stage gate process in 2010 after construction has been completed in May.

Community Overview

This case study will begin to show that the Snow Creek Cottages community meets Building America's 50% WHES initial community goal for the Cold Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria.

For more information on Park City's involvement in the Snow Creek Cottages community, contact Dave Gustafson, (435) 615-5203, dgustafson@parkcity.org or visit the Park City website, <http://www.parkcity.org/index.aspx?page=412>.

Location

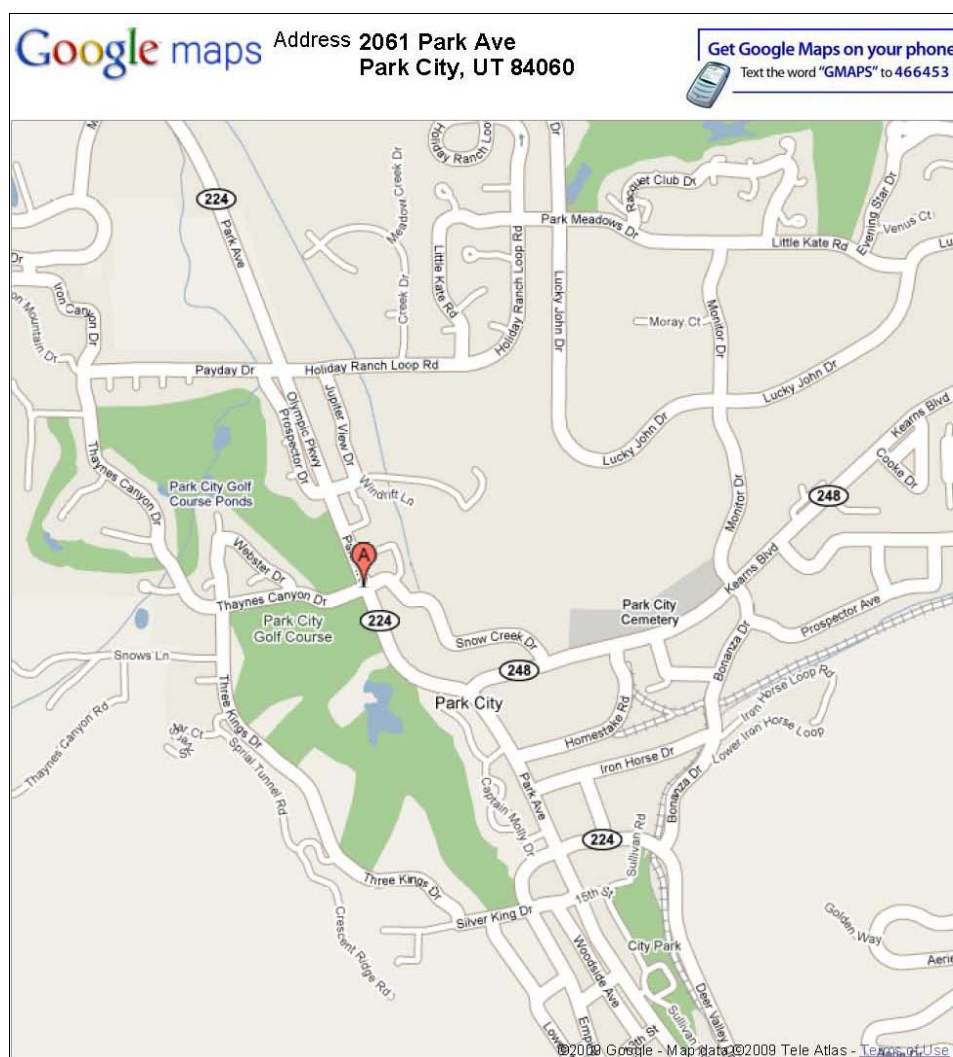


Figure 131: Snow Creek Cottages Site Map

“Must Meet” Gate Criteria -- Source Energy Savings

Benchmarking analysis for the “Deer” floor plan was selected as the representative of the community. Floor plans and elevations can be found in Appendix A of the final report. The “Deer” floor plan is a two-story house representative of a typical Snow Creek Cottage in Park City, with 1,916 square feet of finished floor area, three bedrooms, and three bathrooms. Figure 132 shows the EnergyGauge source energy use graph for the “Deer” floor plan with the BA Benchmark as the reference house. Table 182 summarizes the findings of both simulations. The energy savings for the “Deer” floor plan grouped into five main end-use categories, as seen in Figure 132.

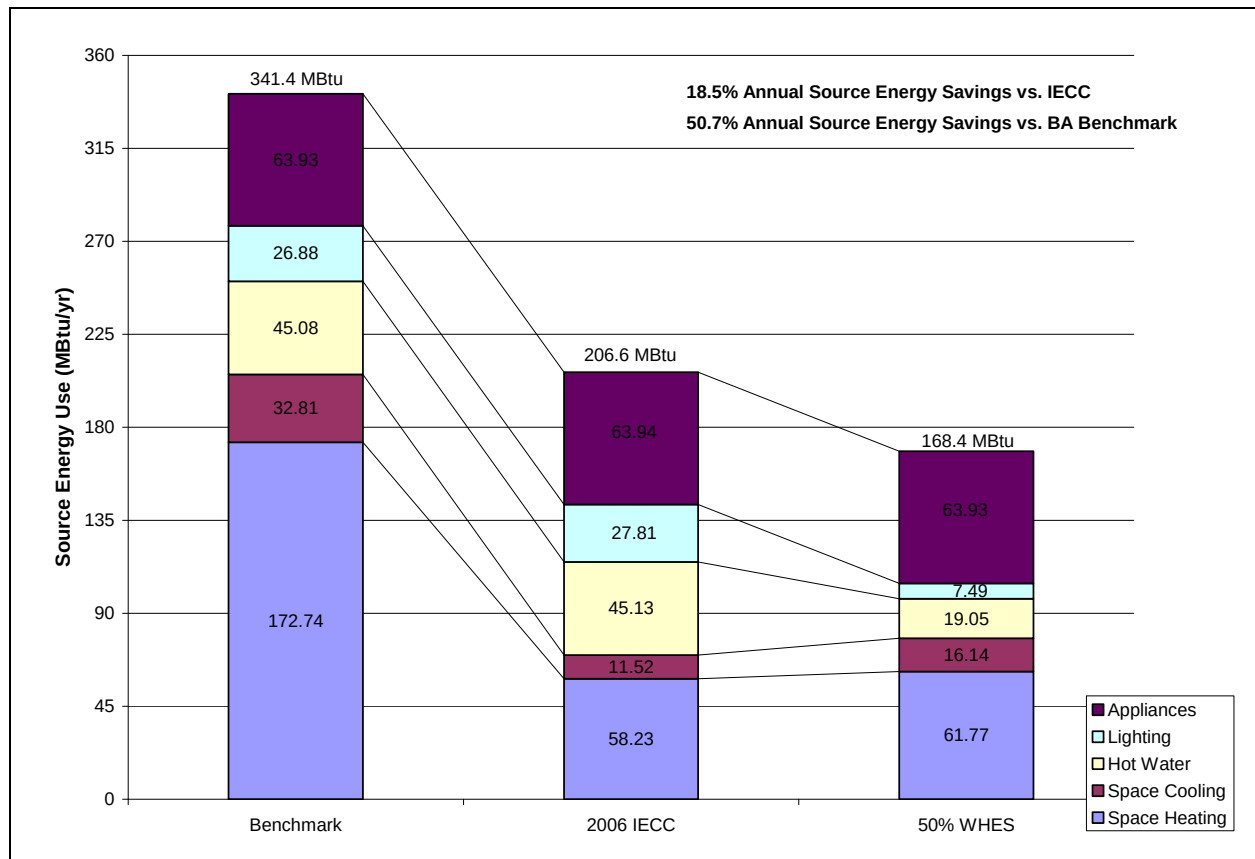


Figure 132. EnergyGauge Source Energy Use-“Deer” Model

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	IECC 2006	Prototype	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	172.7	58.2	61.8	64.2%	-6.1%	32.5%	-1.7%	\$676
Space Cooling	32.8	11.5	16.1	50.8%	-40.2%	4.9%	-2.2%	\$102
DHW	45.1	45.1	19.1	57.7%	57.8%	7.6%	12.6%	\$159
Lighting	26.9	27.8	7.5	72.1%	73.1%	5.7%	9.8%	\$118
Appliances and MELs	63.9	63.9	63.9	0.0%	0.0%	0.0%	0.0%	\$0
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%	\$0
Total Usage/ Savings	341.4	206.6	168.4	50.7%	18.5%	50.7%	18.5%	\$1,055

Table 182. Source Energy Savings for the “Deer” Model

As shown in Table 182, the “Deer” model in the Snow Creek Cottages community meets the Building America goal of 50% energy savings in the Cold Climate Zone with respect to the BA Benchmark. The critical above code energy reduction features implemented in order to reach this goal are as follows:

- ENERGY STAR refrigerator, dishwasher, and clothes washer
- 100% hardwired CFL lighting
- Solar water heating with evacuated tubes
- R23 6” SIPS walls
- R46 SIPS roof
- Heating: Ground Source Heat Pump
- Ducts in conditioned space
- 0.31 U-value windows
- Ventilation cooling

Based on the EnergyGauge simulations providing 50% energy savings compared to the BA Benchmark, Park City’s Snow Creek Cottages community passes the Source Energy Savings “Must Meet” criteria.

“Must Meet” Gate Criteria -- Market Coverage

All thirteen homes within the Snow Creek Cottages community will be completed by May of 2010. Currently all homes are framed ,with rough electrical, plumbing, and HVAC completed.

“Must Meet” Gate Criteria -- Neutral Cost Target

Figure 133 shows the cost neutrality graph for the “Deer” floor plan with the BA Benchmark as the reference house. These costs are based on the utility rates in Wanship, Utah, summarized in Table 183, and include both electric and natural gas energy sources. A condition for the two homes being monitored by BIRA is the homeowners will be sharing their electric bills. BIRA will compare actual versus analytical in a 2010 updated community report.

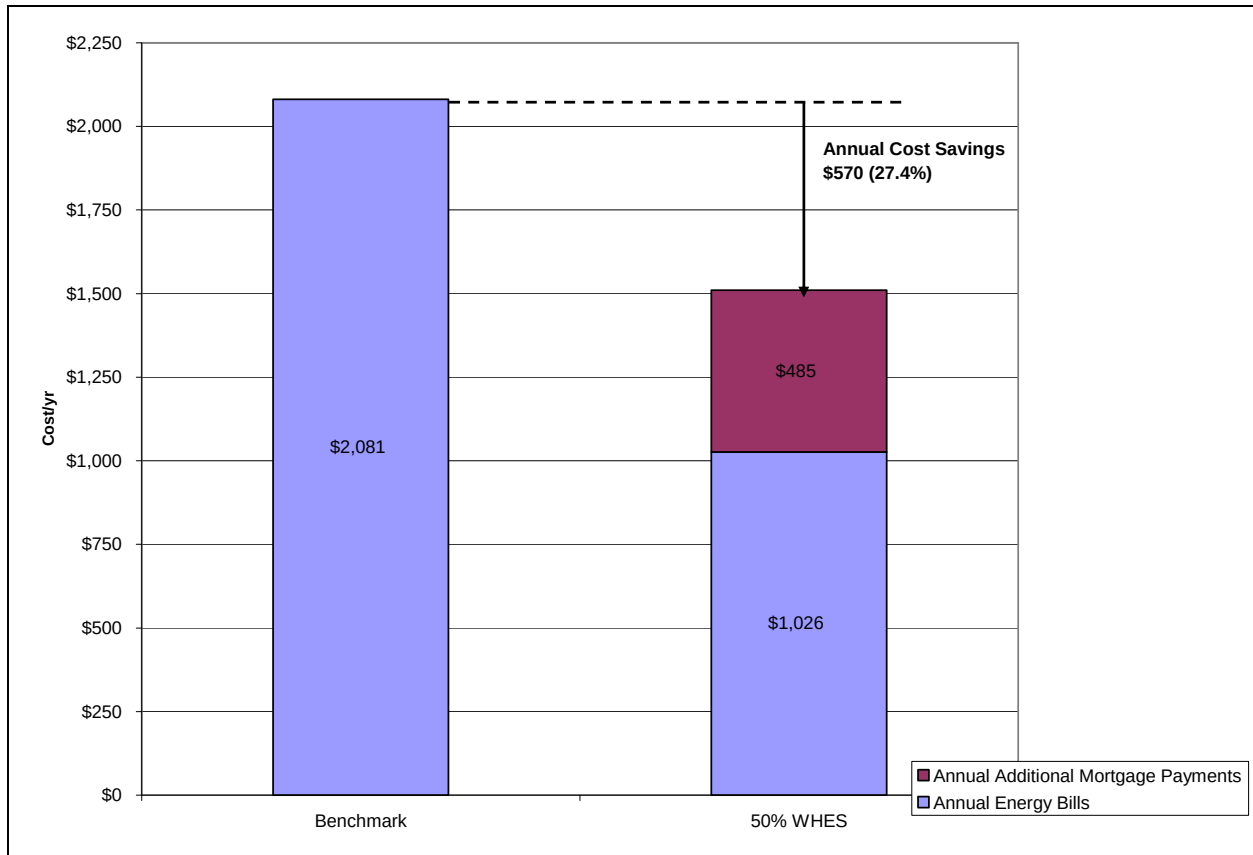


Figure 133. Cost Neutrality- “Deer” Model

Electricity Rate	
Utility	Rocky Mountain Power
Marginal	\$0.07/kWh
Natural Gas Rate	
Utility	QuestStar
Marginal	\$0.79/therm

Table 183. Current Utility Rates for Wanship, Utah

The top half of Table 184 adds a column to Table 182 that details the annual utility bill savings of each of the five main end-use categories in comparison to the BA Benchmark. As shown in Table 184, the annual utility bill savings according to EnergyGauge is \$570. It should be noted

that this includes no fluctuations in utility rates or inflation.

The bottom half of Table 184 is derived from the builder's first cost, detailed in Appendix D of the final report, for each of the energy efficiency features listed. A 10% markup is assumed, the cost is converted into an annuity assuming a 7% loan over 30 years, and inflation is not considered.

As shown in Table 184, the net annual cash flow to the homeowner is approximately \$570. Based on this information, it is clear that the incremental annual cost of energy improvements is much less than the annual reduction in utility bill costs and Park City's Snow Creek Cottages community passes the Neutral Cost Target "Must Meet" criteria.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	IECC 2006	Prototype	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	172.7	58.2	61.8	64.2%	-6.1%	32.5%	-1.7%	\$676
Space Cooling	32.8	11.5	16.1	50.8%	-40.2%	4.9%	-2.2%	\$102
DHW	45.1	45.1	19.1	57.7%	57.8%	7.6%	12.6%	\$159
Lighting	26.9	27.8	7.5	72.1%	73.1%	5.7%	9.8%	\$118
Appliances and MELs	63.9	63.9	63.9	0.0%	0.0%	0.0%	0.0%	\$0
PV	0.0	0.0	0.0	n/a	n/a	0.0%	0.0%	\$0
Total Usage/ Savings	341.4	206.6	168.4	50.7%	18.5%	50.7%	18.5%	\$1,055
		Energy Efficiency Feature			Builder Cost	10% Markup	Total	Annual Mortgage Cost vs. Code
		100% CFL Lighting			\$100	\$10	\$110	(\$9)
		92% EF 40 gal. Water Heater			\$300	\$30	\$330	(\$26)
		Improved Duct Sealing, Envelope Sealing, and Testing			\$1,035	\$103	\$1,138	(\$91)
		SIPS (R26 Exterior Walls)			\$2,601	\$260	\$2,861	(\$228)
		R0 Ceiling Insulation			-\$328	-\$33	-\$360	\$29
		R19 Floor Above Garage Insulation			-\$90	-\$9	-\$99	\$8
		R0 Slab			-\$3,181	-\$318	-\$3,499	\$279
		5/8" Drywall			\$80	\$8	\$88	(\$7)
		Geothermal Heat Pump (Space heating and Cooling)			\$0	\$0	\$0	\$0
		Solar Thermal System			\$4,850	\$485	\$5,335	(\$426)
		Pipe Insulation Water Distribution			\$150	\$15	\$165	(\$13)
		Totals			\$5,517	\$552	\$6,069	(\$485)
		Net Annual Cash Flow to Consumer						

Table 184. Neutral Cost Analysis for the "Deer" Floor Plan

The above analysis does not include the \$2,000 federal tax credit that Park City receives for each new home they build that achieves 50% energy savings for heating and cooling over the 2006 International Energy Conservation Code (IECC). This stems from Building America's goal of finding sustainable solutions.

"Should Meet" Gate Criteria -- Marketability

The Snow Creek Cottages, Park City's affordable housing community will be available for sale through a lottery process likely to occur in the first quarter of 2010. All eligible applicants will have a chance to win the right to purchase one of these units. Size of home to be purchased will be determined by household size - households will be able to purchase a home with one bedroom greater than the number of people in the household. For example, a single person household may purchase a two-bedroom home. Park City is still in the process of developing the pricing and how a household become eligible for the lottery. What we know now is that each household wanting to participate in the lottery will be required to complete a HUD certified Homebuyer Education class. Other eligibility requirements will include:

- At minimum, one adult household member must be a current full-time employee within Park City School District boundaries (preference will be given to those employed within City limits).
- The Snow Creek Cottage must be your primary residence; buyers cannot own another home or condominium. You do not have to be a first-time homebuyer.
- The buyer must be able to get a pre-approval letter from a lender.

Park City has set high energy goals for this community in efforts to demonstrate to the community and the state that cost effective marketable near zero energy homes are feasible.

Should Meet" Gate Criteria -- Builder Commitment

Park City is dedicated to continually building energy efficiently.

Based on this builder's proactive energy efficiency practices at the Snow Creek Cottages, Park City passes the Builder Commitment "Should Meet" criteria.

Should Meet" Gate Criteria -- Gaps Analysis

BIRA is working with U of U, and Park City to identify issues related to construction. BIRA will discuss lessons learned, optimal builder business practices, what not to do, documentation of failures, recommendations for policy improvements, and remaining technical and market barriers to achieving the 50% performance level in the updated community report in 2010.

Should Meet” Gate Criteria -- Quality Assurance

Since this project is led by the city of Park city. The builder has had to place close attention to all codes and standards. Park City has weekly meetings with the builder to assure quality standards are held to a strict standard of excellence. BIRA has assisted Park City in providing BA partners Premier Building Systems (SIPS provider), Utah Solar and Alternative Energy(solar provider), University of Utah(GSHP expertise) as a resource to Park city to advise on proper implementation of advanced systems.

Green One Construction Services - Sage Green – Portland, OR BP2 (2009)

Green One Construction Services’ Sage Green development was evaluated to determine if it met the Building America 50% whole house energy savings goal when compared to the Building America Benchmark in the Marine Climate Zone. This project is currently in the permitting stage with site work and utilities being completed on site. The community was evaluated based on Building America’s Stage Gate 3 “Must Meet” and “Should Meet” criteria. Key research partners in this endeavor are Robert Del Mar and Brady Peeks of the Oregon Department of Energy and David Hales of Washington State University (WSU) Energy Program.

Key Results

It has been determined that the Sage Green community will qualify as a Building America 50% Community in the Marine Climate Zone. This assessment is based on an energy analysis performed using BEopt 0.9.03 and additional information acquired from Green One Construction Services

Gate Status

An energy analysis performed on a typical Sage Green Home shows energy savings of 50.1% compared to the Building America Benchmark. Green One Construction Services expects 18 of these homes to be completed in the Sage Green community in three phases over 18 months. Based on the results of the BEopt analysis the homes will realize annual energy savings of \$800 over the BA Benchmark. Additional cost and schedule information will be included in this study as it becomes available.

Green One Construction Services intends to keep their homes marketable even in the current housing crisis. They intend to market the homes as being capable of net zero annual energy needs when operated in an energy conscious manner. They are committed to building high quality, low energy homes at costs that are comparable to code built homes. Green One Construction Services intends to achieve these results through innovative construction practices and positive relationships with their sub-contractors

Community Overview

Green One Construction was founded by Ben Walsh in 2008 and focuses on high performance residential community projects in Portland Oregon. Ben Walsh previously worked with Tom Walsh & Co. where he acted as project manager for the New Columbia Community revitalization project in Portland. At new Columbia Ben completed 22 Federal Tax credit homes and participated in the Building Industry Research Alliance (BIRA) Building America Program. The new Columbia homes achieved Home Energy Rating Scores in a range from 59 to 66.

The community described in this case study is Green One's Sage Green development located in Portland, Oregon. Portland is located in Building America's Marine Climate Zone and experiences an average annual precipitation of 36 inches, 4522 annual heating degree days (HDD65), and 370 annual cooling degree days (CDD65). This climate provides the greatest opportunity for energy savings from reductions in space heating loads.

Sage Green will consist of 18 homes when complete, all of which will meet the federal tax credit standards. The homes will utilize continuous rigid insulation on the walls R-49 Attic and NFRC 0.20 windows. The homes will be targeted at middle class homeowners looking for a high quality and low energy home. All of the homes will feature PV arrays and are being designed to achieve Net-Zero energy over the course of a year with energy conscious homeowners. The community is provided electricity by Portland General Electric and natural gas by Northwest Natural.

This case study will demonstrate that the Sage Green Community will meet Building America's 50% initial community's goal for the Marine Climate Zone while addressing all of Stage Gate 3 "Must Meet" and "Should Meet" criteria.

"Must Meet" Gate Criteria -- Source Energy Savings

An energy analysis was performed Using BEopt 0.9.03 to model the four units proposed for the Sage Green development. All four unit types demonstrate similar performance and savings. This report will be simplified by showing the results of the BEopt analysis for Unit type C. Unit type C is representative of a typical Sage Green house with 1526 square feet of finished floor area, three bedrooms, and three bathrooms. Two separate simulations were run, one with the BA Benchmark as the reference house, and one with an Oregon code house as the reference house. [Figure 134](#) shows the BEopt source energy use graph for the unit C floor plan with the BA Benchmark as the reference house. All four cardinal orientations were simulated for both reference homes. [Table 185](#) summarizes the findings of both simulations. The energy savings for unit C are averaged over all four orientations and grouped into five main end use categories.

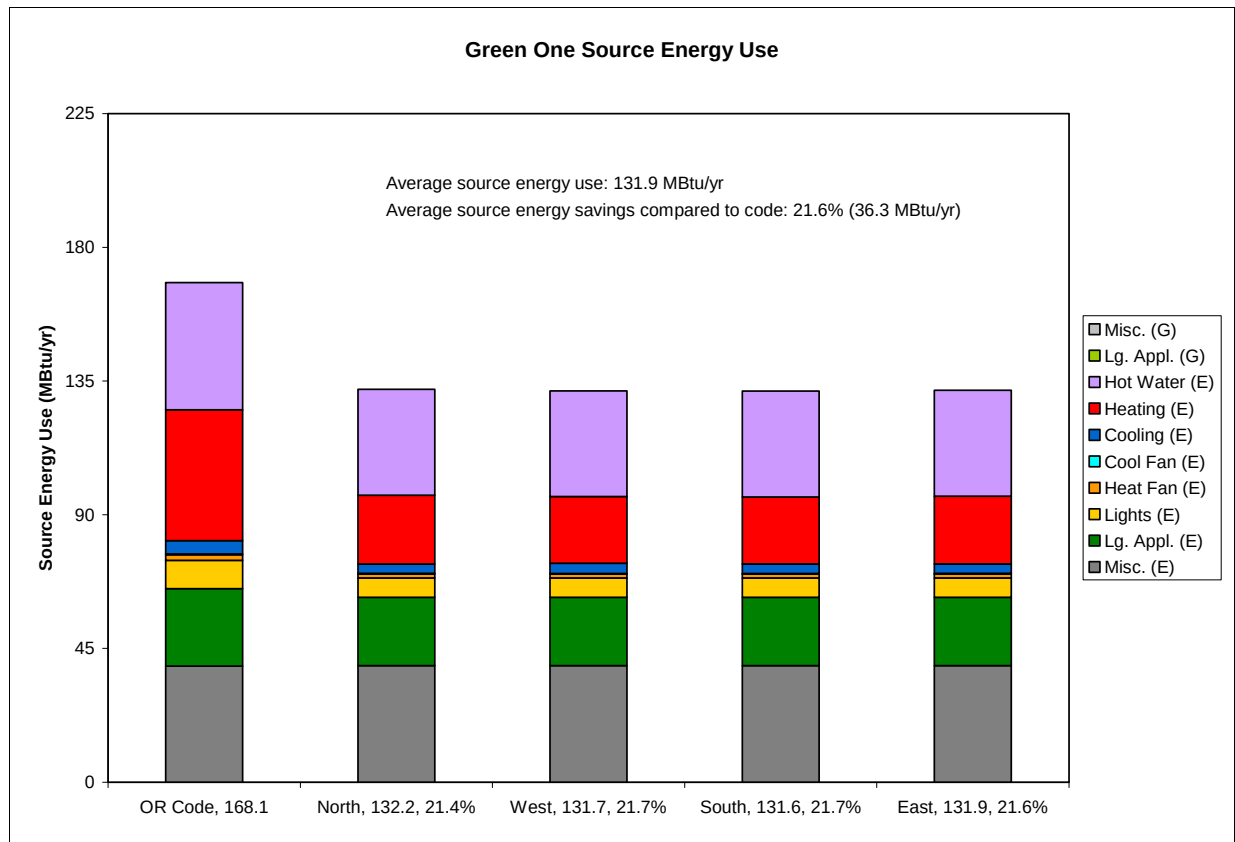


Figure 134: BEopt Source Energy Use
Unit C with the BA Benchmark as the Reference House

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Oregon Code	Unit C	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	115.3	45.9	24.0	79.2%	47.7%	34.5%	13.0%
Space Cooling	15.5	4.7	3.5	77.4%	0.7%	4.5%	0.7%
DHW	45.5	42.8	35.6	21.7%	16.8%	3.7%	4.3%
Lighting	23.3	9.5	6.5	72.0%	31.7%	6.3%	1.8%
Appliances and MELs	64.9	65.2	62.2	4.2%	4.5%	1.0%	1.8%
Total Usage/Savings	264.4	168.1	131.9	50.1%	21.6%	50.1%	21.6%

Table 185: Source Energy Savings for Unit C

As shown in Table 185, the Unit C home at Sage Green will meet the Building America goal of

50% energy savings in the Marine Climate Zone with respect to the BA Benchmark. The critical above code energy reduction features implemented in order to reach this goal are as follows:

- Wall U value 0.035
- R-49 Attic
- Window U value 0.22
- Floor U Value 0.029
- Ventilation with balanced HRV 90% efficient
- Blower door 2.0 ACH-50 (target)
- Heat pump, 18 SEER 9.2 HSPF
- Heat Pump Water Heater, 2.5EF
- Gas Cooking

Sage Green is exceeding specifications prescribed by Oregon High Performance Home tax credit program. This tax credit program utilizes the Northwest Energy Star Homes program to deliver homes that exceed the Energy Star performance specifications. By exceeding these requirements, Ben Walsh will be able to meet the 50% whole house energy savings compared to the BA Benchmark. For a complete list of BEopt inputs for both the Sage Green Unit C plan and the reference house, see Appendix B of the final task report.

“Must Meet” Gate Criteria -- Market Coverage

Sage Green will consist of 18 homes when completed, all of which will meet be 50% above the BA Benchmark. The project is currently underway with permitting, site work and utility services completed. The complete build out of the site will occur in three stages to begin 1st quarter 2010. The project is scheduled to be completed by the end of 2010.

Based on this information, the Sage Green development will pass the Market Coverage “Must Meet” criteria.

“Must Meet” Gate Criteria -- Neutral Cost Target

Sage Green is still in the permitting stage and has yet to incur significant cost for analysis in this report. Ben Walsh is developing building systems that can be completed in a manner that is cost competitive with conventional high quality building practices. This includes development of a wall assembly that utilizes rigid foam directly on the outside of the wall studs and with plywood outside of the foam. This process and assembly can be completed by the framing sub-contractor and should reduce the time and cost of building high performance walls. The assemblies were tested for structural code compliance at Oregon State University.

In addition sound economic construction practices, the 50% whole house energy savings will provide substantial reduction in energy bills, resulting in few, if any, tradeoffs necessary to reach the neutral cost target. Figure 135 shows the BEopt energy cost graph for the Unit C floor

plan with the BA Benchmark as the reference house. These costs are based on the current utility rates in Portland, Oregon, summarized in Table 186 and include both electric and natural gas energy sources. Table 187 demonstrates the annual saving of the Sage Green homes compared to the BA Benchmark and Oregon Code.

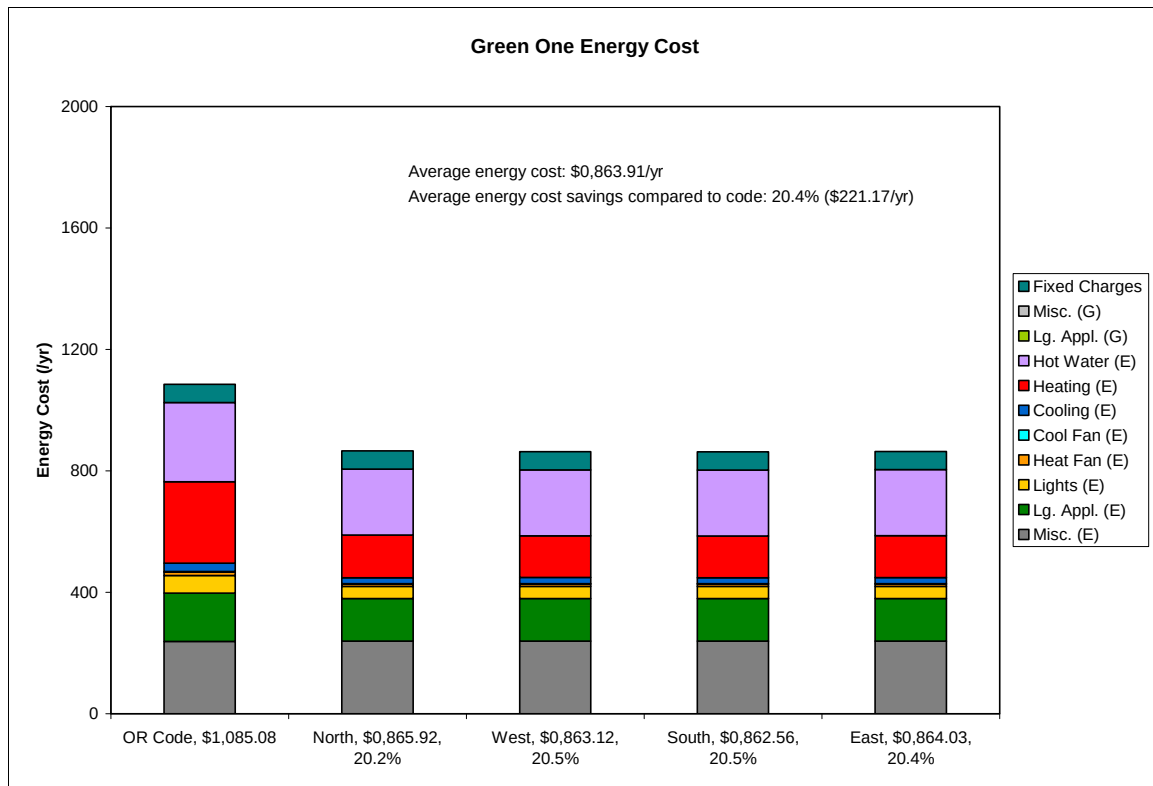


Figure 135: BEopt Energy Cost
Unit C with the BA Benchmark as the Reference House

Electricity Rate	
Utility	Portland General Electric
Marginal	\$0.070/kWh
Fixed	\$5.00/month
Natural Gas Rate	
Utility	Northwest Natural
Marginal	\$1.2245/therm
Fixed	\$6.00/month

Table 186: Current Utility Rates for Portland, Oregon

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	Oregon Code	Unit C	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	115.3	45.9	24.0	79.2%	47.7%	34.5%	13.0%	\$556.68
Space Cooling	15.5	4.7	3.5	77.4%	0.7%	4.5%	0.7%	\$72.90
DHW	45.5	42.8	35.6	21.7%	16.8%	3.7%	4.3%	\$60.09
Lighting	23.3	9.5	6.5	72.0%	31.7%	6.3%	1.8%	\$102.06
Appliances and MELs	64.9	65.2	62.2	4.2%	4.5%	1.0%	1.8%	\$16.52
Total Usage/ Savings	264.4	168.1	131.9	50.1%	21.6%	50.1%	21.6%	\$808.25

Table 187: Modeled annual energy and dollar savings for Sage Green Unit C

It is believed that the energy savings generated in the Sage Green homes will offset the expense of implementing the energy saving measures. In addition to utilizing innovative construction practices, Ben Walsh will qualify for \$3,000 in state tax credits and \$2,900 in utility incentives per home for the energy conservation measures. An additional \$25,000 in state and utility incentives will be available for the installation of 7kW photovoltaic systems on each unit. The cost of implementing the energy saving measures is not yet known but will be compiled in a final report upon completion of the project.

“Should Meet” Gate Criteria -- Marketability

Portland has seen a considerable downturn in the housing market in 2009. Keeping homes marketable in the current housing crisis is a challenge for all builders. Ben Walsh will be utilizing innovative construction methods, a positive relationship with his sub-contractors and well negotiated component pricing to offer the homes at Sage Green at competitive market rates. The main focus of Ben’s marketing message will be the ability for the Sage Green homes to be operated at net zero annual energy for conscientious home owners. Ben believes the combination of excellent energy performance and many healthy home features will give him an edge in marketing the Sage Green Homes.

Ben has experience bringing high performance homes to the marketplace from his involvement in the New Columbia Project. At New Columbia they built 22 Federal tax credit homes and offered them for sale from \$274,900 to \$299,000 which was competitive with code built homes.

Ben has engaged the services of the Energy Trust of Oregon and the Oregon Department of Energy to assist in his marketing strategy. The Energy Trust has implemented a program known as the Energy Performance Score or EPS for new homes. The EPS is a one page summary of the energy performance of the homes akin to the energy rating seen on many appliances. The information generated from the EPS and from this Building America study may be used to show homebuyers the energy savings that their house provides compared to a typical Oregon code house.

“Should Meet” Gate Criteria -- Builder Commitment

Green One was formed by Ben Walsh with the sole purpose of constructing high quality, high value, low energy homes and as such will never build a code home. Ben Walsh and his team have become known in the region for delivering high performance homes at competitive market rates.

In October 2009 Green One invested considerable time and resources developing a ply over foam wall assembly which will be used in the Sage Green homes. Green One took the lead role in designing, building and testing 13 wall assemblies for structural code compliance. The testing evaluated wall assemblies with no foam, 1” of EPS, 1-1/4” of EPS, 1-1/2” of EPS, 2” of

EPS and 4” of. Ben forged a partnership that included Green One Construction, the Oregon Department of Energy, the Energy Trust of Oregon and Building America. Ben Walsh demonstrated his commitment to the project by providing a third of the cost of the testing, Seeking grants for the other two thirds and providing and transporting the wall assemblies.

Ben Walsh’s commitment to building high quality low energy homes is also apparent in his relationship to his sub-contractors. “If people are working on slim margins and if you ask them to up-end their processes, they see this as one thing, and they are absolutely right—loss. They can’t do it,” says Walsh. “Every one of my subcontractors has to know that their profitability is of paramount importance to me.” By demonstrating this commitment to his sub-contractors Ben is able to maintain productive long lasting relationships in which innovative building practices can thrive. The results are lower costs and higher energy savings.

“Should Meet” Gate Criteria -- Gaps Analysis

This analysis will be completed in future reports following construction of the project.

“Should Meet” Gate Criteria -- Quality Assurance

Green One Construction Services is committed to rigorous quality assurance practices. Ben spends considerable time and resources developing new and innovative construction practices and considers a strong quality assurance process to be a key part of evaluating and further improving those processes. While construction has not yet begun at Sage Green, Ben is already demonstrating its commitment to third party verification. He has engaged the Energy Trust of Oregon and the Oregon Department of Energy to validate his energy calculations.

All of the Sage Green homes will be built to the Oregon High Performance Home tax credit standard which includes third party verification of construction practices through the Northwest Energy Star Homes Verifier network. In the state of Oregon 5% to 10% of all Energy Star Homes undergo a second level of quality assurance by an independent third party. Because projects in the High Performance Home tax credit program make up only a small percentage of the total Energy Star Homes program, 100% of these projects are selected for the additional level quality assurance. This will be true of the Sage Green Homes.

Based on this information, the Sage Green community development will pass the Quality Assurance “Should Meet” criteria.

Mololani -- Kaneohe, HI – 50% Hot Humid BP2 (2009)

This report presents the evaluation results of the Forest City Military Communities LLC (referred to herein as “Forest City”) – Mololani Community, Kaneohe, HI development to determine if it meets the Building America 50% whole house energy savings goal when compared to the Building America Benchmark in the Hot/Humid Climate Zone. The community evaluation was

based on the Building America's Stage Gate 3 "Must Meet" and "Should Meet" criteria. The key research partner in this endeavor is Will Boudra, Development Manager of Forest City.

Key Results

This study has determined that the Mololani community qualifies as a Building America 50% Community in the Hot/Humid Climate Zone. This assessment is based on an energy analysis performed using BEopt 0.8.7, incremental costs based on builder estimates, and additional information acquired directly from Forest City. Based on this analysis, the Mololani community is 52.9% more efficient than the Building America Benchmark.

Gate Status

A BEopt energy analysis performed on a representative Mololani house determined energy savings of 52.9% when compared to the Building America Benchmark. Forest City has completed a total of 244 homes, and has plans to construct a total of 759 homes over the next 2 years. Based on the Forest City's energy rate, energy cost savings from BEopt and incremental costs from Forest City, each unit is expected to realize approximately \$1,584.15 per year net cost savings compared to a Building America Benchmark Home. This is due to energy cost savings from energy efficient features and solar hot water substantially in excess of increased construction costs amortized in the mortgage.

Conclusions

Forest City is a large progressive developer and property management company working with the Navy and Marines to deliver comfortable, cost effective energy efficient homes. Forest City builds and manages single family detached and attached homes, townhomes and non-residential projects. As developers of Military housing, Forest City wants to build the most energy efficient and eco-friendly units that they can, to minimize the cost impact on tax payers, who fund construction, operating and maintenance costs for military housing, while providing quality and comfortable housing to the servicemen of our country. They are constructing very energy efficient housing in a climate zone that is largely struggling to meet code, and as such they are a good example of a Building America builder/developer in the Hot/Humid Climate Zone. The Mololani community, currently at 52.9% more efficient than the Building America Benchmark, is an example of their proactive building strategy. Their continuing dedication to improved designs will most certainly create an opportunity for them to build a community that achieves substantially greater than 50% whole house energy savings in the future.

Community Overview

Forest City is managed by Will Boudra, the Development Manager. The community described in this case study is the Mololani community, a development of 4-plex townhomes located in Kaneohe, HI on the island of Oahu. The city is located in Building America's Hot/Humid Climate

Zone and experiences an average annual precipitation of 22.0 inches, and 4474 annual cooling degree days²⁶. This climate provides the opportunity for energy savings from reduction in space cooling loads. The average electric rate is 18 cents/kWh, and due to the high cost of natural gas, \$3.50/therm, their units are all electric.

The Mololani community will consist of 759 homes when complete, and will be built with the quality control guidelines developed by DOE's Builders Challenge. The two-story, three bedroom, 3 bathroom homes are all 2x4 16" o.c. steel-framed construction with R15 insulation. The homes will accommodate E1-E9 and O1-O5 ranked servicemen. The community is provided electricity by Hawaii Electric (HECO), there is no natural gas service.

This case study shows that the Mololani community meets Building America's 50% initial communities goal for the Hot/Humid Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria.

For more information on the Mololani community, contact Will Boudra, Development Manager, at WilliamBoudra@forestcity.net or at (808) 839-8784.

"Must Meet" Gate Criteria -- Source Energy Savings

Using BEopt 0.8.7, an energy analysis was performed on Mololani's 110 floor plan. Floor plans and elevations can be found in Appendix A of the final report. The 110 floor plan is a two-story town home representative of all 4-plex units in the Mololani community, with 1,693 square feet of finished floor area, three bedrooms and three bathrooms. Simulations were evaluated and compared to the BA Benchmark as the reference house. Figure 136 is a graph of the BEopt source energy use for the 110 floor plan compared with the BA Benchmark reference house. All four cardinal orientations (North, South, East and West) were simulated for both the 110 and reference homes. Table 129 summarizes the findings of both simulations. The energy savings for 110 are averaged over all four orientations and grouped into five main end use categories.

Figure 136 compares annual source energy usage between the Building America Benchmark and the average of the 4 cardinal orientations of the Mololani homes. Major end uses are depicted to illustrate the magnitude of each load.

²⁶ <http://www.climate-zone.com/climate/united-states/hawaii/honolulu/>

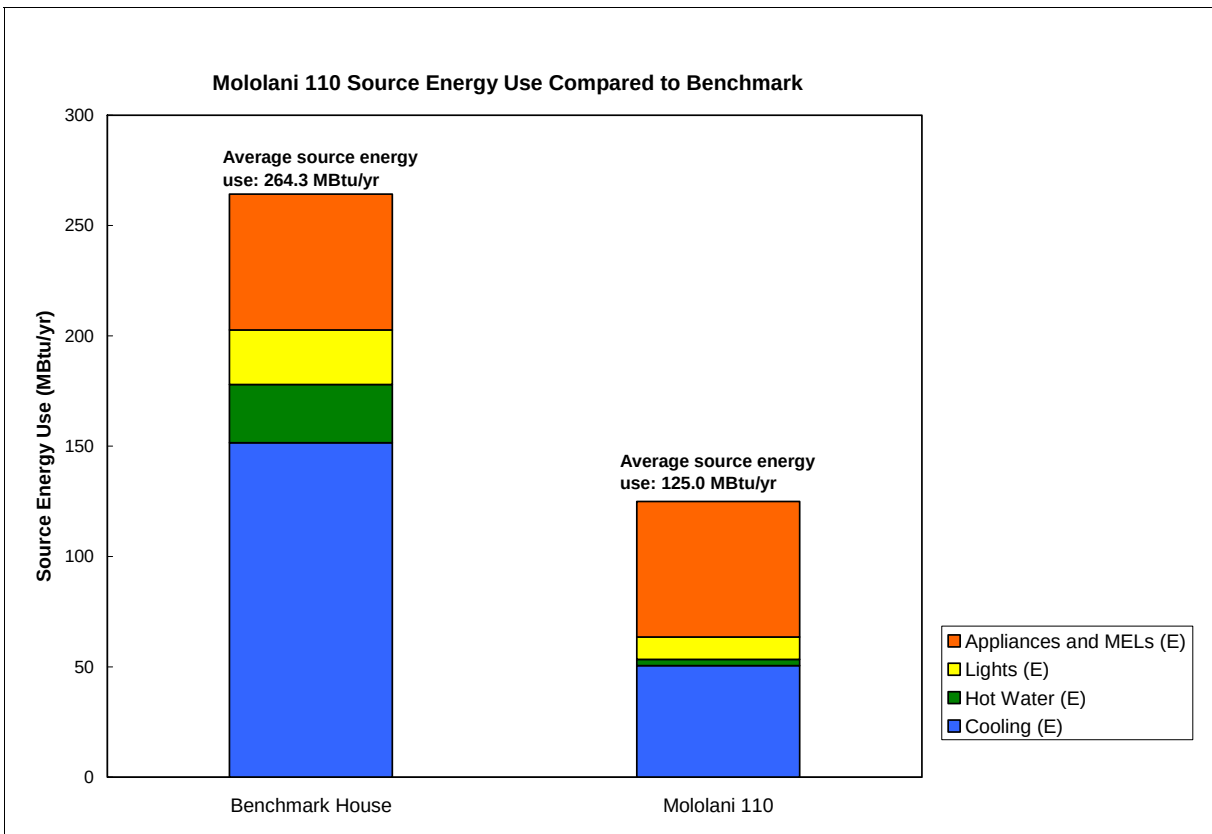


**Figure 136. BEopt Source Energy Use – Average of 4 Cardinal Orientations
110 with the BA Benchmark as the Reference House**

Table 129 compares energy usage between the Building America benchmark, Forest City building practices pre-BA and their new 50% community. The table is broken down into major end use loads.

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark (MBtu/yr)	Pre- Building America (MBtu/yr)	50% Design (MBtu/yr)	Percent of End Use		Percent of Total	
				vs. Benchmark	vs. Pre- BA	vs. Benchmark	vs. Pre- BA
Space Heating	1.0	1.0	1.0	0.0%	0.0%	0.0%	0.0%
Space Cooling	151.6	77.3	49.5	67.3%	35.9%	38.5%	17.2%
DHW	26.4	6.3	2.8	89.5%	55.8%	8.9%	2.2%
Lighting	24.8	11.8	10.2	58.8%	13.4%	5.5%	1.0%
Appliances and MELs	61.5	64.9	61.4	0.2%	5.3%	0.0%	2.1%
Total Usage/ Savings	265.3	161.3	125.0	52.9%	22.5%	52.9%	22.5%

Table 188: Source Energy Savings for the 110 Floor Plan

As shown in Table 188, the designed Mololani house meets the Building America goal of 50% energy savings in the Hot/Humid Climate Zone with respect to the BA Benchmark. The above-code energy efficiency features implemented in order to reach this goal are as follows:

Basic Information			
	Builder	Forest City 50% Community	Forest City Pre-Building America
	Development	Mololani	Baseline
	Plan	110	N/A
	House Type	Single Family Attached	Single Family Attached
	Current Energy Savings (BA Benchmark)	52.9%	35%
	Current Energy Savings (Pre-BA)	17%	N/A
Envelope			
	Wall Insulation	R13 batts 2x4 16"o.c.	R-11 batts 2x4 16" o.c.
	Attic Insulation	R25 Cellulose	R-19 Cellulose
	Garage Ceiling	R11 Fiberglass	R-11
	Radiant Barrier	Yes	None
	Infiltration	0.00020 SLA	0.00050 SLA
Thermal Mass			
	Exposed Slab	40% exposed	No Exposed Floor
Windows & Shading			
	Window Areas	16.0% F50 B50 L0 R0	Matches Actual
	Window Type	Low-e low SHGC (.35/.23)	.40/.40
Lg. Appliances			
	Refrigerator	EnergyStar	Standard
	Cooking Range	EnergyStar – Electric	Electric
	Dishwasher	EnergyStar	Standard
	Clothes Dryer	EnergyStar - Electric	Electric
	Clothes Washer	EnergyStar (H-Axis)	Standard
Lighting			
	Hardwired Lighting	100% CFL	50% CFL
Equipment			
	Air Conditioner	SEER 16	SEER 13
	Water Heater	120 Gal .80 EF Electric	Electric 0.58 EF
	Ducts	R-8	R-4.2
Renewables			
	Solar DHW	32 Sq. Ft Solar DHW	No Solar DHW

Table 189: Feature comparison between Forest City Pre and Post Building America

The ducts were modeled in the attic, which is conservative since the ducts running to the first floor are in conditioned space. Based on the BEopt simulation providing 52.9% energy savings compared to the BA Benchmark, the Mololani community passes the Source Energy Savings “Must Meet” criteria.

“Must Meet” Gate Criteria -- Market Coverage

The Mololani community will consist of 759 homes when completed. 244 homes 50% homes were finished in October of 2009, exceeding the required 10 home minimum. The remaining homes are to be completed as part of a two year build-out. The remaining 515 homes will be constructed to above Builder’s Challenge specifications, using the DOE’s QA/QC protocols to maintain consistency.

Based on this information, Forest City’s Mololani community passes the Market Coverage “Must Meet” criteria.

“Must Meet” Gate Criteria -- Neutral Cost Target

Forest City has been able to keep its costs marketable while implementing energy efficiency features. Costs are naturally higher in Hawaii due to materials being imported, however thanks to their large production scale, they have worked with vendors to quickly bring costs to mature-market costs. This effort is largely driven by their large scale build-out. In addition, the 52.9% whole house energy savings provides substantial reduction in energy bills, allowing the homes to quickly recuperate the incremental cost of the energy efficient features. Figure 137 shows the BEopt energy cost graph for the 110 floor plan compared to that for the BA Benchmark reference house. These costs are based on the current utility rates on Oahu, HI, summarized in Table 189. HECO utilizes a flat rate structure, which was used in our BEopt modeling.

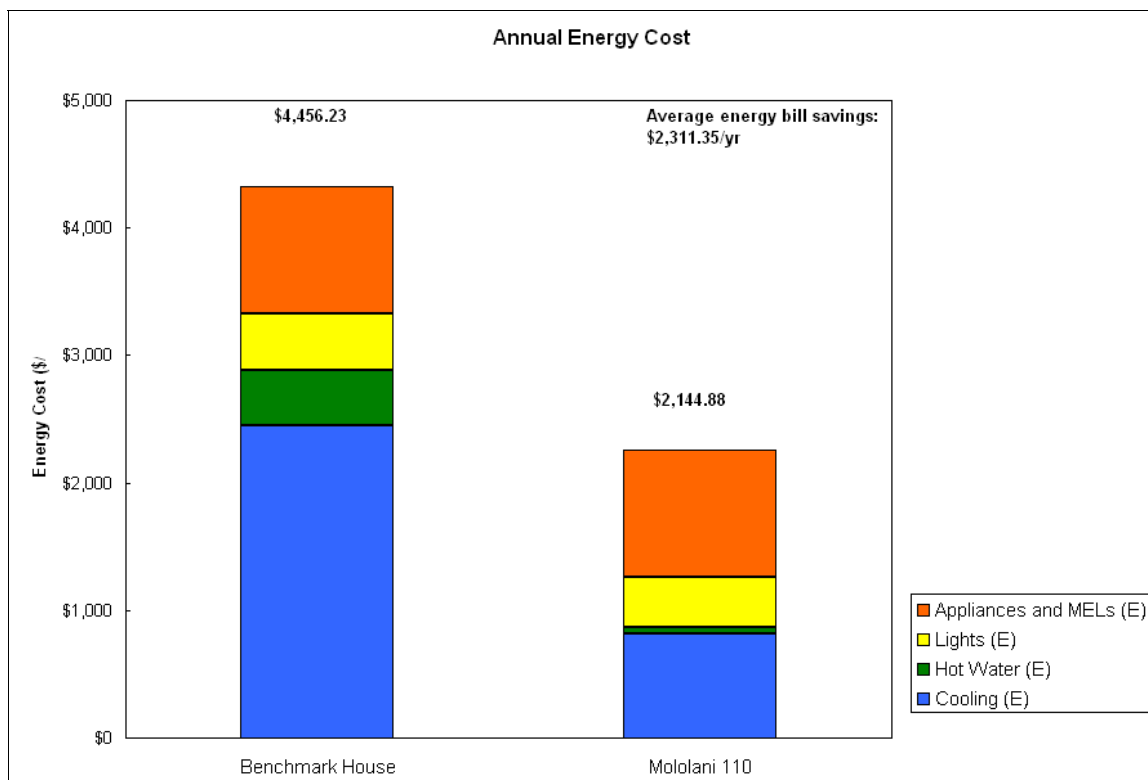


Figure 137. BEopt Energy Cost
110 with the BA Benchmark as the Reference House

Electricity Rate	
Utility	Hawaii Electric Company
Marginal	\$0.18
Fixed	\$8.00/month
Natural Gas Rate	
Utility	N/A
Marginal	N/A
Fixed	N/A

Table 190. Current Utility Rates for Oahu, HI

As part of this effort, BIRA researched cost-mitigating options for the Mololani project, including utility rebates, and state and local tax credits. HECO provides a \$1,000 rebate for solar hot water systems; other than that, Hawaii does not currently have any energy efficiency programs to support this project. While Federal Tax Credits would generally be applicable to homes that are this efficient, due to Forest City's relationship with the US Navy and Marines, they are not eligible for Federal Tax Credits. However, this was mitigated by first determining the most cost effective method of reaching the 50% WHES level, and second by Forest City working with its vendors to establish volume, mature market pricing even though this project employed substantially more efficient products than are typical on the island. Table 191 details

the incremental cost of each energy efficient feature.

Table 192 details the energy savings and the corresponding annual utility bill savings for each of the five main end-use categories in comparison to the BA Benchmark. Again, these values are averaged over all four orientations. As shown in Table 192, the BEopt-estimated annual utility bill savings are \$2,343.94 compared to a Building America Benchmark home. It should be noted that this does not include fluctuations in utility rates or inflation.

The bottom section of Table 192 details the costs and amortized mortgage increment for the efficiency improvements using Forest City's current costs. These costs are derived from the builder's first costs, and are detailed in Appendix D of the final report for each of the energy efficiency features listed. The cost is converted into an amortized mortgage incremental cost assuming a 7% loan over 30 years. Inflation is not considered.

Energy Efficiency Feature	Builder Cost
R-25 Attic Insulation	439.2
R-13 Wall	118.51
Windows (U-Value 0.35, SHGC 0.23)	47.6
SEER 16 Cooling Unit	\$592.00
R-8 Ducts in Attic	\$98.88
Solar Hot Water	\$6,620.00 ²⁷
Energy Star Appliances	\$628.00
Totals	\$8,544.19

Table 191: Detailed Incremental Cost of Energy Efficient Features for 110 Unit

²⁷ <http://www.hawaiienergy.com/solar/index.html>

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	Pre-Building America	50% Design	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Pre-BA	vs. Benchmark	vs. Pre-BA	vs. Benchmark
Space Heating	1.0	1.0	1.0	0.0%	0.0%	0.0%	0.0%	\$0.00
Space Cooling	151.6	77.3	49.5	67.3%	35.9%	38.5%	17.2%	\$1,633.89
DHW	26.4	6.3	2.8	89.5%	55.8%	8.9%	2.2%	\$381.63
Lighting	24.8	11.8	10.2	58.8%	13.4%	5.5%	1.0%	\$235.87
Appliances and MELs	61.5	64.9	61.4	0.2%	5.3%	0.0%	2.1%	\$92.55
Total Usage/ Savings	265.3	161.3	125.0	52.9%	22.5%	52.9%	22.5%	\$2,343.94
					Energy Efficiency Feature			Annual Mortgage Cost vs. Code
					R-25 Attic Insulation			\$35.06
					R-13 Wall			\$9.46
					Windows (U-Value 0.35, SHGC 0.23)			\$3.80
					SEER 16 Cooling Unit			\$47.26
					R-8 Ducts in Attic			\$7.89
					Solar Hot Water			\$606.17
					Energy Star Appliances			\$50.14
					Total Annual Mortgage Cost			\$759.79
					Net Annual Cash Flow to Consumer			\$1,584.15

Table 192. Neutral Cost Analysis for the 110 Floor Plan

As shown in Table 192, the net annual cash flow to the homeowner is approximately \$1,584.15. Based on this information, it is clear that the incremental annual cost of energy improvements is much less than the annual reduction in utility bill costs and Forest City's Mololani community passes the Neutral Cost Target "Must Meet" criteria.

"Should Meet" Gate Criteria -- Marketability

As the developer of housing for military personnel, Forest City is not having problems occupying these homes. The homes are rented out within a week of final inspection. The homes are being constructed as a plan to replace older, less efficient homes, and to increase the number of units to improve housing for our troops and maximize the use of available land. The homes are being constructed for Junior Officers, having ranks between E1-E9 and O1-O5. Forest City will also using this opportunity to educate younger enlisted servicemen on the benefits of energy efficient homes, and how to minimize occupant energy usage.

The training well be especially important if Forest City switches to a monthly allowance type billing system for utility usage. This system is similar to a Tiered energy rate structure, except Tier 1 would be covered, and Tier 2 would have to be paid for by the current occupants. Education along with this structure would help to greatly reduce energy consumption in each of the units.

However, if these homes were for sale, they would still be cost competitive with the market. The average cost for a comparable house is around \$600,000²⁸, and with a monthly rent of \$2,500, the 30 year amortized cost is \$372,271.24, almost half the market rate of homes in the area. In addition, the incremental cost of the energy efficient features is dramatically offset by the reduced utility rate, largely due to the high electricity rate in Hawaii.

Based on current sales and marketing information, Forest City's Mololani community passes the Marketability "Should Meet" criteria.

"Should Meet" Gate Criteria -- Builder Commitment

Forest City Military Communities LLC made a commitment to build all of their homes as energy efficient homes. In 2007, they began construction of homes at the 35% BA benchmark. Since then, they have further upgraded features and construction practices to reach the 50% WHES level, and are committed to building their homes beyond both Energy Star and Builders Challenge program benchmarks.

Forest City has committed significant time and resources to educate their staff, subcontractors, and customers about the benefits of high performance homes. Their commitment to energy

²⁸ http://www.zillow.com/homes/kaneohe,-hi_rb/#/homes/for_sale/Kaneohe-HI/sf,multi_type/12157_rid/0-1700_size/21.443583,-157.726106,21.367988,-157.856397_rect/12_zm/1_rs/

efficiency is evident by the amount of building science training that Forest City staff has received from the BIRA team. In 2009, BIRA traveled to Forest City's numerous communities to test and inspect homes both prior to drywall and near final, and to train the field staff. This has resulted in improved insulation installation, tighter homes and improved ducting to improve the homes' efficiency to these improved BAP levels. This team commitment helps differentiate Forest City from other production builders.

Based on this builder's proactive energy efficiency practices at the Mololani community, and their expressed commitments to build to the Builders Challenge and to the 50% WHES level in other communities, Forest City passes the Builder Commitment "Should Meet" criteria.

"Should Meet" Gate Criteria -- Gaps Analysis

Forest City had a few problems with proper sealing of the home, and installation of insulation and ducting. Construction practices in Hawaii are not as refined or rigorous as in some other parts of the nation, and even though Forest City is committed to more efficient homes, we experienced some difficulties in getting subcontractors to meet the required installation techniques, or QA/QC. These difficulties were overcome with sufficient training and improved Forest City QA methods. However, infrastructure for good market penetration of these quality construction practices is currently lacking in HI.

Problems included gaps and compression in the insulation, air gaps in the top and bottom plates, and unsealed air handlers and plenums. Fortunately, these issues were easy to address to subcontractors that were eager to learn. Today, their homes are testing at <2.5 SLA and <4% duct leakage with very good insulation standards.

The final gap with Forest City's Mololani Community has to do with occupant driven electric loads. As a military community, the occupants do not pay for their utility bills, and as such are not as conscientious about either the impacts of their energy-use behaviors (e.g., thermostat settings) nor the magnitude and costs of their energy consumption. This has already been manifested in the utility bills for the first 244 homes built, ranging from \$94 to \$408 compared to our BEopt estimate of \$178.75. To combat this issue, Forest City is taking a two-step approach: Home Energy Management (HEM) systems and utility allowances.

Regarding use of HEM systems, Forest City will be prototyping the Verve Living System in three of their homes to test the feasibility, constructability and energy savings produced by the system. The HEM system will reduce lighting and cooling loads through a whole house control switch, as well as occupant, door and window sensors. If a door or window is left open, the HVAC system will automatically shut down.

Additionally, Forest City is putting more responsibility on the occupants to properly manage their energy use, by imposing a utility bill allowance on each unit. The allowance is similar to a 2 Tier structure, the first Tier of energy use will be covered by Forest City, and everything above

will have to be paid by the occupants. This approach, coupled with a HEM system and educational material should reduce the energy consumption of the occupants.

In the future, Forest City plans on working with Building America to continue to develop increasingly efficient homes that further reduce heating and cooling loads.

“Should Meet” Gate Criteria -- Quality Assurance

Forest City has demonstrated a strong commitment to quality assurance. Working with BIRA, Forest City has adopted aggressive inspection and third-party verification protocols and procedures to ensure that everything is properly installed and working according to the BA and Builders Challenge quality criteria. BIRA has worked with the developer’s superintendents and construction managers to ensure that their construction protocols are up-to-date, and that they have procedures in place to verify everything is meeting specified efficiency and quality specifications.

Based on this information, Forest City’s Mololani community passes the Quality Assurance “Should Meet” criteria.

Artistic Homes – NM/CO – 50% Cold and Hot/Mixed Dry BP2 (2009)

The report documents the evaluation of Artistic Homes’ twelve (12) net zero energy homes (scattered in Cold and Hot-Dry Zones) relative to the Building America’s whole house energy savings (WHES) goal when compared to the Building America Benchmark in the Cold and Hot/Mixed-Dry Climate Zones. These 12 homes (or a Net-ZEH community) will be evaluated based on Building America’s Stage Gate 3 “Must Meet” and “Should Meet” Gate Criteria.

Key Results

Artistic Homes’ net zero energy homes qualify as a Building America 50%+ Community in the Cold and Hot/Mixed-Dry climate zones based on an energy analysis performed using EnergyGauge, collected utility bills, the incremental costs based on builder estimates, and additional information gained first hand from the builder.

Gate Status

The community remains in Stage Gate 3. The net zero energy homes have been calculated to have at least 55.7% WHES without PV. This can be attributed to many above-code features, listed in Appendix C of the final report. These features will reduce the annual bills enough to offset the additional incremental cost of the above-code features, thus meeting the neutral cost analysis criteria. Further energy usage data will be collected when they are available to verify estimated savings. While the builder has adopted this approach with the features, they are still looking for ways to build the houses more cost effectively.

Conclusions

Energy simulations have shown that the net zero homes will meet the 50%+ WHES level. Preliminary results from utility bills already collected show that energy simulations have overestimated energy usage and underestimated energy generation. This has a positive effect on the neutral cost analysis, as increasing utility savings will help reinforce cost neutrality. Further utility bills will be collected to verify the estimated energy usage levels.

Artistic Homes is a good example of a Building America Builder. They have adopted a practice to make all of their standard baseline home has WHES levels of near 50%, and are motivated to explore possibilities to build homes in a more cost effective manner. Their commitment to building cost effective, affordable high performance homes makes them a valuable partner to achieving the next steps to reach commercially viable zero energy homes by 2020.

Community Overview

Artistic Homes is a leading-edge, family-owned production builder in the southwest region and continues to push the envelope with their LEED-H Platinum, near-zero energy production homes.

Recently, Artistic Homes has committed to providing high performance, energy saving homes as their baseline, while offering true ZEH as an option. They have led the way in New Mexico in terms of energy-efficient designs while demanding high standards of construction. This allows them to include an energy use and home comfort guarantee with every home.

Artistic Homes has developed ten net zero energy houses, and are constructing two more Net-ZEHs. The homes are located in various cities throughout New Mexico and Colorado, including Albuquerque, Farmington, Rio Rancho, Durango, and Bayfield. Some of the cities are located within Cold climates and some are located in Mixed-Dry climates.

This case study shows that Artistic Homes net zero homes meet the Building America's 50%+ WHES initial communities' goal for Hot/Mixed-Dry and Cold climates, while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" Gate criteria.

For more information about Artistic Homes, visit their website at <http://www.artistichomes.com/>.

"Must Meet" Gate Criteria -- Source Energy Savings

Table 193 and Table 194 show the WHES calculations of the same plan (plan 2118, available in Appendix B of the final report) in two different climate zones: one in a Hot/Mixed-Dry climate (Albuquerque), and one in a Cold climate (Farmington). This plan is representative of a typical net zero energy home schematic and size that Artistic Homes currently builds. The projected

source energy savings were derived from Energy Gauge 2.7.0. Without PV generation, the Albuquerque home is projected to have a WHES of 55.7%. The Farmington house is projected to have a WHES of 55.9%. PV generation will increase the projected savings to over 90% WHES. This is due to the more energy efficient, above code features installed into the house.

Description End Use	Estimated Annual Source Energy		Estimated Source Energy Savings
	Benchmark (Mbtu/yr)	Actual (Mbtu/yr)	
Space Heating	121.2	31.7	73.9%
Space Cooling	38.0	6.7	82.2%
DHW	42.3	6.3	85.0%
Lighting	27.7	8.0	72.1%
Appliances and MELs	64.5	62.3	3.4%
Outside Air Ventilation Fan	2.1	16.4	-696.6%
Total	296.8	131.4	55.7%

Table 193: Albuquerque WHES Summary (Hot/Mixed Dry)

Description End Use	Estimated Annual Source Energy		Estimated Source Energy Savings
	Benchmark (Mbtu/yr)	Actual (Mbtu/yr)	
Space Heating	148.4	41.0	72.4%
Space Cooling	34.7	5.8	83.3%
DHW	45.2	8.6	80.9%
Lighting	28.7	8.0	72.1%
Appliances and MELs	64.5	62.3	3.4%
Outside Air Ventilation Fan	2.1	17.0	-710.9%
Total	323.6	142.7	55.9%

Table 194: Farmington WHES Summary (Cold)

As shown in Table 193 and Table 194, both houses exceed the next Building America goal of 50%+ WHES with respect to the BA benchmark in Hot/Mixed Dry and Cold climates. The features were selected prior to BIRA involvement. Artistic Homes had previously worked with the Building Science Consortium (BSC), another Building America team, and came to use the majority of these features in their standard net zero home design. The critical above code energy reduction features implemented in order to reach these savings levels are as follows:

- OVE framing:
 - R-21 wall insulation
 - R-50 attic insulation
- 0.31/0.31 U-value/SHGC windows
- 9.0 HSPF, 15 SEER heat pump
- Ducts inside conditioned space

- 100% fluorescent lighting
- Flat plate collector solar hot water

The homes are all electric. The Albuquerque house is expected to use 11,124 kWh annually, while generating 10,570 kWh via the photovoltaic panels. 554 kWh is the estimated net electricity used. The Farmington house is expected to use 11,124 kWh annually, while generating 10,570 kWh via the photovoltaic panels. 554 kWh is the estimated net electricity used.

Analyzing the monthly utility bills from a net zero house in Rio Rancho (see Appendix H of the final report) shows a positive return on the amount of money due from the months of April through August. The house generated on a monthly basis between 850-1,011 kWh. Electricity usage fluctuated between months, but the highest month out of the months collected was 254 kWh. These figures are more favorable than the estimated 554 kWh annual net electricity used and results in utility bill refunds between \$110-130 per month.

“Must Meet” Gate Criteria -- Market Coverage

Artistic Homes has completed 10 zero energy homes. They are currently building an additional 2 more for a total of 12. Therefore, this project meets the criteria for market coverage minimum of 10 homes.

“Must Meet” Gate Criteria -- Neutral Cost Target

The 55.7% reduction in the Albuquerque house’s whole house energy savings provides a substantial reduction in energy bills. The incremental cost calculation (see Appendix E of the final report) shows that despite adding in the advanced energy features, the savings in utility bills will offset the additional cost. When financed as part of a 30-year mortgage at 7% interest, the incremental annual cost will be reduced by \$483.09 after utility savings are taken into account (see Table E-2 of the final report). The same house in Farmington should also see a similar reduction in the incremental annual cost.

Based on this information, it is clear that the incremental annual cost of energy improvements is less than the annual reduction in utility bill costs. Therefore, the Artistic Homes prototype passes the Neutral Cost Target “Must Meet” criteria. Monthly utility bills collected also suggest that the estimated utility bill savings figures used in the cost neutral analysis are underestimated, thus further reinforcing cost neutrality.

“Should Meet” Gate Criteria -- Marketability

Keeping homes marketable in the current housing market has been a challenge for Artistic Homes. The main focus has been keeping costs down while including large ticket items such as solar thermal and photovoltaics. However, Artistic believes that their differentiation as energy

efficient home builders can also be used as a marketing tool.

One such marketing flyer that Artistic uses to help potential homebuyers see value in the higher upfront costs deals with showing the true cost of ownership after 7, 17, and 30 years, shown below in Table 195 and Table 196. (see Appendix I of the final report for original copy)

	Base Amount			End of yr 7		
	New Code Built Home	Artistic Standard	Artistic ZEH	New Code Built Home	Artistic Standard	Artistic ZEH
Basic Information						
Square footage	2157	2157	2157	2157	2157	2157
LEED-H	N/A	Silver	Platinum	N/A	Silver	Platinum
E-Scale	100	53	0	100	53	0
Photovoltaic	No	No	5.5 kWh	No	No	5.5 kWh
Solar Thermal	No	No	Yes	No	No	Yes
EPA IAQ	No	Yes	Yes	No	Yes	Yes
Sales Price	\$211,000	\$220,000	\$270,000	\$211,000	\$220,000	\$270,000
Cost of Ownership						
Yearly Mortgage Payment	\$13,596.00	\$14,172.00	\$17,400.00	\$95,172.00	\$99,204.00	\$121,800.00
Utility Cost	\$2,500.00	\$1,565.00	\$0.00	\$19,745.74	\$12,360.83	\$0.00
Total Yearly Expenditures	-	-	-	\$114,917.74	\$111,564.83	\$121,800.00
Ownership Savings						
Renewable Energy Credit	\$0.00	\$0.00	\$1,268.47	\$0.00	\$0.00	\$8,879.27
Utility Savings	\$0.00	\$935.00	\$2,500.00	\$0.00	\$7,384.91	\$19,745.74
1st Time Homebuyer Tax Credit	\$8,000.00	\$8,000.00	\$8,000.00	\$8,000.00	\$8,000.00	\$8,000.00
NM Sustainable Building Tax Credit	\$0.00	\$7,274.75	\$13,089.05	\$0.00	\$7,274.75	\$13,089.05
Federal Solar Tax Credit 30%	\$0.00	\$0.00	\$11,484.00	\$0.00	\$0.00	\$11,484.00
Federal Solar Thermal Tax Credit	\$0.00	\$0.00	\$1,692.00	\$0.00	\$0.00	\$1,692.00
NM Solar Tax Credit 10%	\$0.00	\$0.00	\$3,828.00	\$0.00	\$0.00	\$3,828.00
Total Yearly Offsets	-	-	-	\$8,000.00	\$22,659.66	\$66,718.06
True Cost of Ownership	-	-	-	\$106,917.74	\$88,905.18	\$55,081.94
Average Cost per year	-	-	-	\$15,273.96	\$12,700.74	\$7,868.85

Table 195: True Cost of Ownership after Base and 7 Years

	End of yr 17			End of yr 30		
	New Code Built Home	Artistic Standard	Artistic ZEH	New Code Built Home	Artistic Standard	Artistic ZEH
Basic Information						
Square footage	2157	2157	2157	2157	2157	2157
LEED-H	N/A	Silver	Platinum	N/A	Silver	Platinum
E-Scale	100	53	0	100	53	0
Photovoltaic	No	No	5.5 kWh	No	No	5.5 kWh
Solar Thermal	No	No	Yes	No	No	Yes
EPA IAQ	No	Yes	Yes	No	Yes	Yes
Sales Price	\$211,000	\$220,000	\$270,000	\$211,000	\$220,000	\$270,000
Cost of Ownership						
Yearly Mortgage Payment	\$231.13	\$240,924.00	\$295,800.00	\$407,880.00	\$425,160.00	\$522,000.00
Utility Cost	\$59,243.78	\$37,086.61	\$0.00	\$140,212.34	\$87,772.93	\$0.00
Total Yearly Expenditures	\$290,375.78	\$278,010.61	\$295,800.00	\$548,092.34	\$512,932.93	\$522,000.00
Ownership Savings						
Renewable Energy Credit	\$0.00	\$0.00	\$15,221.61	\$0.00	\$0.00	\$15,221.61
Utility Savings	\$0.00	\$22,157.17	\$59,243.78	\$0.00	\$52,439.42	\$140,212.34
1st Time Homebuyer Tax Credit	\$8,000.00	\$8,000.00	\$8,000.00	\$8,000.00	\$8,000.00	\$8,000.00
NM Sustainable Building Tax Credit	\$0.00	\$7,274.75	\$13,089.05	\$0.00	\$7,274.75	\$13,089.05
Federal Solar Tax Credit 30%	\$0.00	\$0.00	\$11,484.00	\$0.00	\$0.00	\$11,484.00
Federal Solar Thermal Tax Credit	\$0.00	\$0.00	\$1,692.00	\$0.00	\$0.00	\$1,692.00
NM Solar Tax Credit 10%	\$0.00	\$0.00	\$3,828.00	\$0.00	\$0.00	\$3,828.00
Total Yearly Offsets	\$8,000.00	\$37,431.92	\$112,558.44	\$8,000.00	\$67,714.17	\$193,527.00
True Cost of Ownership	\$282,375.78	\$240,578.69	\$183,241.56	\$540,092.34	\$445,218.76	\$328,473.00
Average Cost per year	\$16,610.34	\$14,151.69	\$10,778.92	\$18,003.08	\$14,840.63	\$10,949.10

Table 196: True Cost of Ownership after 17 and 30 Years

Based on this information, Artistic Homes' community passes the Marketability "Should Meet" Stage Gate criteria

"Should Meet" Gate Criteria -- Market Coverage

Artistic builds homes in Mixed-Dry and Cold climates in two states: New Mexico and Colorado. These climates and states cover a range of different weather conditions and construction practices via jurisdictions satisfying the Market Coverage "Should Meet" Stage Gate criteria.

"Should Meet" Gate Criteria -- Builder Commitment

Artistic Homes prides itself to "raising the bar" when it comes to building high performance homes. A standard Artistic Homes house will typically be close to 50% WHES; Artistic also offer net zero energy homes as an option. They are currently working towards building net zero homes that are cost effective and affordable. In fact, Artistic Homes is planning to start construction on a 100% Net-ZEH community of 500 homes in Aztec, NM in early 2010.

Their energy efficiency ways have led them to be a finalist for the 2010 Energy Value Housing Award, an energy efficiency award honoring builders who voluntarily incorporate energy efficiency into all aspects of new home construction. A homeowner of one of the net zero homes has said,

"I wanted a larger home without the added cost of a bigger monthly utility bill that comes with it. Artistic Homes have allowed me to have the most efficient home possible with a True Net Zero package at a price I could afford. Taking advantage of the all energy tax credits (including a monthly credit from the utility company) allows me to pay off the house in half the time without ever having to worry about a monthly utility bill. Having a LEED-H Platinum certified house is satisfying to know that I am doing my part to reduce my overall carbon footprint."

"Should Meet" Gate Criteria -- Gaps Analysis

Although the analysis has shown that cost neutrality has been met, there are still builders out there wary to meet the upfront cost to upgrade their standard building features. To overcome this market barrier, additional research is needed to find alternative, less expensive methods that do not sacrifice energy efficiency. Artistic is open to such suggestions and this is another reason why Artistic is an important partner; they are committed to pushing the limits in terms of energy efficiency while doing it as cost effectively as possible. Information regarding documentation of failures, recommendations for policy improvements, and optimal builder business practices will be collected to develop a production construction process that ensures correct installation steps that meets building standards.

“Should Meet” Gate Criteria -- Quality Assurance

Artistic Homes has demonstrated a strong commitment to quality assurance. As part of their ENERGY STAR and federal tax credit standards, all homes must pass third-party testing and inspections. Inspections include:

- Total duct leakage test at system rough-in on every house
- Insulation and thermal by-pass inspection
- On-site confirmation of window U-values
- On-site confirmation of qualifying HVAC and appliance equipment efficiencies
- On-site lighting inspection
- Prior to occupancy, at least 10% of homes are retested to confirm duct leakage to the exterior is less than 6% at 50 Pascals and blower door tests to confirm envelope tightness.

Artistic’s process emphasizes coordination with subcontractors who share and support their commitment to producing a superior product and who take pride in maintaining high standards of quality.

Waikulu – Oahu, HI – 50% Hot Humid BP2 (2009)

This report presents the evaluation results of the Forest City Military Communities LLC (referred to herein as “Forest City”) – Waikulu Community, Oahu, HI development to determine if it meets the Building America 50% whole house energy savings goal when compared to the Building America Benchmark in the Hot/Humid Climate Zone. The community evaluation was based on the Building America’s Stage Gate 3 “Must Meet” and “Should Meet” criteria. The key research partner in this endeavor is Will Boudra, Development Manager of Forest City.

Key Results

This study has determined that the Waikulu community qualifies as a Building America 50% Community in the Hot/Humid Climate Zone. This assessment is based on an energy analysis performed using BEopt 0.9.02, incremental costs based on builder estimates, and additional information acquired directly from Forest City. Based on this analysis, the Waikulu community is 51.4% more efficient than the Building America Benchmark.

Gate Status

A BEopt energy analysis performed on a representative Waikulu house determined energy savings of 51.4% when compared to the Building America Benchmark. Forest City has completed a total of 165 homes, and has plans to construct a total of 184 homes over the next 2 years. Based on the Forest City’s energy rate, energy cost savings from BEopt and incremental costs from Forest City, each unit is expected to realize approximately \$1072.67 per

year net cost savings compared to a Building America Benchmark Home. This is due to energy cost savings from energy efficient features and solar hot water substantially in excess of increased construction costs amortized in the mortgage.

Conclusions

Forest City is a large progressive developer and property management company working with the Navy and Marines to deliver comfortable, cost effective energy efficient homes. Forest City builds and manages single family detached and attached homes, townhomes and non-residential projects. As developers of Military housing, Forest City wants to build the most energy efficient and eco-friendly units that they can, to minimize the cost impact on tax payers, who fund construction, operating and maintenance costs for military housing, while providing quality and comfortable housing to the servicemen of our country. They are constructing very energy efficient housing in a climate zone that is largely struggling to meet code, and as such they are a good example of a Building America builder/developer in the Hot/Humid Climate Zone. The Waikulu community, currently at 51.4% more efficient than the Building America Benchmark, is an example of their proactive building strategy. Their continuing dedication to improved designs will most certainly create an opportunity for them to build a community that achieves substantially greater than 50% whole house energy savings in the future.

Overview

Forest City is managed by Will Boudra, the Development Manager. The community described in this case study is the Waikulu community, a development of duplex townhomes located in Kaneohe, HI on the island of Oahu. The city is located in Building America's Hot/Humid Climate Zone and experiences an average annual precipitation of 22.0 inches, and 4474 annual cooling degree days²⁹. This climate provides the opportunity for energy savings from reduction in space cooling loads. The average electric rate is 18 cents/kWh, and due to the high cost of natural gas, \$3.50/therm, their units are all electric.

The Waikulu community will consist of 349 homes when complete, and will be built with the quality control guidelines developed under the DOE's Builders Challenge program. The two-story, three bedroom, 3 bathroom homes are all 2x4 16" o.c. steel-framed construction with R11 insulation. The homes will accommodate E1-E9 and O1-O5 ranked servicemen. The community is provided electricity by Hawaii Electric (HECO). There is no natural gas service.

This case study shows that the Waikulu community meets Building America's 50% initial communities goal for the Hot/Humid Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria.

For more information on the Waikulu community, contact Will Boudra, Development Manager,

²⁹ <http://www.climate-zone.com/climate/united-states/hawaii/honolulu/>

at WilliamBoudra@forestcity.net or at (808) 839-8784.

“Must Meet” Gate Criteria -- Source Energy Savings

Using BEopt 0.9.02, an energy analysis was performed on Waikulu’s 1651 floor plan. Floor plans and elevations can be found in Appendix B of the final report. The 1651 floor plan is a two-story town home representative of all duplex units in the Waikulu community, with 1,651 square feet of finished floor area, three bedrooms and three bathrooms. Simulations were evaluated and compared to the BA Benchmark as the reference house. Figure 138 is a graph of the BEopt source energy use for the 1651 floor plan compared with the BA Benchmark reference house. All four cardinal orientations (North, South, East and West) were simulated for both the 1651 and reference homes. Figure 138 compares annual source energy usage between the Building America Benchmark and the average of the 4 cardinal orientations of the Waikulu homes. Major end uses are depicted to illustrate the magnitude of each load.

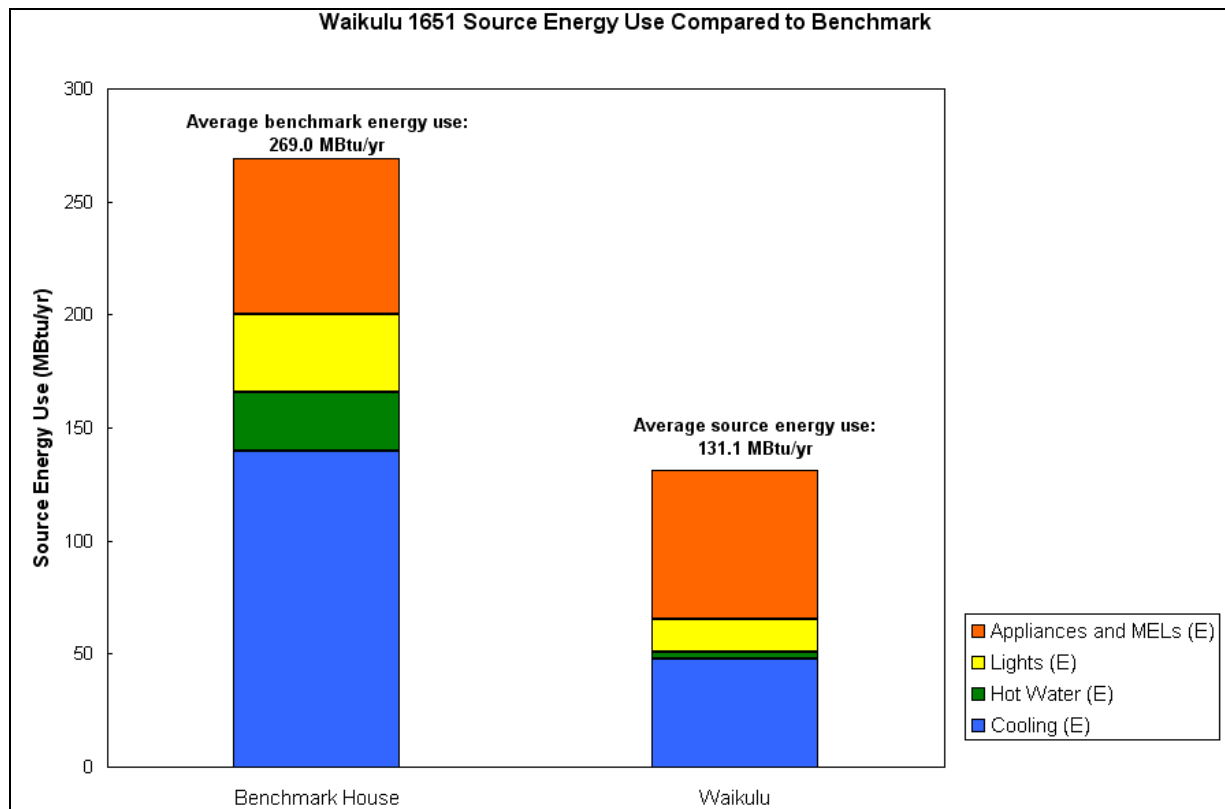


Figure 138. BEopt Source Energy Use – average of 4 cardinal orientations 1651 with the BA Benchmark as the Reference House

Table 197 summarizes the findings of both simulations. The energy savings for 1651 are averaged over all four orientations and grouped into five main end-use categories. Table 197 is broken down into major end-use loads and compares energy usage between the Building America benchmark, Forest City building practices pre-BA and their new 50% community.

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Pre-Building America	50% Design	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Pre-BA	vs. Benchmark	vs. Pre-BA
Space Heating	1.0	1.0	1.0	0.0%	0.0%	0.0%	0.0%
Space Cooling	139.6	77.3	47.0	66.4%	39.3%	34.3%	18.8%
DHW	26.3	6.3	3.3	87.6%	48.0%	8.5%	1.9%
Lighting	34.4	11.8	14.4	58.2%	-22.1%	7.4%	-1.6%
Appliances and MELs	68.6	64.9	65.7	4.3%	-1.2%	1.1%	-0.5%
Total Usage/Savings	270.0	161.3	131.3	51.4%	18.6%	51.4%	18.6%

Table 197. Source Energy Savings for the 1651 Floor Plan

As shown in Table 197, the designed Waikulu house meets the Building America goal of 50% energy savings in the Hot/Humid Climate Zone with respect to the BA Benchmark. The above-code energy efficiency features implemented in order to reach this goal are as follows:

Basic Information			
	Builder	Forest City 50% Community	Forest City Pre-Building America
	Development	Waikulu	Baseline
	Plan	1651	N/A
	House Type	Single Family Attached	Single Family Attached
	Current Energy Savings (BA Benchmark)	51.4%	35%
	Current Energy Savings (Pre-BA)	18.6%	N/A
Envelope			
	Wall Insulation	R11 batts 2x4 16"o.c.	R-11 batts 2x4 16" o.c.
	Attic Insulation	R19 Cellulose	R-19 Cellulose
	Garage Ceiling	R11	R-11
	Radiant Barrier	Yes	None
	Infiltration	0.00020 SLA	0.00050 SLA
Thermal Mass			
	Exposed Slab	40% exposed	No Exposed Floor
Windows & Shading			
	Window Areas	11.7% F89 B28 L49 R0	Matches Actual
	Window Type	Low-e low SHGC (.35/.23)	.40/.40
Lg. Appliances			
	Refrigerator	EnergyStar	Standard
	Cooking Range	EnergyStar – Electric	Electric

	Dishwasher	EnergyStar	Standard
	Clothes Dryer	EnergyStar - Electric	Electric
	Clothes Washer	EnergyStar (H-Axis)	Standard
Lighting			
	Hardwired Lighting	100% CFL	50% CFL
Equipment			
	Air Conditioner	SEER 16	SEER 13
	Water Heater	80 Gal .95 EF Electric	Electric .58 EF
	Ducts	R-8 in Conditioned Space	R-4.2
Renewables			
	Solar DHW	32 Sq. Ft Solar DHW	No Solar DHW

Table 198. Feature comparison between Forest City Pre and Post Building America

Based on the BEopt simulation providing 51.4% energy savings compared to the BA Benchmark, the Waikulu community passes the Source Energy Savings “Must Meet” criteria.

“Must Meet” Gate Criteria -- Market Coverage

The Waikulu community will consist of 349 homes when completed. 165 homes were finished in October of 2009, exceeding the required 10 home minimum. The remaining homes are to be completed as part of a two-year build-out. The remaining 184 homes will be constructed to above Builder’s Challenge specifications, using the DOE’s QA/QC protocols to maintain consistency.

Based on this information, Forest City’s Waikulu community passes the Market Coverage “Must Meet” criteria.

“Must Meet” Gate Criteria -- Neutral Cost Target

Forest City has been able to keep its costs marketable while implementing energy efficiency features. Costs are naturally higher in Hawaii due to materials being imported. However, thanks to their large production scale, they have worked with vendors to quickly bring costs to mature-market costs. This effort is largely driven by their large scale build-out. In addition, the 51.4% whole house energy savings provides substantial reduction in energy bills, allowing the homes to quickly recuperate the incremental cost of the energy efficient features. Figure 139 shows the BEopt energy cost graph for the 1651 floor plan compared to that for the BA Benchmark reference house. These costs are based on the current utility rates on Oahu, HI, summarized in Table 199. HECO utilizes a flat rate structure, which was used in our BEopt modeling.

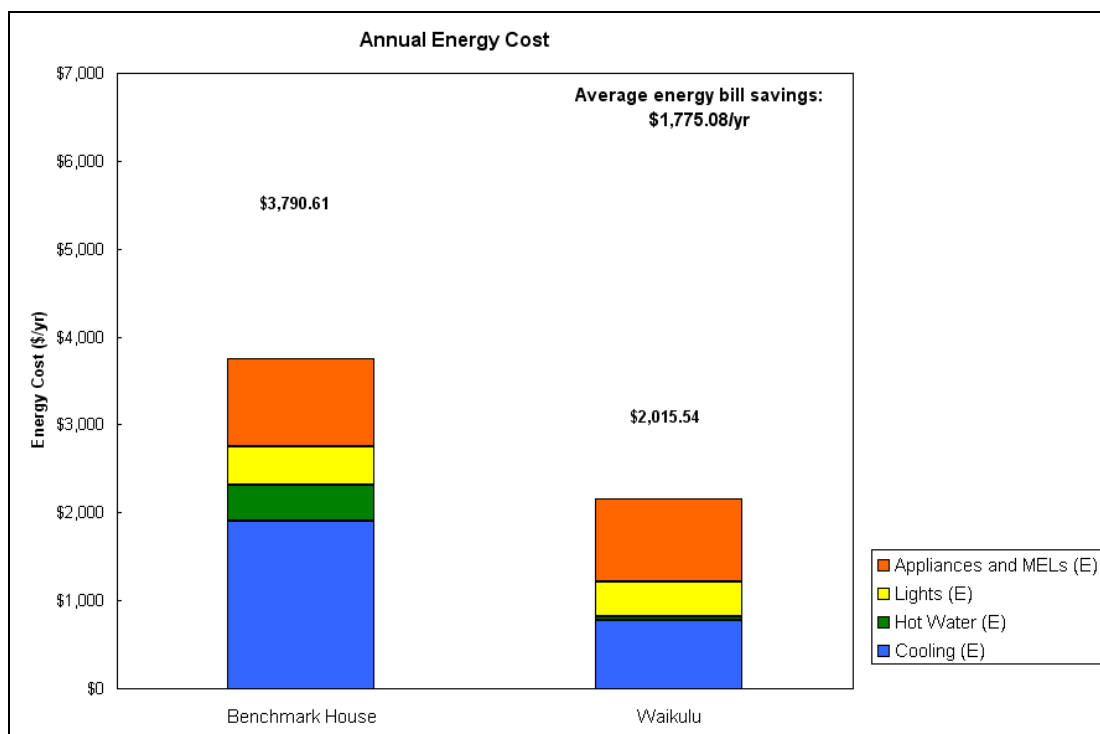


Figure 139. BEopt Energy Cost
1651 with the BA Benchmark as the Reference House

Electricity Rate	
Utility	Hawaii Electric Company
Marginal	\$0.18
Fixed	\$8.00/month
Natural Gas Rate	
Utility	N/A
Marginal	N/A
Fixed	N/A

Table 199. Current Utility Rates for Oahu, HI

As part of this effort, BIRA researched cost-mitigating options for the Waikulu project, including utility rebates, and state and local tax credits. HECO provides a \$1,000 rebate for solar hot water systems; other than that, Hawaii does not currently have any energy efficiency programs to support this project. While Federal Tax Credits would generally be applicable to homes that are this efficient, due to Forest City's relationship with the US Navy and Marines, they are not eligible for Federal Tax Credits. However, this was mitigated by first determining the most cost effective method of reaching the 50% WHES level, and second by Forest City working with its vendors to establish volume, mature market pricing even though this project employed substantially more efficient products than are typical on the island. Table 200 details the

incremental cost of each energy efficient feature.

Table 201 details the energy savings and the corresponding annual utility bill savings for each of the five main end-use categories in comparison to the BA Benchmark. Again, these values are averaged over all four orientations. As shown in Table 201, the BEopt-estimated annual utility bill savings are \$1,775.08 compared to a Building America Benchmark home. It should be noted that this does not include fluctuations in utility rates or inflation.

The bottom section of Table 201 details the costs and amortized mortgage increment for the efficiency improvements using Forest City's current costs. These costs are derived from the builder's first costs, and are detailed in the final report for each of the energy efficiency features listed. The cost is converted into an amortized mortgage incremental cost assuming a 7% loan over 30 years. Inflation is not considered.

Energy Efficiency Feature	Builder Cost
Windows (U-Value 0.35, SHGC 0.23)	\$ 59.15
SEER 16 Cooling Unit	\$ 592.00
R-8 Ducts in Conditioned Space	\$ 99.12
Solar Hot Water	\$6,620.00 ³⁰
Energy Star Appliances	\$ 628.00
Totals	\$7998.27

Table 200: Detailed incremental cost of energy efficient features for 1651 unit

³⁰ <http://www.hawaiienergy.com/solar/index.html>

Description End Use	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings vs. Benchmark
	Benchmark	Pre-Building America	50% Design	Percent of End Use		Percent of Total		
	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Pre-BA	vs. Benchmark	vs. Pre-BA	
Space Heating	1.0	1.0	1.0	0.0%	0.0%	0.0%	0.0%	\$0.00
Space Cooling	139.6	77.3	47.0	66.4%	39.3%	34.3%	18.8%	\$1,130.16
DHW	26.3	6.3	3.3	87.6%	48.0%	8.5%	1.9%	\$373.57
Lighting	34.4	11.8	14.4	58.2%	-22.1%	7.4%	-1.6%	\$225.36
Appliances and MELs	68.6	64.9	65.7	4.3%	-1.2%	1.1%	-0.5%	\$45.99
Total Usage/ Savings	270.0	161.3	131.3	51.4%	18.6%	51.4%	18.6%	\$1,775.08
					Energy Efficiency Feature			Annual Mortgage Cost vs. Code
					Windows (U-Value 0.35, SHGC 0.23)			\$5.19
					SEER 16 Cooling Unit			\$51.99
					R-8 Ducts in Conditioned Space			\$8.70
					Solar Hot Water			\$581.37
					Energy Star Appliances			\$55.15
					Total Annual Mortgage Cost			\$702.41
					Net Annual Cash Flow to Consumer			\$1072.67

Table 201. Neutral Cost Analysis for the 1651 Floor Plan

As shown in Table 201, the net annual cash flow to the homeowner is approximately \$1072.67. Based on this information, it is clear that the incremental annual cost of energy improvements is much less than the annual reduction in utility bill costs and Forest City's Waikulu community passes the Neutral Cost Target "Must Meet" criteria.

"Should Meet" Gate Criteria -- Marketability

As the developer of housing for military personnel, Forest City is not having problems occupying these homes. The homes are rented out within a week of final inspection. The homes are being constructed as a plan to replace older, less efficient homes, and to increase the number of units to improve housing for our troops and maximize the use of available land. The homes are being constructed for Junior Officers, having ranks between E1-E9 and O1-O5. Forest City will also using this opportunity to educate younger enlisted servicemen on the benefits of energy efficient homes, and how to minimize occupant energy usage.

The training will be particularly important if Forest City switches to a monthly allowance type billing system for utility usage. This system is similar to a Tiered energy rate structure, except Tier 1 would be covered, and Tier 2 would have to be paid for by the current occupants. Education along with this structure would help to greatly reduce energy consumption in each of the units.

However, if these homes were for sale, they would still be cost competitive with the market. The average cost for a comparable house is around \$600,000³¹, and with a monthly rent of \$2,500, the 30 year amortized cost is \$372,271.24, almost half the market rate of homes in the area. In addition, the incremental cost of the energy efficient features is dramatically offset by the reduced utility rate, largely due to the high electricity rate in Hawaii.

Based on current sales and marketing information, Forest City's Waikulu community passes the Marketability "Should Meet" criteria.

"Should Meet" Gate Criteria -- Builder Commitment

Forest City Military Communities LLC made a commitment to build all of their homes as energy efficient homes. In 2007, they began construction of homes at the 35% BA benchmark. Since then, they have further upgraded features and construction practices to reach the 50% WHES level, and are committed to building their homes beyond both Energy Star and Builders Challenge program benchmarks.

Forest City has committed significant time and resources to educate their staff, subcontractors, and customers about the benefits of high performance homes. Their commitment to energy

³¹ http://www.zillow.com/homes/kaneohe,-hi_rb/#/homes/for_sale/Kaneohe-HI/sf,multi_type/12157_rid/0-1700_size/21.443583,-157.726106,21.367988,-157.856397_rect/12_zm/1_rs/

efficiency is evident by the amount of building science training that Forest City staff has received from the BIRA team. In 2009, BIRA traveled to Forest City's numerous communities to test and inspect homes both prior to drywall and near final, and to train the field staff. This has resulted in improved insulation installation, tighter homes and improved ducting to improve the homes' efficiency to these improved BAP levels. This team commitment helps differentiate Forest City from other production builders.

Based on this builder's proactive energy efficiency practices at the Waikulu community, and their expressed commitments to build to the Builders Challenge and to the 50% WHES level in other communities, Forest City passes the Builder Commitment "Should Meet" criteria.

"Should Meet" Gate Criteria -- Gaps Analysis

Forest City had a few problems with proper sealing of the home and installation of insulation and ducting. Construction practices in Hawaii are not as refined or rigorous as in some other parts of the nation and, even though Forest City is committed to more efficient homes, we experienced some difficulties in getting subcontractors to meet the required installation techniques or QA/QC. These difficulties were overcome with sufficient training and improved Forest City QA methods. However, infrastructure for good market penetration of these quality construction practices is currently lacking in HI.

Problems included gaps and compression in the insulation, air gaps in the top and bottom plates, and unsealed air handlers and plenums. Fortunately, these issues were easy to address with subcontractors that were eager to learn. Currently, their homes are testing at <2.5 SLA and <4% duct leakage with very good insulation standards.

The final gap with Forest City's Waikulu Community has to do with occupant driven electric loads. As a military community, the occupants do not pay for their utility bills, and as such are not as conscientious about either the impacts of their energy-use behaviors (e.g., thermostat settings) nor the magnitude and costs of their energy consumption. This has already been manifested in the utility bills for the first homes built, ranging from \$94 to \$408 compared to our BEopt estimate of \$147.92. To combat this issue, Forest city is implementing utility allowances.

Forest City is putting more responsibility on the occupants to properly manage their energy use, by imposing a utility bill allowance on each unit. The allowance is similar to a two tier structure, the first tier of energy use will be covered by Forest City, and everything above will have to be paid by the occupants. This approach, coupled with educational material should reduce the energy consumption of the occupants.

In the future, Forest City plans on working with Building America to continue to develop increasingly efficient homes that further reduce heating and cooling loads.

“Should Meet” Gate Criteria -- Quality Assurance

Forest City has demonstrated a strong commitment to quality assurance. Working with BIRA, Forest City has adopted aggressive inspection and third-party verification protocols and procedures to ensure that everything is properly installed and working according to the BA and Builders Challenge quality criteria. BIRA has worked with the developer’s superintendents and construction managers to ensure that their construction protocols are up-to-date, and that they have procedures in place to verify everything is meeting specified efficiency and quality specifications.

Based on this information, Forest City’s Waikulu community passes the Quality Assurance “Should Meet” criteria.

DR Horton –Makalae at Sea Country – 50% Hot-Humid BP3 (2010)

This report presents the evaluation results for Makalae at Sea Country (herein referred to as the “Community”), a Hot-Humid community-scale project of ten or more homes with 50% whole house energy savings (WHES) when compared to the Building America (BA) Benchmark. This community is being developed by DR Horton, Schuler Division (DRH) to evaluate the feasibility of mass-scale production of high efficiency, sustainable homes. The community evaluation was based on the BA Stage Gate 3 “Must Meet” and “Should Meet” criteria (See Appendix A of the final report).

Key Results

Initial energy and cost analysis indicates the Community qualifies as a BA 50% Community in the Hot-Humid Climate Zone. This assessment is based on an energy analysis performed using Energy Gauge® USA v.2.8.02, incremental costs based on builder estimates, and additional information gained through best building practice training, performance testing and inspections. 50% WHES was achieved by improving DRH’s standard building practices and implementing a mandatory quality assurance and quality control (QA/QC) process for all new construction.

Gate Status

Two floor plans within the Community were analyzed and were found to have at least 50% WHES. This can be attributed to the above-code features listed in [Table 202](#). These features will reduce the annual bills enough to offset the additional incremental cost for the above-code features, thus meeting the neutral cost analysis criteria. Homeowners can expect to see approximately \$2,872 to \$3,147 per year (dependent on floor plan) net cost savings compared to the BA Benchmark. A minimum of ten 50% WHES homes will be completed in the community. Based on the information, the current Stage Gate 3 “Must Meet” criteria have been achieved.

Conclusions

BIRA has analyzed and evaluated the performance of the Community's final production building designs using energy simulations and test data collected from rough stage and final stage building performance testing on model homes in the community. The Community meets the 50% Hot-Humid Climate Zone community and stage gate requirements. DRH is a prime example of a builder that partners with BA as they are committed to improving their standard building practices and are utilizing the lessons learned from the development of the Community. Through training and feedback from performance tests and inspections, DRH is successfully developing an affordable, energy efficient community.

Overview

In early 2010, DRH committed to partnering with BIRA to build two BA prototypes in the Community. DRH agreed to incorporate the BA program at the community scale (a minimum of ten homes) if, and only if, the two prototypes were deemed successful in terms of constructability, marketability, and cost-effectiveness. To date, both prototypes have demonstrated success in these criteria and the additional eight homes are planned for construction in the Community. The ultimate goal of this partnership is to explore construction practices beyond the current DRH building standards that are both cost-effective and maintainable.

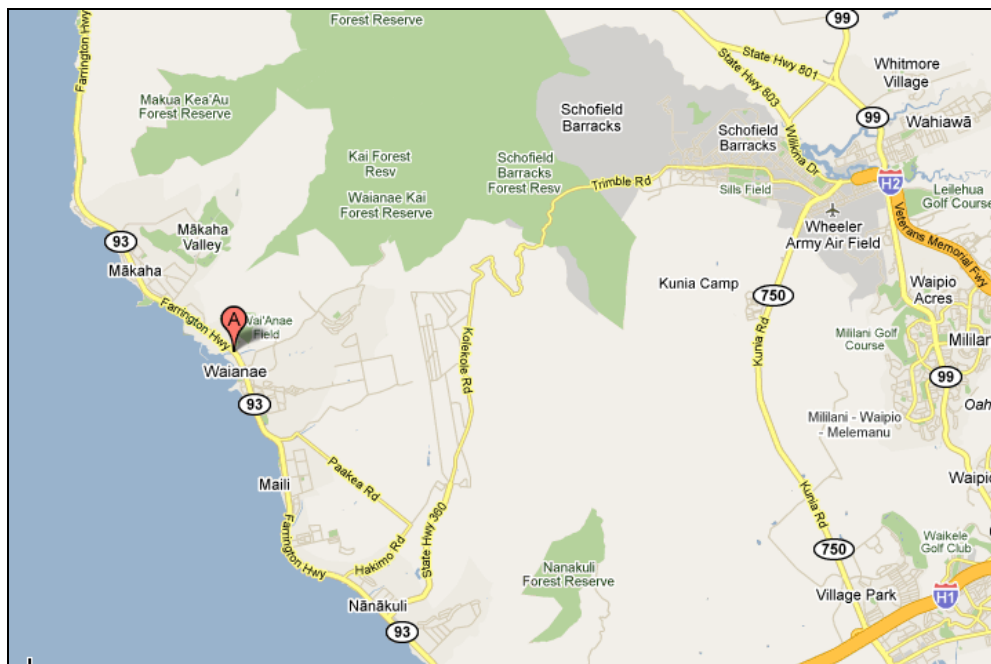


Figure 140. Community map

Energy costs in Hawaii are among the nation's highest and homeowners are becoming increasingly aware of the benefits of energy conservation. As a production builder, DRH is

investigating the feasibility of additional building costs required to achieve higher energy efficiency, and the ability to justify and market the enhancements to homeowners as a quick return-on-investment.

Green Sands Inc., the architectural firm for the Community, is a BIRA partner and has assisted in the development of realistic and achievable energy efficient building practices for DRH. Green Sands Inc. specializes in energy efficiency design and understands the expectations and limitations of the Community's designs and current building practices. They will continue to consult with DRH as a BIRA partner regarding innovative building designs, technologies, and best building practices.

Builder:	DR Horton, Schuler Division, LLC
Community:	Makalae at Sea Country
Community Size:	280 Total/ 10 BA homes
Conditioned Floor Area:	1,244-1,360 sq. ft.
Location:	Waianae, HI
Climate Zone:	Hot-Humid
Goal:	50% WHES

Table 202. Project Snapshot



Figure 141. Computer rendering - Model 3 prototype (1,360 sq. ft.)



Figure 142. Computer rendering- Model 5 prototype (1,244 sq. ft.)

“Must Meet” Gate Criteria -- Source Energy Savings

This report will document successful 50% WHES community-scale construction and highlight DRH’s ability to produce quality construction and quality assurance on the homes.

BIRA has met with DRH to discuss and advise them on the benefits and advantages of constructing energy efficient homes in the Community. After reviewing their current building and construction practices, BIRA was able to provide simple and effective energy conservation solutions while preserving affordability.

Models	Model 3	Model 5
Stories	1	2
CFA (sq. ft.)	1, 360	1,244
Beds	3	4
Foundation	Slab	Slab

Table 203. Floor plan information

Description	Annual Source Energy				Estimated Source Energy Savings					
	BA Benchmark (BA BM)	IECC 2006	Builders Practice (BP)	50% WHES Prototype	Percent of End Use			Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. BABM	vs. IECC	vs. BP	vs. BABM	vs. IECC	vs. BP
Space Heating	0.4	0.2	0.2	0.2	58.7%	30.0%	15.0%	0.1%	0.0%	0.0%
Space Cooling	113.1	64.3	49.4	41.1	63.7%	36.1%	16.8%	32.4%	13.2%	6.4%
DHW	25.6	27.9	1.3	1.3	95.0%	95.4%	0.0%	11.0%	15.1%	0.0%
Lighting	21.8	22.5	17.0	6.1	72.1%	73.1%	64.4%	7.1%	9.3%	8.5%
Appliances and MELs	61.2	61.2	61.0	61.0	0.5%	0.5%	0.0%	0.1%	0.2%	0.0%
PV	0.0	0.0	0.0	0.0	0%	0%	0%	0%	0%	0%
Total Usage/ Savings	222.1	176.1	128.8	109.5	50.7%	37.8%	15.0%	50.7%	37.8%	15.0%

Table 204. Model 3 WHES summary

Description	Annual Source Energy				Estimated Source Energy Savings					
	BA Benchmark (BA BM)	IECC 2006	Builders Practice (BP)	50% WHES Prototype	Percent of End Use			Percent of Total		
End Use	(MBtu/yr.)	(MBtu/yr.)	(MBtu/yr.)	(MBtu/yr.)	vs. BA BM	vs. IECC	vs. BP	vs. BA BM	vs. IECC	vs. BP
Space Heating	0.4	0.1	0.2	0.0	87.9%	30.7%	71.5%	0.1%	0.0%	0.1%
Space Cooling	108.2	62.8	50.2	38.0	64.9%	39.6%	24.4%	31.2%	13.6%	9.0%
DHW	29.2	31.5	3.1	2.3	92.1%	92.7%	25.3%	11.9%	16.0%	0.6%
Lighting	20.7	21.4	16.2	5.8	72.1%	73.1%	64.4%	6.6%	8.6%	7.6%
Appliances and MELs	67.0	67.0	67.0	65.5	2.2%	2.2%	2.2%	0.7%	0.8%	1.1%
PV	0.0	0.0	0.0	0.0	0%	0%	0%	0%	0%	0%
Total Usage/ Savings	225.6	182.8	136.7	111.6	50.5%	38.9%	18.3%	50.5%	38.9%	18.3%

Table 205. Model 5 WHES summary

Table 204 and Table 205 show the WHES calculations of two floor plans, Model 3 and Model 5, (see final report Appendix B) in the Community. These plans are representative of a typical home schematic and size that DRH currently builds. The projected source energy savings were derived from Energy Gauge® 2.7.0.2. The Model 3 is projected to have a WHES of 50.7%. The Model 5 is projected to have a WHES of 50.7%.

Both plans can meet the BA goal of 50% WHES with respect to the BA benchmark in the Hot-Humid Climate Zone. Prior to BIRA's involvement, DRH's standard building practices included above-code features, such as high efficiency windows, A/C, and water heater. The building envelope was not addressed due to the gaps of building science knowledge in the construction labor force in Hawaii, and lack of a standard QA/QC process. To achieve DRH's goal of developing a sustainable, energy efficient standard building practice, the general contractors and site workers were required to complete building science training provided by BIRA. A standard QA/QC process is being developed with assistance from BIRA. For more information on the training and QA/QC process, please see the "Gap Analysis" and "Quality Assurance" sections.

The critical above-code energy reduction features implemented in order to reach these savings levels are as follows:

DRH Building Practice	Model 3- BA 50% Prototype (One Story)	Model 5- BA 50% Prototype (Two Story)
R11 Wall Insulation	R11 Wall Insulation	R15 Wall Insulation + R5 exterior sheathing (Icynene)
R19 Attic Insulation + Attic Radiant Barrier	R19 Attic Insulation + Attic Radiant Barrier	R35 Attic Insulation + Attic Radiant Barrier
Low Air Infiltration Rate (7.8 ACH @50)	Low Air Infiltration Rate (4.7 ACH @50)	Low Air Infiltration Rate (4.7 ACH @50)
Dual Glazed, Low-E (0.35 U-value/ 0.30 SHGC)	Dual Glazed, Low-E (0.35 U-value/ 0.30 SHGC)	Dual Glazed, Low-E (0.35 U-value/ 0.30 SHGC)
SEER 15.5 AC	SEER 15.5 AC	SEER 15.5 AC
0.95 EF Water Heater	0.95 EF Water Heater	0.95 EF Water Heater
Solar Thermal Water Heater- 32 sq. ft. closed loop	Solar Thermal Water Heater- 32 sq. ft. closed loop	Solar Thermal Water Heater- 32 sq. ft. closed loop
ENERGY STAR® Qualified Dishwasher	ENERGY STAR® Qualified Dishwasher	ENERGY STAR® Qualified Dishwasher
40% CFL Lighting	100% CFL Lighting	100% CFL Lighting

Table 206. Building features

Model 3 demonstrates the importance of quality construction very well. To reach the 50%

WHES, DRH's standard building practices only needed two building feature modifications in Model 3: 100% CFL and low air infiltration rate (4.7 ACH50). Model 5 could not follow the same 50% WHES pathway due to its greater building envelope area. This issue was addressed by increasing the wall and ceiling insulation to R-20 and R-35, respectively. Icynene® spray insulation will be used in Model 5 to achieve the target R-value.

DRH, along with most production builders in Hawaii, use steel framing as standard practice. There are significant concerns regarding steel's high thermal conductivity. The only way to properly insulate the envelope when using steel framing is to provide a thermal break. Insulating exterior sheathing is an option. In the case of Model 5, Icynene® will be used as insulating exterior sheathing, as shown in Figure 143 below. DRH understands the importance of providing a thermal break when using steel framing and plans to incorporate it for all 50% WHES Model 5 homes.

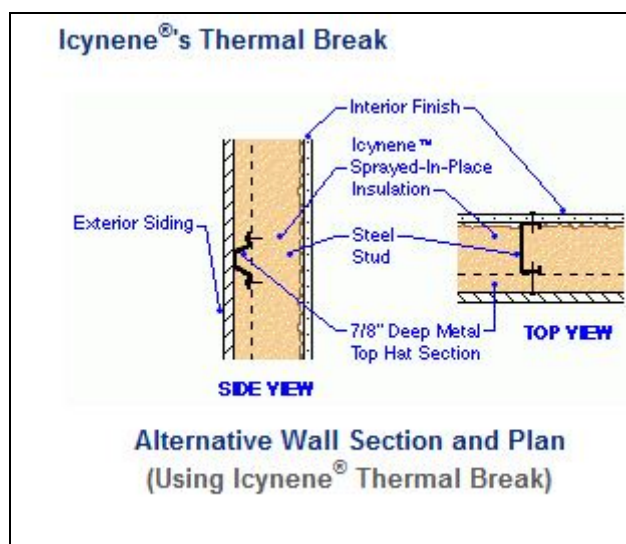


Figure 143. Icynene® thermal break illustration

Due to Hawaii's high cost of natural gas, all homes in the Community are electric only. Model 3 is expected to use 108.3 MBtu annually. Model 5 is expected to use slightly more, with 111.6 MBtu annually.

Figure 144 and Figure 145 illustrate the source energy use graph for Model 3 and Model 5, respectively. The Benchmark, IECC 2006, builder's practices, and 50% WHES source energy use are compared and show the significant energy consumption reduction for each design. The five main end-use categories include space heating, space cooling, hot water, lighting, and appliances.

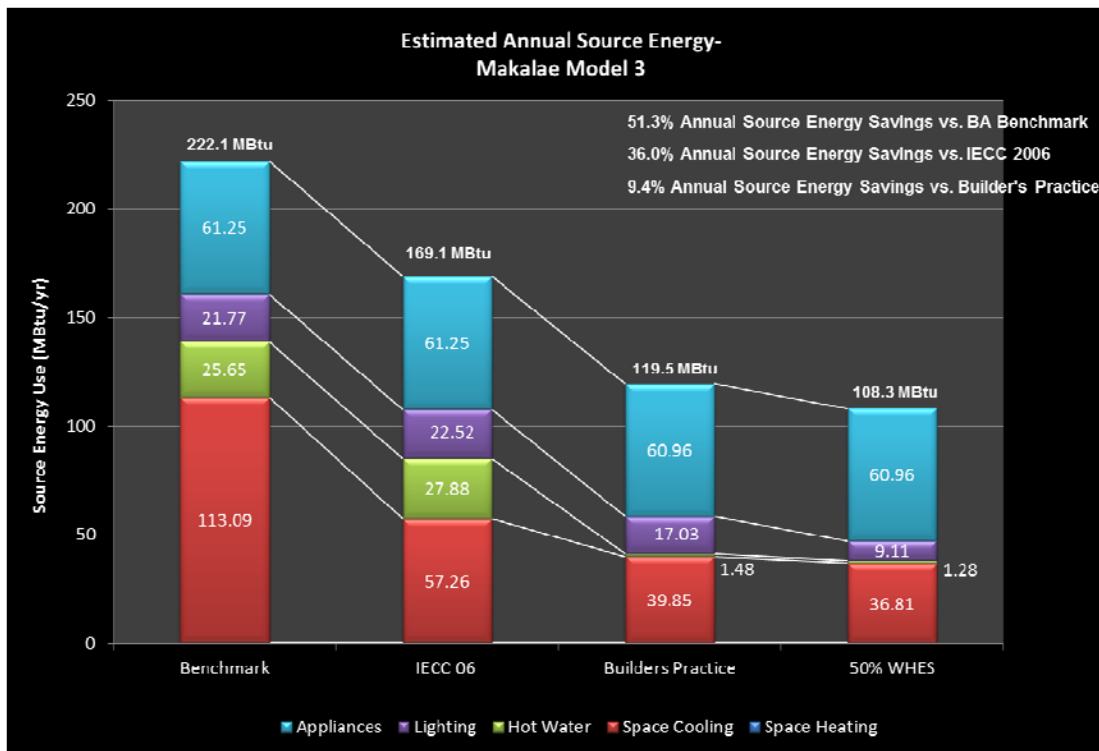


Figure 144. Estimated annual source energy- Model 3

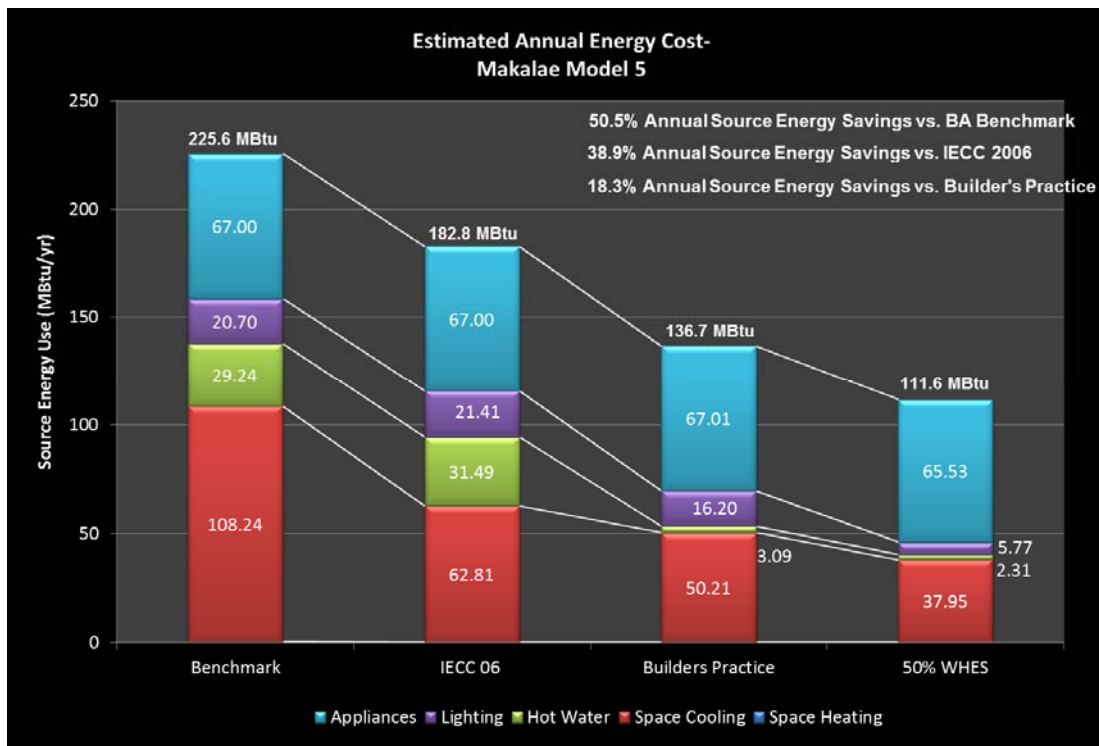


Figure 145. Estimated annual source energy- Model 5

“Must Meet” Gate Criteria -- Market Coverage

The Community’s 50% WHES pathway was developed by improving DRH’s standard building practices and implementing a QA/QC process which will ensure all homes are built in an energy efficient manner. The QA/QC process was based on DOE’s Best Building Practices in the Hot-Humid Climate Zone. Other regions within the Hot-Humid Climate Zone can and should include a similar QA/QC process. The building materials are “off-the-shelf” products and are not region-specific. The 50% WHES pathway can be utilized in a range of different weather conditions and construction practices, therefore satisfying the Market Coverage “Should Meet” Stage Gate criteria.

“Must Meet” Gate Criteria -- Neutral Cost Target

On average, Hawaii’s construction labor costs are higher than the rest of the nation. Due to the high labor costs, installation time was a key issue; however, the incremental cost analysis shows only the material costs for all building features. Labor costs are builder and region-specific and cannot easily be translated to another location in the Hot-Humid Climate Zone. The raw building features’ costs were provided by DRH. The neutral cost analysis includes a 10% builder markup.

The average 50.6% reduction in Model 3 and Model 5’s WHES provides a substantial reduction in energy bills. The incremental cost calculation (shown in final report Appendix C) shows that despite adding in the advanced energy features, the savings in utility bills will offset the additional cost. When financed as part of a 30-year mortgage at 7% interest, the incremental annual cost will be reduced by \$3,147 and \$2,872 for both models, after utility savings are taken into account, as shown in [Figure 146](#) and [Figure 147](#).

Based on this information, it is clear that the incremental annual cost of energy improvements are less than the annual reduction in utility bill costs. Therefore, the homes pass the Neutral Cost target “Must Meet” criteria.

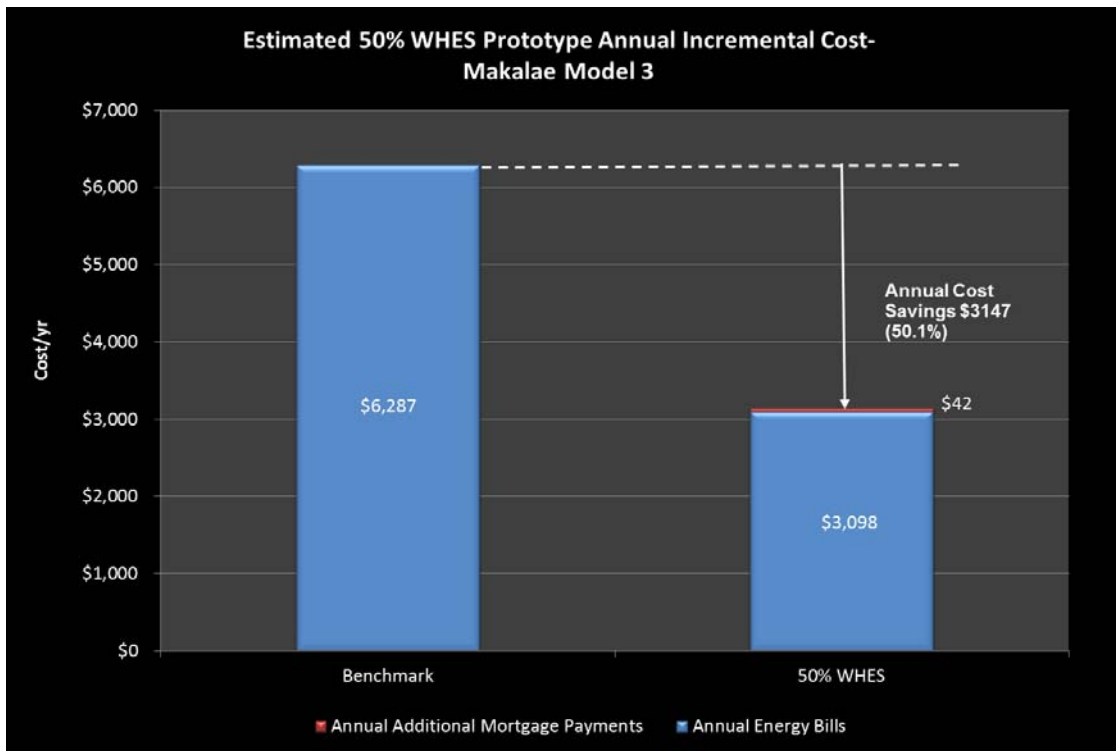


Figure 146. Estimated annual incremental costs – Model 3

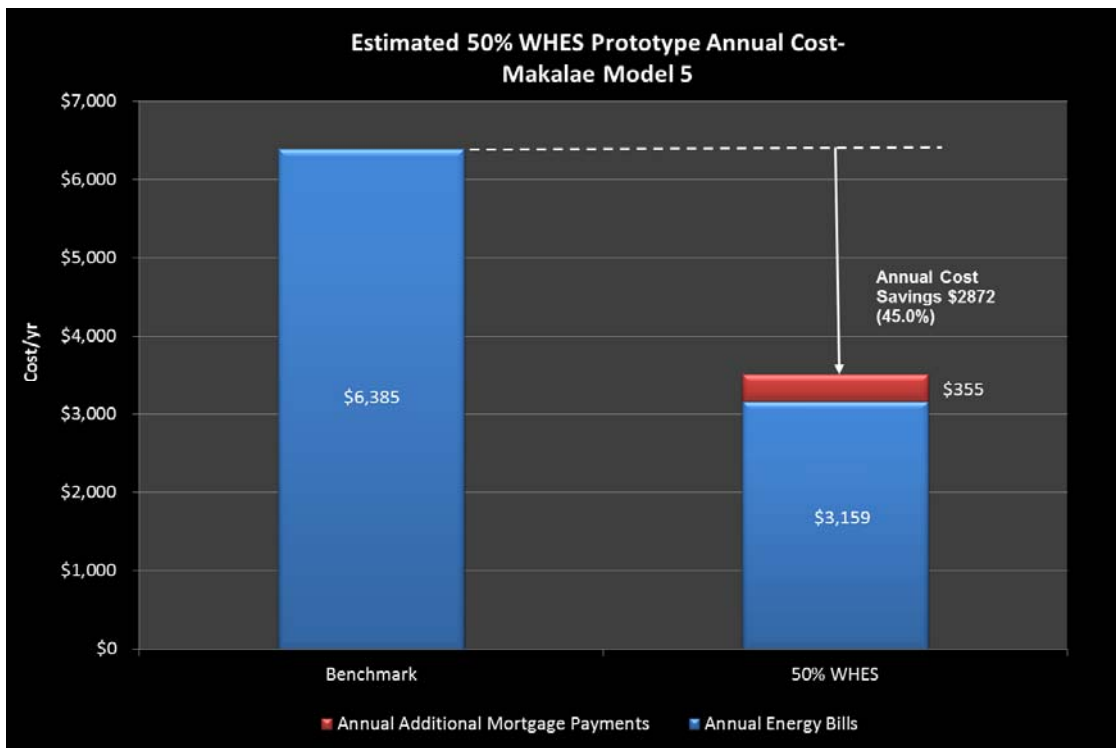


Figure 147. Estimated annual incremental costs- Model 5

On average, the 50% WHES homes will save 38.4% more in utility bills than a home built to IECC 2006 standards and 16.7 % more than a home built to DRH's building practices.

Figure 148 and Figure 149 illustrate the annual utility bill costs for the main end-use categories. The graph demonstrates cost savings in all categories for both plans. The highest cost saving is achieved in "Lighting" with the 100 % CFL, when compared to the builder's standard practices. The 50% WHES pathway included no improvements to DRH's standard building practice for A/C efficiency (SEER 15.5) however, the improvement to the air infiltration rate substantially reduced the space cooling costs. The tight envelope retains more conditioned air, thereby allowing the A/C to work more efficiently (less energy consumed for the same cooling load).

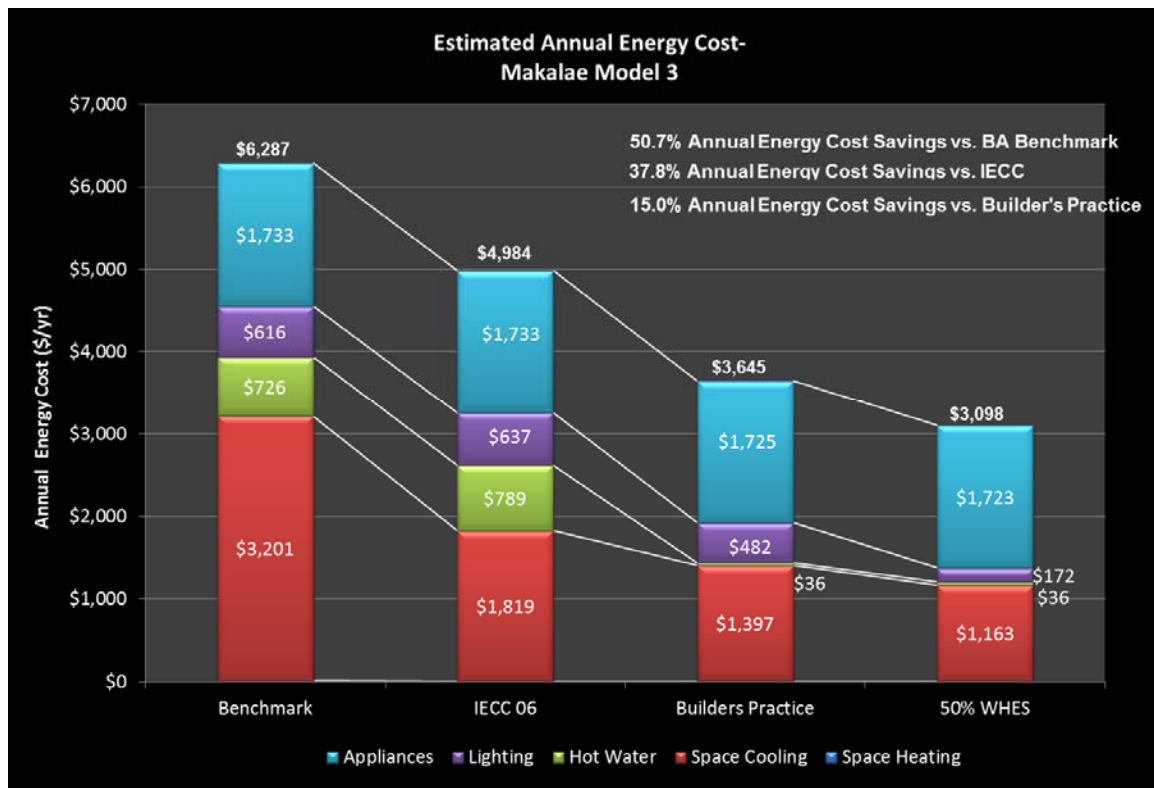


Figure 148. Estimated annual energy costs- Model 3

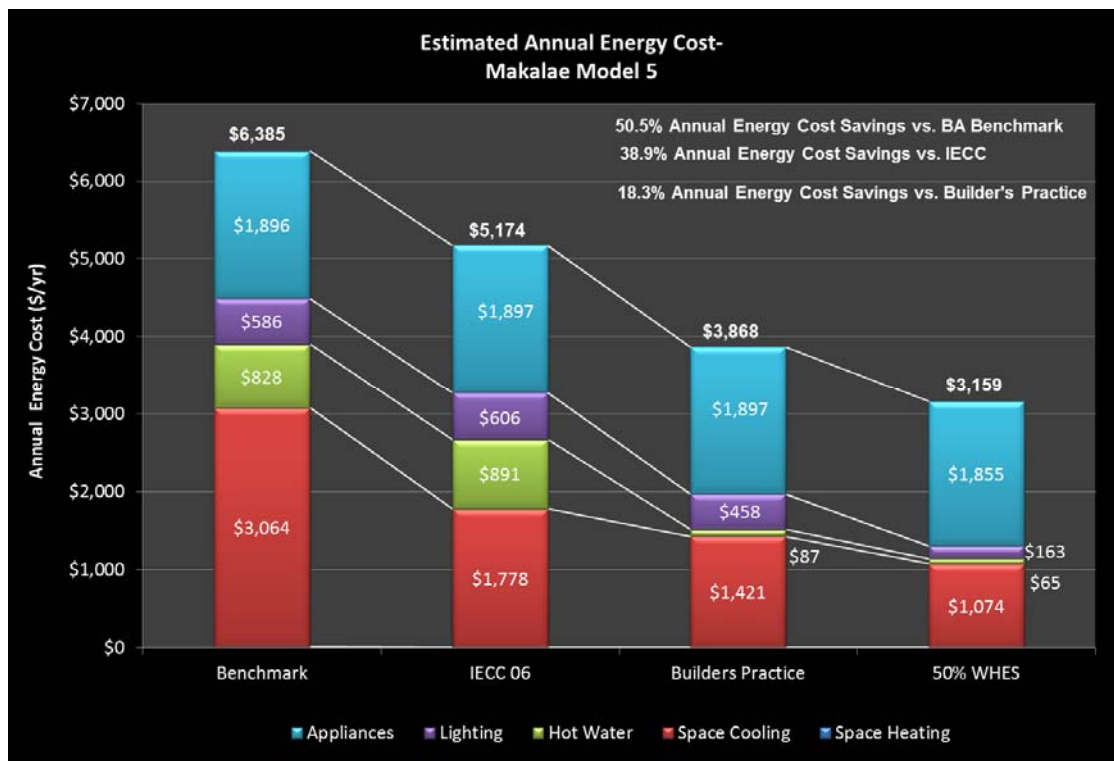


Figure 149. Estimated Annual Energy Costs- Model 5

"Should Meet" Gate Criteria -- Marketability

As one of the nation's largest production builders, DRH is experienced with the volatile nature of the housing market. Through their many years of experience, they have developed successful marketing strategies. Typically, marketing efforts included media coverage (TV, websites, and radio advertisements) for upcoming projects and would emphasize the homes' luxurious qualities, such as hardwood floors and granite countertops. Recently in the Hawaiian market, homebuyers are showing interest in energy efficiency and DRH has experienced an increase in the demand for sustainable homes. Hawaii residents are increasingly aware of their state's high utility costs. As a production builder, DRH has responded to the challenge by providing high efficiency homes, while remaining marketable and cost efficient.

Though the Makalae community is located in a desirable area (near the coast and within a half-hour drive to major cities), highlighting the cost savings of the 50% WHES homes will be critical to help potential homebuyers recognize value in the higher upfront costs. Strategic marketing, in addition to homebuyer education, will play a role in presenting the Community as a preferred residence.

Although DRH is receiving increased requests for sustainable homes, each potential homebuyer defines sustainability differently. As DRH develops improved standard building practices, they have focused most of their building alterations towards energy efficient upgrades. By doing so,

DRH will market energy efficiency as sustainable in terms of cost-effectiveness, resource conservation (through reduced source energy production), and durability through the improved QA/QC process.

Based on this information, the Community passes the Marketability “Should Meet” Stage Gate criteria

“Should Meet” Gate Criteria -- Builder Commitment

As previously mentioned, DRH has developed Model 3 and Model 5 with 50% WHES to determine the feasibility of constructing sustainable, energy efficient homes while remaining cost efficient and marketable. DRH has demonstrated a high level of commitment to improving their standard building practice. At their request, BIRA traveled to the community site to provide comprehensive best building practice training, not only to the general contractors and construction workers, but also directly to DRH management. By educating those in charge of design, implementation, and product selection, there is a reduced chance for confusion or different interpretations of proper building practices. Prior to BIRA’s involvement, DRH’s standard building practices utilized above-code features. They are committed to expanding their energy efficient standard building practices to reach the 50% WHES level as evident from the effort shown so far.

“Should Meet” Gate Criteria -- Gaps Analysis

The greatest gap in developing the Community was ensuring the homes are built in an energy efficient manner, including tight building envelope and quality insulation installation. All BA homes are designed from a whole house, systems approach. This approach recognizes the importance of each building feature’s role in reducing the whole house energy consumption. The above- code building features have an additional cost that is justified with utility bill savings, however without a quality constructed envelope, the building features will not perform as efficiently as possible. For example, the 50% WHES pathway included the same AC efficiency as used in DRH’s building practice; however there was a 3.0 to 12.3 MBtu (plan dependent) reduction in the space cooling load due to the improvements to the building envelope. Best building practice training and a complete QA/QC process, which includes required performance testing and inspection, is the only way to ensure all building features were correctly constructed and implemented.

Prior to BIRA’s involvement, DRH did not have a documented QA/QC process for their subcontractors. Without guidance, it was up to the individual subcontractor to construct, seal, and install all features as required by code. Energy efficiency was not addressed. With BIRA’s assistance, DRH is in the process of finalizing a QA/QC process to use in conjunction with their improved energy efficient standard building practice.

Other minor gaps include the learning curve for properly installing Icynene® insulation. To

ensure the product remains cost effective it must be installed in a timely manner, or protracted labor costs can quickly reduce its energy cost savings. Continued training and experience with the product will help to reduce labor costs.

“Should Meet” Gate Criteria -- Quality Assurance

One of the first objectives to achieving a 50% WHES community is implementing additional QA/QC policies into DRH’s standard building practices. BIRA has identified improvements for DRH’s construction practices to take full advantage of the energy efficient features and to maximize best building practices. Construction practices and building code requirements in Hawaii are not as refined or rigorous as in other parts of the nation. In order to improve DRH’s QA/QC procedures, BIRA has provided significant training and advice directly to DRH management and subcontractors so that they can incorporate the skills and knowledge learned into a division-wide building practice guideline and protocol.

Most of the training was conducted in the Model 3 and Model 5 at rough stage construction. This provided the ideal setting to demonstrate the correct and incorrect building practices. By utilizing the homes at the rough stage, the trainer was able to provide Community-specific feedback and guidance on how to make the necessary changes to reach the 50% WHES.

Model 3 and Model 5 demonstrated the importance of QA/QC. During BIRA’s site visit, performance tests were completed on a sample of homes in the Community. All homes were constructed by the same subcontractor and construction workers. The average air infiltration rate was 7.8 ACH50. The trainer used these results to point out areas of improvement. The final performance test results showed the improvement in construction quality with a 3.1 ACH50 reduction (4.7 ACH50 at final testing).

Currently, DRH is in the process of compiling a QA/QC process with appropriate third-party testing and inspections. The following areas are under review:

- Total duct leakage test at system rough-in on every house
- Insulation and thermal by-pass inspection
- On-site confirmation of window U-values
- On-site confirmation of qualifying HVAC and appliance equipment efficiencies
- On-site lighting inspection
- Prior to occupancy, at least 10% of homes are re-tested to confirm duct leakage to the exterior is less than 6% at 50 Pascals and to confirm envelope tightness. DRH understands the importance of coordinating with subcontractors to ensure their building practices are implemented correctly. The QA/QC process will formalize this understanding.

Visionary Home Builders – Tierra Del Sol – 50% Hot/Mixed-Dry Community BP3 (2010)

This report presents the evaluation results for Tierra Del Sol (herein referred to as the “Community”), a Mixed-Hot Dry community-scale project of ten or more homes with 50% whole house energy savings (WHES) when compared to the Building America (BA) Benchmark without Photovoltaic (PV). This community is being developed by the Housing Authority of the County of San Joaquin (herein referred to as the “County”), in conjunction with the designated community developer Visionary Home Builders (VHB), and constructed by the modular home manufacturer ZETA Communities (ZETA), to evaluate the feasibility for mass-scale production of high efficiency, low income housing. The community evaluation was based on the BA Stage Gate 3 “Must Meet” and “Should Meet” criteria (See Appendix A of the community report). Goals for the Community include net-zero energy bills and CALGreen certification³². Key partners in this endeavor are Gregory Arnaudo of the County, Matthew Thompson of VHB, and Shilpa Sankaren of ZETA.

Key Results

The results of this study showed that the Community qualifies as a Building America 50% Community in the Mixed-Hot Dry Climate Zone. This assessment is based on an energy analysis performed using EnergyGauge® USA v.2.8.04, incremental costs based on builder estimates, and additional information gained from builder partner feedback. The 50% WHES was achieved by incorporating energy efficient building practices and utilizing quality assurance and quality control (QA/QC) procedures. Furthermore, the Community has demonstrated it will be capable of achieving net-zero utility bills for the homeowners by using energy efficient building practices and renewable energy.

Gate Status

The advanced energy efficient building features and construction practices required for 50% WHES will reduce the annual energy bills enough to offset the additional incremental cost for the above-code features, thus meeting the neutral cost analysis criteria. Without PV, the homeowners can expect to see approximately \$914 per year in net cost savings compared to the BA Benchmark. A minimum of ten 50% WHES homes will be completed in the community by next April. Based on the information gathered, the current Stage Gate 3 “Must Meet” criteria have been achieved.

Conclusions

BIRA has analyzed and evaluated the performance of the Community’s final production building

³² Currently CALGreen is a voluntary program; however, all California building permits applied for on or after January 1, 2011 will require residential and commercial developers to implement a wide range of sustainability measures. The CALGreen program addresses five key components of home building, including energy efficiency, indoor air quality, waste management, wood conservation, and water conservation

designs using energy simulations. The Community meets the 50% Mixed- Hot Dry Climate Zone community and stage gate requirements. With cooperation from the County, VHB, and ZETA, the Community successfully demonstrates the ability to provide affordable, energy efficient housing. All building partners are committed to improving their standard building practices and are utilizing the lessons learned from the development of the Community. This project is currently in the development stage, awaiting finalized marketing plans targeting home sales during the upcoming holiday season; site work and utilities are in the process of being complete.

Overview

As non-profit agencies, the County and VHB understand the need to develop sustainable, energy efficient housing that will meet the affordability needs of low income households in the Central Valley of California. Critical requirements of this Community include maintaining long-term affordability for the homeowners through net-zero utility bills and low operation and maintenance costs. Modular construction was selected for its ability to satisfy all such project requirements.

ZETA, an experienced zero-energy modular home manufacturer and BIRA partner will construct twenty-two homes at the ZETA factory in Sacramento, CA, and transport them approximately forty-five miles south to the Community site in Stockton, CA. Utilization of modular construction provides a unique opportunity to investigate the feasibility of mass-scale, modular home manufacturing, with respect to ZETA's ability to produce quality construction and provide quality assurance on their product.

Under the Building America program, BIRA researched and developed the technological pathway for 50% WHES and net zero energy homes in the Community. The technological pathways were developed by selecting and analyzing viable systems and building practices that reduce whole house energy consumption by at least 50% relative the BA benchmark; then selecting renewable energy systems (PVT ECHO™ Solar System) which will produce as much energy as the home consumes.

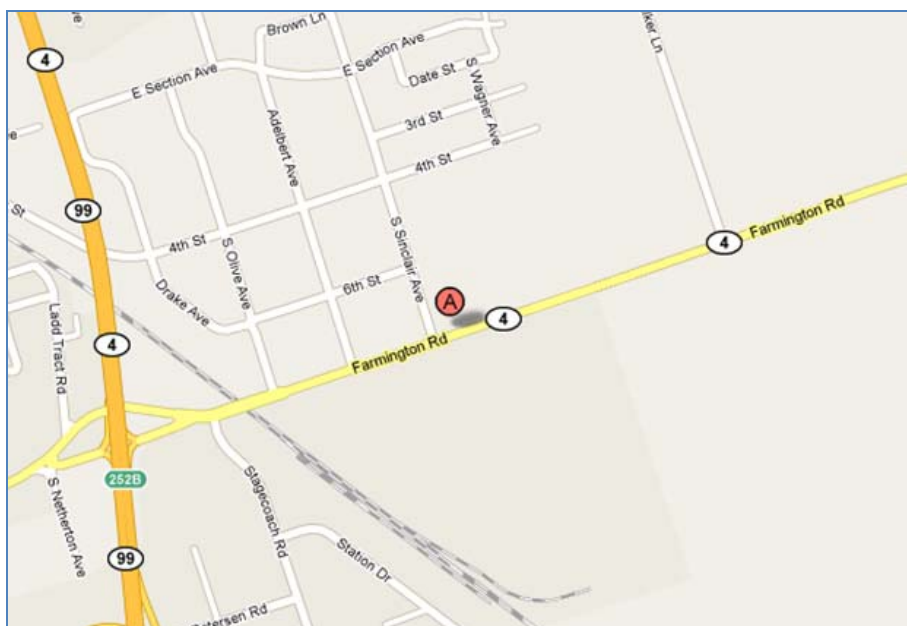


Figure 150. Area map of the Tierra Del Sol community,

 located on Del Ray Court, **Stockton, CA 95215**

This report will document successful 50% WHES community-scale construction in the Mixed-Hot Dry Climate Zone and highlight the ability to produce affordable, modularly constructed, sustainable homes.

Developer:	Visionary Home Builders
Builder:	ZETA Communities
Community:	Tierra Del Sol
Community Size:	22 homes
Conditioned Floor Area:	1,253 sq. ft.
Location:	Stockton, CA
Climate Zone:	Mixed-Hot Dry
Goal:	50% WHES, Net-Zero Utility Bills, CALGreen Certification

Table 207. Tierra Del Sol community information



Figure 151. Computer rendering of Exterior View of Unit 101, a Tierra Del Sol floor plan.

“Must Meet” Gate Criteria -- Source Energy Savings

An energy analysis was performed using EnergyGauge® USA v.2.8.04 to model Unit 101, the only floor plan proposed for the Community. Unit 101 consists of 1,253 square feet of finished floor area, three bedrooms, and two bathrooms. All twenty-two homes in the Community will be placed on the same street, with ten homes on each side of the street facing east and west and two homes angled southwest and southeast in the cul-de-sac. All orientations were included in simulation. The energy savings was averaged over all four orientations and grouped into five main end use categories. Natural gas lines will not be included in the construction of the Community site; all homes will use electricity only.

Electricity Rate	
Utility	Pacific Gas & Electric
Marginal	\$0.13/kWh
Natural Gas Rate	
Utility	N/A
Marginal	N/A

Table 208. Tierra Del Sol utility provider and marginal costs

The projected source energy savings are shown below. Based on simulation results, Unit 101 is expected to achieve 58.6% WHES without PV and 101.3% WHES with PV.

Description	Annual Source Energy				Estimated Source Energy Savings					
	BA Benchmark (BABM)	Title 24 (T24)	Builders Practice (BP)	Unit 101	Percent of End Use			Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. BABM	vs. T24	vs. BP	vs. BABM	vs. T24	vs. BP
Space Heating	34.5	31.4	19.7	11.7	66.0%	62.6%	40.4%	13.1%	11.9%	5.7%
Space Cooling	26.3	24.1	10.5	8.0	69.8%	67.0%	24.3%	10.6%	9.8%	1.8%
DHW	38.8	36.2	36.0	1.0	97.4%	97.2%	97.2%	21.7%	21.4%	25.1%
Lighting	20.8	19.8	19.8	5.8	72.1%	70.7%	70.7%	8.6%	8.5%	10.0%
Appliances and MELs	53.2	53.2	53.2	45.4	14.7%	14.7%	14.7%	4.5%	4.7%	5.6%
PV	0.0	0.0	0.0	-74.2	0%	0%	0%	0%	0%	0%
Total Usage/ Savings	173.7	164.7	139.2	-2.3	101.3%	101.4%	101.6%	101.3%	101.4%	101.6%

Table 209. Annual source energy and estimated source energy savings of the BA Benchmark, Title 24, builder's practice and Tierra Del Sol homes

As shown in [Table 209](#), the Community meets the BA goal of 50% WHES with respect to the BA benchmark in the Mixed-Hot Dry climate.

For the successful development of an affordable NZE community, it is critical to minimize the need for costly renewable energy (i.e. photovoltaic systems) by maximizing the energy efficiency of the building envelope and HVAC systems. VHB's standard building practice is to construct homes which are at least 15% more energy efficient than code compliance (California Building Energy Efficiency Standards - Title 24). The builder's standard practices, along with the capabilities of the modular home manufacturer, were taken into consideration by BIRA when the 50% WHES pathway was designed.

Since ZETA specializes in building high quality, sustainable homes, their facility is fully equipped with technology built beyond industry standards to produce energy efficient homes. By utilizing the full capabilities of ZETA's facility, BIRA was able to prescribe advanced building features including high R-value envelope, low air infiltration rate (tight envelope sealing), high efficiency windows, thermal storage crawlspace, and PVT ECHO™ system.

Title 24 Code Compliant- Prescriptive Method	VHB Builder's Practice	BA Prototype - Unit 101
R-7 Stem Walls/Unvented Crawlspace	R-13 Stem Walls/Unvented Crawlspace	R-13 Stem Walls/Unvented Crawlspace with high fly ash concrete floor for thermal storage
R-29 Wall Insulation	R-21 Wall Insulation + R-4.2 Exterior Sheathing	R-21 Wall Insulation + R-4.2 Exterior Sheathing
R-49 Attic Insulation + Attic Radiant Barrier	R-49 Attic Insulation + Attic Radiant Barrier	R-49 Attic Insulation + Attic Radiant Barrier
Average Air Infiltration Rate (8.74 ACH @50)	Average Air Infiltration Rate (8.74 ACH @50)	Low Air Infiltration Rate (3.0 ACH @50)
1/2" sheetrock	1/2" sheetrock	Added thermal mass- 5/8" sheetrock
Dual Glazed, Low-E (0.38 U-value/ 0.40 SHGC)	Dual Glazed, Low-E (0.31 U-value/ 0.23 SHGC)	Dual Glazed, Low-E (0.31 U-value/ 0.23 SHGC)
Elec. Heat Pump- SEER 13/7.7 HSPF	Elec. Heat Pump- SEER 17/9.0 HSPF	Elec. Heat Pump- SEER 17/9.5 HSPF
R-8 Ducts/Unconditioned Space	R-8 Ducts/Unconditioned Space	R-8 Ducts/Conditioned Space
50 Gallon Water Heater- 0.86 EF	50 Gallon Water Heater- 0.88 EF	120 Gallon Water Heater- 0.95 EF
N/A	N/A	PVT ECHO Solar System- 4.0 kW PV and 200 sq. ft. closed loop solar thermal water heater
Standard Appliances	Standard Appliances	ENERGY STAR® Qualified Appliances
20% CFL Lighting	20% CFL Lighting	100% CFL Lighting

Table 210: Tierra Del Sol building features for code compliance, builder's practice and 50% WHES

The prefabricated homes by ZETA will have the building features listed in [Table 210](#) under BA Prototype fully installed in the manufacturing facility prior to site delivery. Furthermore, ZETA provides each home a utility core. The core combines mechanical, plumbing, and electrical systems into a unit that connects to the site's infrastructure systems during onsite installation. The inherent advantages of providing a fully-functional, turn-key home are reductions in risk, cost and time, and unpredictable project schedules.

The structural integrity of a modular home is of critical importance due to the need to transport the homes from the facility to the site location. Subsequently, ZETA's standard construction practices include 2x6, 24" o. c. lumber framing, 0.5" exterior rigid sheathing, and 5/8" sheetrock applied to interior envelope. This construction practice allows higher R-value insulation in the walls and assists in providing tight envelope air sealing.

The homes will include a highly efficient HVAC system which will work in conjunction with a thermal storage crawlspace. The airhandler of the electric heat pump will be located in the attic with minimal ducting running from the airhandler through an interior wall to the crawlspace. The crawlspace will act as a plenum and provide conditioned air to the living space through floor supply vents. When the HVAC system is not being operated, the thermal storage crawlspace utilizes high flyash concrete to store day time heat and provide nighttime cooling.

The HVAC airhandler was placed in the attic so that PVT's ECHO™ solar system would have direct tie-in access from the roof. The ECHO™ solar system is a unique renewable energy system which utilizes more solar energy by allowing basic PV panels to harvest not only electrical but also thermal energy. Traditional PV systems lose efficiency at high temperatures, however the ECHO™ system was designed to decrease PV temperature by transferring the thermal energy. The thermal energy is then used for water heating and supplemental space heating and cooling (achieved through an air heat exchanger).

Utilization of such innovative HVAC and renewable energy systems were made possible through the whole-systems approach to the design, construction and operation of the homes, meaning that architectural, mechanical and structural systems were designed together with better precision, fit and operational efficiency.

Figure 152 illustrate the source energy use graph for Unit 101. The Benchmark, Title 24, builder's practice, and 50% WHES source energy uses are compared and show the significant energy consumption reduction for each design. The five main end-use categories include space heating, space cooling, hot water, lighting, and appliances. Unit 101 is expected to use approximately 71.9 MBtu annually. This represents a 58.6% reduction compared to the BA Benchmark.

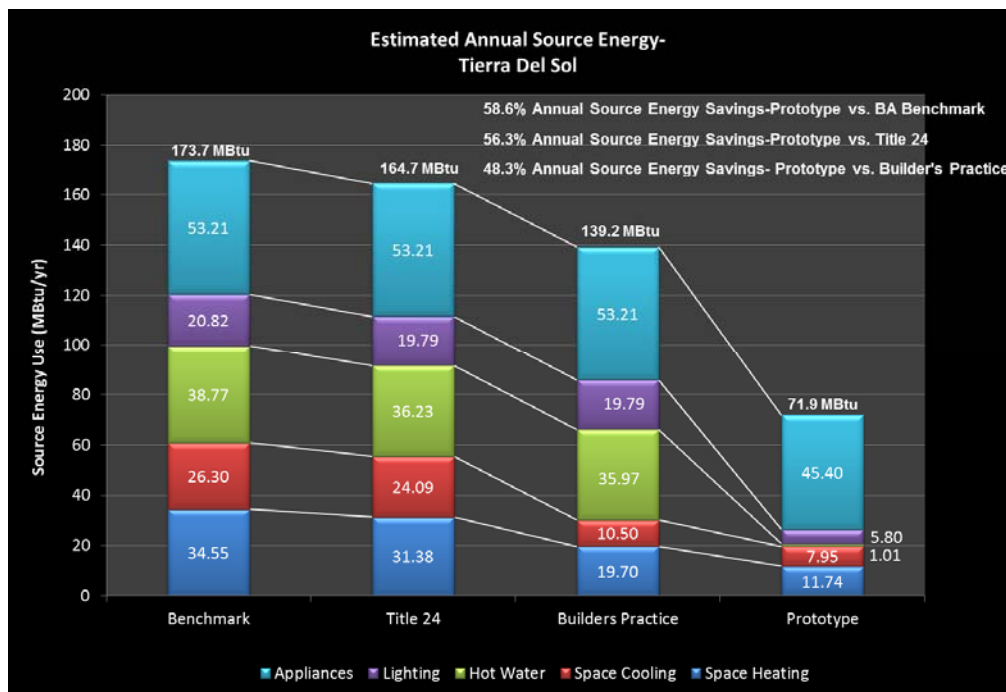


Figure 152. Tierra Del Sol estimated annual source energy for the BA Benchmark, Title 24, Builder's Practice, and 50% WHES (labeled prototype)

"Must Meet" Gate Criteria -- Market Coverage

Initially, eight of the twenty two homes were estimated to be complete and ready for sale in the Community before January 1, 2011, however all homes have been placed on hold while a marketing strategy is developed. Understandably there is some hesitance to present these low-income homes during the holiday season. The traditional high peak for home sales is from May through September. The holiday season can put homebuyers in a predicament where they temporarily cannot or will not purchase a home due to other financial commitments during that time.

Consequently, it is estimated the Community will begin construction in the beginning of next year with all homes complete by March 2011. To reduce risk of vandalism and maintenance costs on vacant homes, the developers would like to ensure all homes are occupied within two weeks of completion. To achieve this goal, the homes will be constructed and shipped in sets of four every two weeks. Based on this information, the Community meets the BA criteria for market coverage for a minimum of ten homes.

"Must Meet" Gate Criteria -- Neutral Cost Target

In early 2009, BIRA met with the County to discuss the use of funds from the federal HOME Investment Partnership Program³³. The County was allocated \$1,610,587 in HOME funds to be

³³ The HOME Investment Partnerships Program (HOME) is a type of United States Federal assistance provided by

used for eligible activities such as homeowner rehabilitation, homebuyer assistance, and affordable housing construction. \$241,576 of the County's HOME funding will be used for the financing of energy conservation enhancements in the Community.

Despite various sources of funding from both the local and federal levels for the development of low income housing, the cost of construction remains a significant issue. To ensure the homes remain affordable for low incoming households, the technological pathway used to provide energy savings was designed to be as cost-effective as possible. The most cost-effective technological pathway to achieve whole house energy savings starts with an advanced thermal envelope, then incorporates highly efficient HVAC and water heating systems. Once those building features and measures were put into place, the remaining energy savings required to provide net zero energy bills was achieved through renewable energy from PV.

ZETA was selected as the modular home manufacturer due to their ability to utilize the required cost-effective technological pathway for the Community. Modular construction provides numerous project cost-savings through significant reductions in total development time including construction of both the foundations and units occurring in parallel rather than linearly. Using an off-site facility and inventory system ensures there are no weather delays, material shortfalls, worker downtimes, or unanticipated site issues. ZETA estimates that their precision-building process decreases construction waste by approximately 50% compared to site-built construction. Efficient fabrication reduces labor time and associated costs and shorter construction time reduces holding costs. Furthermore, ZETA provides the developer with a fixed budget for construction, delivery and installation so there are no surprises or cost overruns.

Unlike a traditional home, the purchase price of a home in the Community does not reflect the true cost of construction or any builder cost mark-up for profitability. Developed as low income housing, the home purchase price will be less than the appraised value. This cost savings to the homebuyers is made possible through use of funding from such sources as the federal HOME program.

As for all construction projects, installation time and associated labor costs were key issues, however the incremental cost analysis shows only the material costs for all building features. Labor costs are builder and region specific and cannot easily be translated to other projects. The incremental cost analysis includes raw building features' costs, provided by ZETA. It should be noted that fluctuations in utility rates were not accounted for either.

the U.S. Department of Housing and Urban Development (HUD) to States in order to provide decent and affordable housing, particularly housing for low- and very low-income Americans. It is the largest federal block grant to states and local governments designed exclusively to create affordable housing for low-income families, providing over US \$2 billion each year. The program is commonly referred to as the Home Investment or Home Partnership Program, and is often operating in conjunction with other housing and other urban development programs, such as the CDBG program. Its federal identification number, or CFDA number, is 14.239.

The average 58.6% WHES reduction in Unit 101 provides a substantial reduction in energy bills. The incremental cost calculation (shown in community report Appendix D) demonstrates that despite the additional cost of the advanced energy features, the savings in utility bills will offset the additional cost. When financed as part of a 30-year mortgage at 7% interest, the incremental annual cost will be reduced by \$914, after utility savings are taken into account, as shown in [Figure 153](#).

Traditional market-value mortgage rates and terms were used in the incremental cost analysis as a conservative representation of potential cost savings. Through use of low interest financing available for low income households, cost savings could increase. Energy efficient mortgages could also be a possible solution for low income households to qualify for the higher home purchase price.

Currently, simulations show the 50% WHES can provide cost savings to the homeowner, however, the net zero energy technological pathway appears to be limited to being cost neutral if not slightly over. These calculations are based on the traditional mortgage standards and do not take into account any of the funding or financing opportunities for low income households, and therefore do not necessarily represent a true barrier/gap for this current project. However, for the same net zero energy technological pathway to be used under standard conditions, the current renewable energy market will need to mature to reflect more appropriate product costs in comparison to potential energy savings, or energy costs will need to increase in order to achieve more savings through renewable energy.

Based on this information, the incremental annual cost of energy improvements to achieve 50% WHES is less than the annual reduction in utility bill costs. Therefore, the homes pass the Neutral Cost Target “Must Meet” criteria.

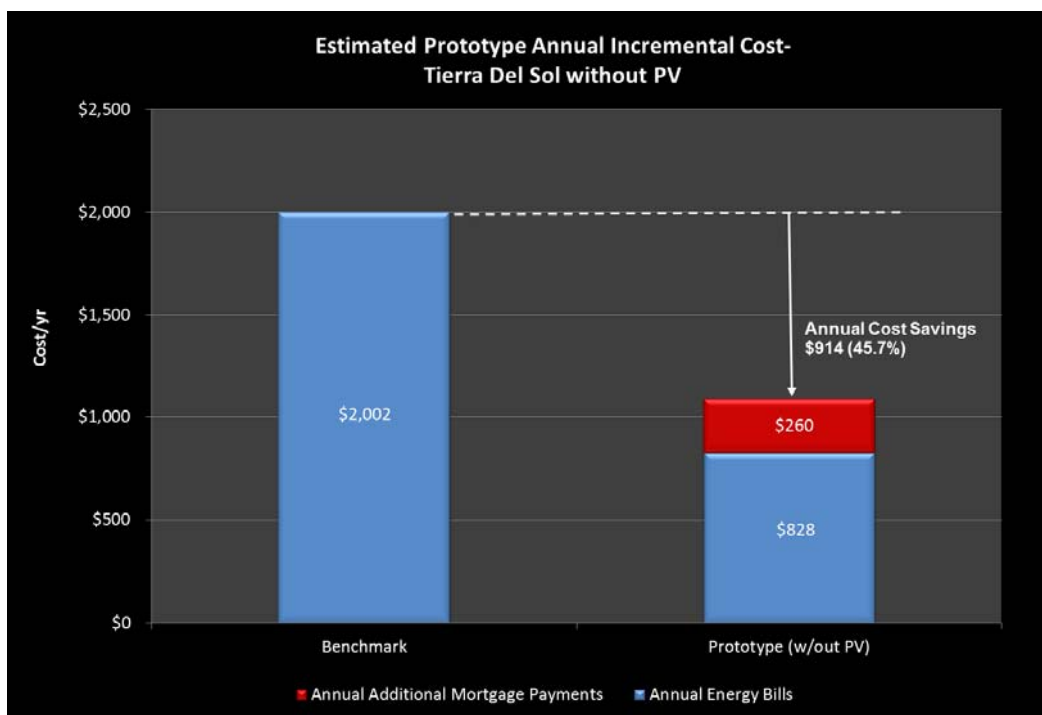


Figure 153. Tierra Del Sol estimated annual incremental costs for the BA Benchmark and the prototype without PV

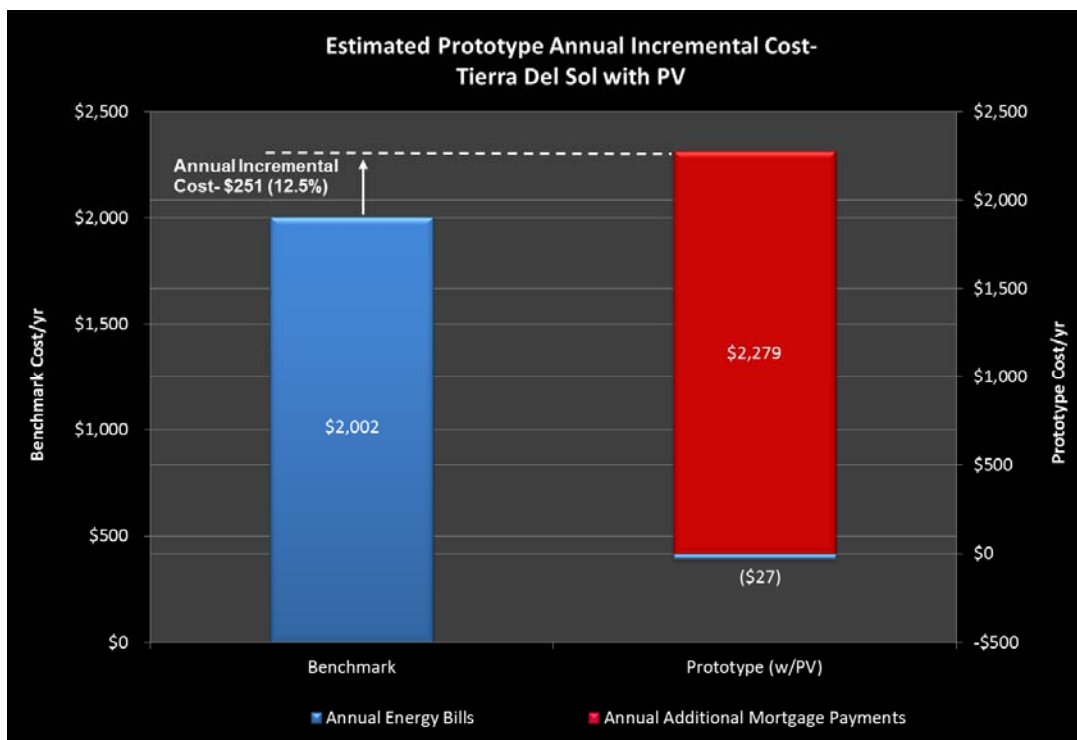


Figure 154. Tierra Del Sol estimated annual incremental costs for the BA Benchmark and the prototype with PV

The PV system required to achieve net zero energy does not provide enough utility cost savings to completely offset the significant incremental cost to remain truly cost neutral. Under the standard mortgage conditions (stated above), net zero energy could require the homeowner to pay an additional \$251 annually when compared to Benchmark, as shown in Figure 154. This incremental cost was determined via energy simulations and therefore is simply an estimate, moreover worst case financing for low income households was used. More accurate incremental costs (relative low income funding), along with accurate utility costs could show the net zero energy home is cost neutral.

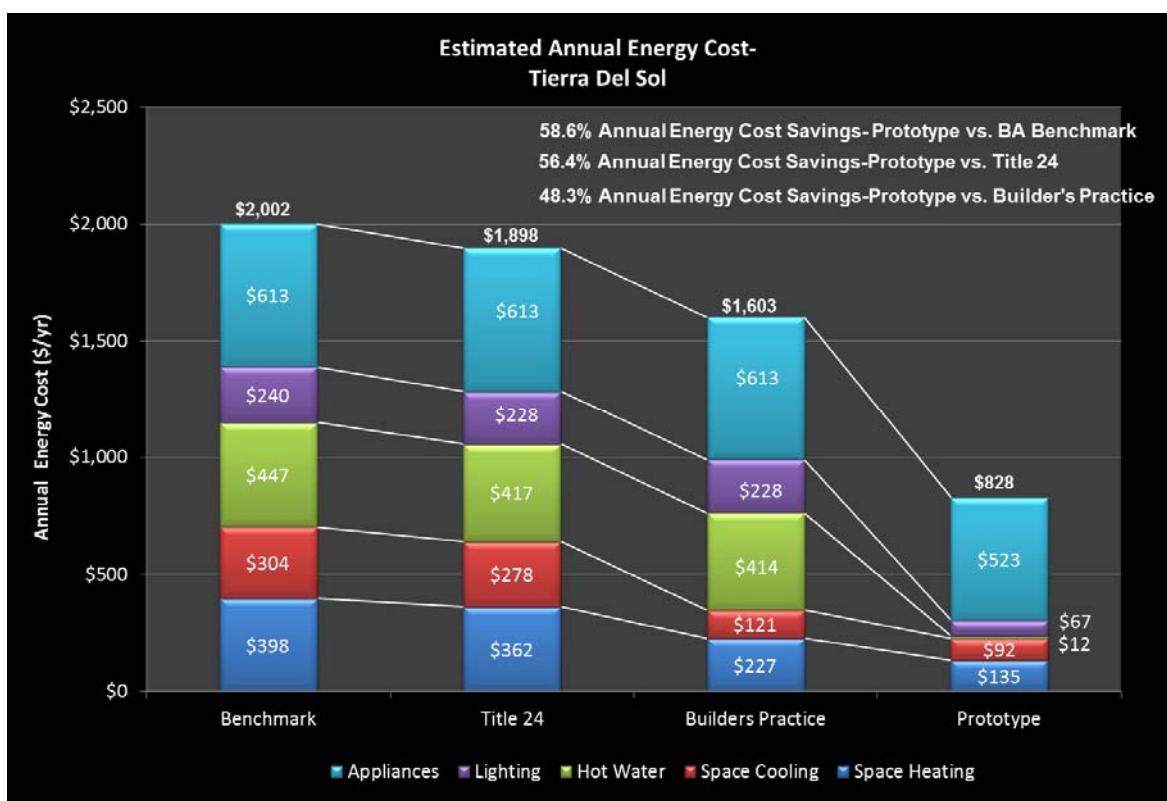


Figure 155. Tierra Del Sol estimated annual energy costs for BA Benchmark, Title 24, builder's practice and 50% WHES

Figure 155 illustrates the annual utility bill cost savings for the main end-use categories. The highest cost saving is achieved in "Hot Water" with the use of 0.95 EF, 120 gallon electric water heater and supplemental solar thermal water heating from the PVT ECHO system, when compared to the builder's standard practices. Because of the high efficiency water heater and renewable solar thermal energy, the expected annual cost for all hot water consumption is only \$12. On average, Unit 101 will save 58.6% more in utility bills than a home built to the BA Benchmark level, 56.4% more than Title 24 standards and 48.3% more than a home built to VHB's typical building practices.

“Should Meet” Gate Criteria – Marketability

The developers are in the process of establishing a marketing strategy for successful home sales during the upcoming holiday season. Both the County and VHB are familiar with the low income housing market and understand from experience that low income households typically have less savings and disposable income to apply towards a down payment. These funds are even more limited around the holiday season due to other possible financial obligations.

VHB has mentioned there is less demand from low income households for energy efficiency compared to higher income households. This is most likely due to the higher upfront cost of the above code home without understanding the long term cost savings benefits from lower operations and maintenance costs. To successfully market energy efficiency, the homebuyer must be presented with all known benefits received with the higher home purchase prices. The main focus of VHB’s marketing message will be the ability for the homes to be operated at net zero annual energy for conscientious homeowners. Furthermore, funding and financing from the developers will be made available to assist with the higher upfront costs for the energy efficiency upgrades.

A possible marketing strategy includes hosting a block party event at the Community site with one model unit available for touring. The model unit will serve as an interactive classroom for homebuyer education about energy efficiency and sustainability. Another marketing strategy to raise interest in the Community and support the potentially high demand of the homes is offering the homes through a lottery process. All eligible applicants will have a chance to win the right to purchase one of the units. Each household wanting to participate in the lottery will be required to complete a HUD certified Homebuyer Education class (currently available through VHB). Based on this information, the Community passes the Marketability “Should Meet” Stage Gate criteria.

“Should Meet” Gate Criteria – Market Coverage

While the modular construction and the associated stringent QA/QC procedures played a vital role in the successful development of the Community, the same 50%+ WHES pathway could have been achieved through use of high quality onsite construction. The building materials are “off-the-shelf” products and are not region specific. However, the cost-effectiveness of the 50% WHES will invariably be dependent on labor costs and regional variations. Modular construction presents viable cost savings and in most cases presents an improved cost benefit over onsite construction. By fabricating the homes in a factory setting, installation time is reduced along with material costs due to precision cut and assembly. That being said, all modular home manufactures do not have the same building practice. When using modular construction, the project can be limited to the capabilities of the manufacturing facility.

The 50% WHES pathway can be utilized in a range of different weather conditions and construction practices, therefore satisfying the Market Coverage “Should Meet” Stage Gate criteria.

“Should Meet” Gate Criteria -- Builder Commitment

The County and VHB are developing the Community to determine the feasibility of constructing sustainable, affordable energy efficient homes. With project goals including net zero energy and CALGreen certification, the developers have shown a strong commitment to push their building practices to the limit of currently available sustainable technology and home design. Affordable net zero energy requires a strong 50%+ WHES pathway to ensure costly renewable energy systems are kept to a minimum. Although the developer’s standard building practice did not include modular construction, they were committed to achieving the project’s goals and understanding the cost benefits of alternate construction practices.

They are committed to expanding their energy efficient standard building practices to reach the 50% WHES level as evidenced from the effort shown so far, thereby satisfying the Market Coverage “Should Meet” Stage Gate criteria.

“Should Meet” Gate Criteria -- Gaps Analysis

Prior to the introduction of ZETA, another modular home manufacturer was selected for the construction of the Tierra Del Sol community. However, this manufacturer was not able to incorporate many energy efficient products and lacked familiarity with thermal bridging techniques, including high R-value envelope insulation and low air infiltration, thereby limiting the selection of building features. Based on energy model simulations, the original prescribed building features (limited by the modular home factory) would require a 5.5 kW PV system to provide the remaining energy necessary to achieve a net-zero energy home. The estimated required PV system was reduced to 4.0 kW with ZETA’s ability to incorporate energy efficient building features and advanced thermal bridging techniques. The ZETA manufacturing process has provided the most cost-effective technological pathway for 50% WHES and net zero energy, which to date represented the greatest gap for the successful development of the Community.

The purchase price of low-income housing must be within an obtainable range. All perspective homebuyers would need to qualify as low income households and have the ability to provide a down payment. The County will work with homebuyers to help finance the home purchase by providing a silent second mortgage (funded by the federal HOME program) which will cover the difference between what the homebuyer can afford and the purchase price.

“Should Meet” Gate Criteria -- Quality Assurance

Modular home construction is different than manufactured home construction (i.e. mobile homes) in terms of building code standards. Modular home construction adheres to the same

building code standards as onsite built homes. ZETA homes meet and exceed local and State of California building codes and energy efficiency standards under Title 24. In addition, in accordance with the State of California Department of Housing & Community Development's modular housing policies, third-party building inspectors evaluate and provide the seal of approval for off-site construction at ZETA's clean tech facility. Local building departments inspect and approve the on-site construction of the foundation, utility connections and the finished home. Inspections and testing requirements include:

- Total duct leakage test at system rough-in on every house
- Insulation and thermal by-pass inspection
- On-site confirmation of window U-values
- On-site confirmation of qualifying HVAC and appliance equipment efficiencies
- On-site lighting inspection
- Prior to occupancy, at least 10% of homes are re-tested to confirm duct leakage to the exterior is less than 6% at 50 Pascals and to confirm envelope tightness

Furthermore, the homes were designed to comply with CALGreen program standards. By receiving CALGreen certification, the County is ensuring all homes will achieve quantifiable and verifiable environmental benefits through continuous efficient resource management and will provide a sustainable, healthy living environment. Historically, the County has not required energy efficiency or sustainable measures to be included for county-funded homes; however the Community will be used to demonstrate the feasibility of implementing such requirements on larger scale projects.

By fabricating off-site and employing proprietary innovations for the building envelope and mechanical systems, ZETA achieves higher quality while reducing waste and cost. ZETA only constructs with dry lumber and frames indoors with jigs and pre-cut material to produce structures with better dimensional control, strength and rigidity. ZETA's waterproofing and mold resistant strategies and materials exceed conventional building standards. Installing high performance materials off-site allows for better control, greater worker access and an efficient fabrication sequence. As a result, ZETA's building envelope is more reliable than conventional construction. In addition, most interior finishes are installed in the factory, further improving quality and reducing cost.

Prior to fabrication and production in the manufacturing facility, BIRA will provide DOE-approved best building practice training (specific to the Hot-Mixed Dry climate region). Factory and construction site visits will occur on a regular basis by BIRA to ensure successful project development, to assist in implementing proper building practice, and to coordinate and document project information and updates. Despite ZETA's experience with net zero energy construction, a training session will be useful in coordinating the specific project requirements to factory workers. Performance testing and inspection results will be compiled and evaluated relative to the simulated energy consumption estimates.

Green One Construction Services - Sage Green 50% Marine Community Completion Report BP3 (2010)

This report provides evaluation details for Green One Construction Services' Sage Green development relative to the Building America 50% whole house energy savings (WHES) goal when compared to the Building America (BA) Benchmark in the Marine Climate Zone. This project is currently in the permitting stage with site work and utilities being completed on site. The community is evaluated based on BA's Stage Gate 3 "Must Meet" and "Should Meet" criteria.

Key Results

Sage Green community qualifies as a BA 50% Community in the Marine Climate Zone. This assessment is based on an energy analysis performed using BEopt 0.9.03 and additional information acquired from Green One Construction Services.

Gate Status

An energy analysis performed on a typical Sage Green Home shows energy savings of 50.1%, compared to the BA Benchmark. With the current status of depressed housing sales in the Portland metropolitan area, Green One Construction Services will begin completion of this project after sale closure of the five (5) completed houses. Based on the results of the BEopt analysis, the homes will realize annual energy savings of \$800 over the BA Benchmark. Additional cost and schedule information will be included in this study as it becomes available. Green One Construction Services intends to keep its homes marketable even in the current housing crisis. They intend to market the homes as being capable of net-zero annual energy needs when operated in an energy conscious manner. They are committed to building high-quality, low-energy homes at costs that are comparable to code-built homes. Green One Construction Services intends to achieve these results through innovative construction practices and positive relationships with their subcontractors.

Conclusion

Sage Green will consist of 18 homes when complete, all of which will meet the federal tax credit standards. Sage Green is exceeding specifications prescribed by Oregon Business Energy Tax Credit, High Performance Home program. By exceeding these requirements, Sage Green meets the 50% whole house energy savings compared to BA Benchmark.

Project Overview and Background

The following report presents the evaluation of Green One's Sage Green community relative to the BA 50% WHES goal when compared to the BA Benchmark in the Marine Climate Zone. The community is evaluated based on BA's Stage Gate 3 "Must Meet" and "Should Meet" criteria

(See community report Appendix A). Detailed case study data is provided in appendices at the end of this report. Key partners include Alan Seymour and Robert Del Mar of the Oregon Department of Energy, and David Hales of the Washington State University (WSU) Energy Program.

Green One Construction was founded by Ben Walsh in 2008 and focuses on high-performance residential community projects in Portland, Oregon. Ben Walsh previously worked with Tom Walsh & Co. where he acted as project manager for the New Columbia Community revitalization project in Portland. At New Columbia, Ben completed 22 federal tax credit homes and participated in the Building Industry Research Alliance (BIRA) Building America Program. The New Columbia homes achieved Home Energy Rating Scores in a range from 59 to 66.

Community Overview

The community described in this case study is Green One's Sage Green development located in Portland, Oregon. Portland is located in BA's Marine Climate Zone and experiences an average annual precipitation of 36 inches, 4,522 annual heating degree days (HDD65), and 370 annual cooling degree days (CDD65). This climate provides the greatest opportunity for energy savings from reductions in space heating loads.

Sage Green will consist of 18 homes when complete, all of which will meet the federal tax credit standards. The homes will utilize continuous rigid insulation on the walls, R-49 attic and NFRC 0.22 windows. The homes will be targeted at middle-class homeowners looking for a high-quality and low-energy home. All of the homes will feature PV arrays and are being designed to achieve net zero energy over the course of a year with energy conscious homeowners. The community is provided electricity by Portland General Electric and natural gas by Northwest Natural.

This case study demonstrates that Sage Green Community meets Building America's 50% initial community's goal for the Marine Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria.

"Must Meet" Gate Criteria -- Source Energy Savings

An energy analysis was performed using BEopt 0.9.03 to model the four units proposed for the Sage Green development. All four unit types demonstrate similar performance and savings. This report will be simplified by showing the results of the BEopt analysis for Unit C. Unit C is representative of a typical Sage Green house with 1,526 sq. ft. of finished floor area, three bedrooms and three bathrooms. Two separate simulations were run, one with the BA Benchmark as a reference house, and one with an Oregon code house as a reference house. [Figure 156](#) shows the BEopt source energy use graph for the Unit C floor plan with the BA Benchmark as the reference house. All four cardinal orientations were simulated for both reference homes. [Table 185](#) summarizes the findings of both simulations. The energy savings

for Unit C are averaged over all four orientations and grouped into five main end-use categories.

As shown in [Table 185](#), the Unit C home at Sage Green meets the Building America goal of 50% energy savings in the Marine Climate Zone with respect to the BA Benchmark. The critical above code energy reduction features implemented in order to reach this goal are as follows:

- Wall U-factor 0.035
- R-49 Attic
- Window U-factor 0.22 (average)
- Floor U-factor 0.029
- Ventilation with balanced HRV 90% efficient
- Blower door 2.0 ACH-50 (target)
- Heat pump, 18 SEER 9.2 HSPF
- Heat pump water heater, 2.5EF
- Gas cooking

The Sage Green homes utilize a unique wall, christened the “Walsh Wall.” See completion report Appendix B of the community completion report for details of this specific wall assembly, including cost data (incremental costs).

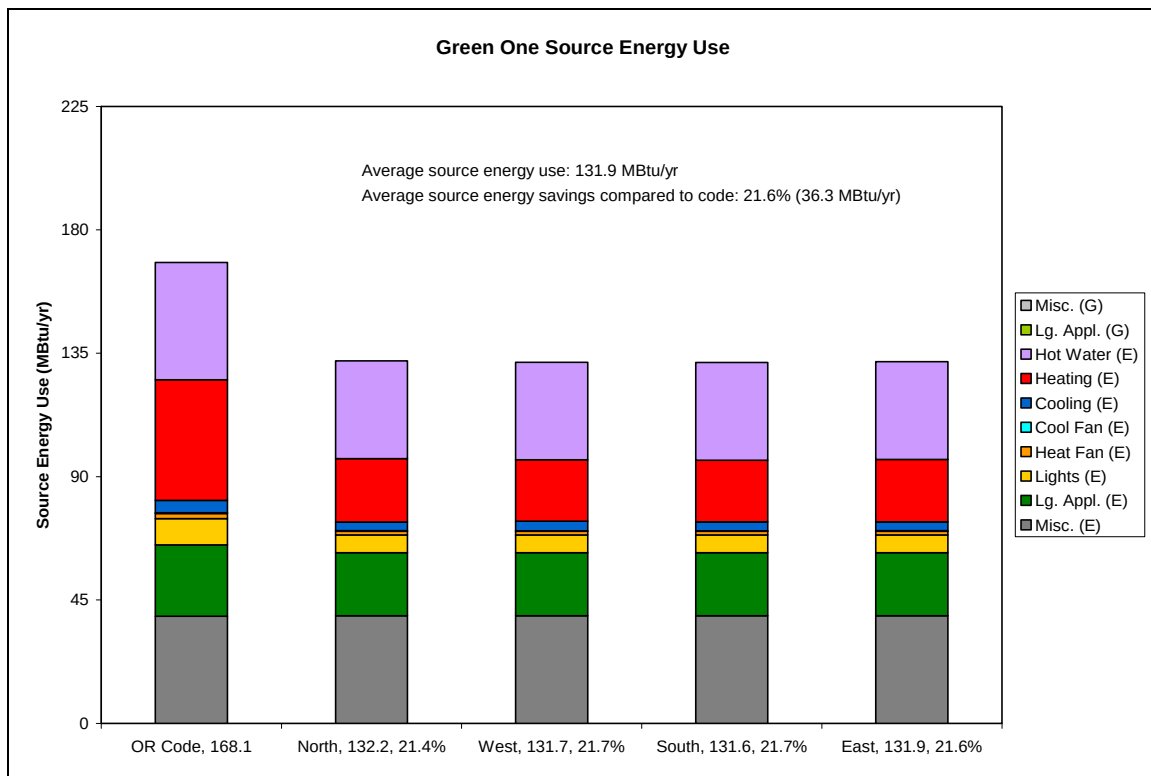


Figure 156. BEopt source energy use for Unit C with

the BA Benchmark as the reference house

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Oregon Code	Unit C	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	115.3	45.9	24.0	79.2%	47.7%	34.5%	13.0%
Space Cooling	15.5	4.7	3.5	77.4%	0.7%	4.5%	0.7%
DHW	45.5	42.8	35.6	21.7%	16.8%	3.7%	4.3%
Lighting	23.3	9.5	6.5	72.0%	31.7%	6.3%	1.8%
Appliances and MELs	64.9	65.2	62.2	4.2%	4.5%	1.0%	1.8%
Total Usage/ Savings	264.4	168.1	131.9	50.1%	21.6%	50.1%	21.6%

Table 211: Source energy savings for Unit C

Sage Green is exceeding specifications prescribed by Oregon Business Energy Tax Credit, High Performance Home program. This tax credit program utilizes the Northwest ENERGY STAR[®] Homes program to deliver homes that exceed ENERGY STAR[®] performance specifications. By exceeding these requirements, Ben Walsh meets the 50% WHES compared to BA Benchmark. For a complete list of BEopt inputs for both Sage Green Unit C plan and reference house, see completion report Appendix C.

“Must Meet” Gate Criteria -- Market Coverage

Sage Green will consist of 18 homes when completed, all of which will be 50% above the BA Benchmark. The project currently has five completed projects. The original build-out of the site was slated to be completed at the end of 2010, however the new home market in the Portland metropolitan area has been severely depressed. Future starts for this project will begin after the five finished homes have sales that are in closing.

“Must Meet” Gate Criteria -- Neutral Cost Target

Ben Walsh has developed building systems that were completed in a manner that is cost-competitive with conventional high quality building practices. This includes development of a wall assembly that utilizes rigid foam directly on the outside of wall studs and with plywood outside of foam. This process and assembly can be completed by the framing subcontractor and should reduce the time and cost of building high performance walls. The assemblies were tested for structural code compliance at Oregon State University. See completion report Appendix C for details of this wall system.

In addition to sound economic construction practices, the 50% WHES will provide substantial reduction in energy bills, resulting in few, if any, tradeoffs necessary to reach the neutral cost target. Figure 157 shows the BEopt energy cost graph for Unit C floor plan with BA Benchmark as the reference house. These costs are based on the current utility rates in Portland, Oregon, summarized in Table 212, and include both electric and natural gas energy sources. Table 213 demonstrates the annual saving of the Sage Green homes compared to the BA Benchmark and Oregon code.

It is believed that energy savings generated in Sage Green homes will offset the expense of implementing energy saving measures. In addition to utilizing innovative construction practices, Walsh will qualify for \$3,000 in state tax credits and \$2,900 in utility incentives per home for the energy conservation measures. An additional \$25,000 in state and utility incentives will be available for the installation of 7 kW photovoltaic (PV) systems on each unit. The incremental costs of improving the building envelope were an additional \$10,000 over a code home. The HVAC incremental cost, which includes total HRV costs, was an additional \$5,000 over a code home. Total costs of the PV system were varied from \$35,000 to \$49,368 for the system.

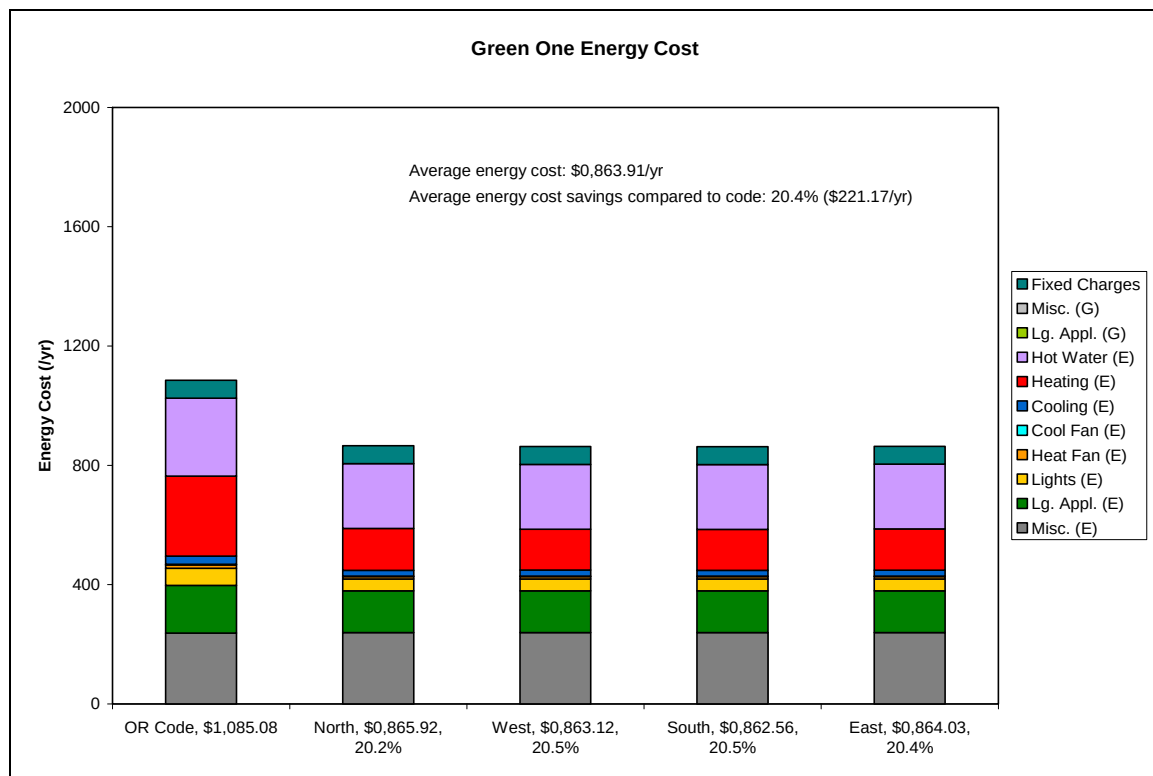


Figure 157. BEopt energy cost for Unit C with the BA Benchmark as the reference house

Electricity Rate

Utility	Portland General Electric
Marginal	\$0.070/kWh
Fixed	\$5.00/month
Natural Gas Rate	
Utility	Northwest Natural
Marginal	\$1.2245/therm
Fixed	\$6.00/month

Table 212. Current utility rates for Portland, Oregon

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	Oregon Code	Unit C	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	115.3	45.9	24.0	79.2%	47.7%	34.5%	13.0%	\$556.68
Space Cooling	15.5	4.7	3.5	77.4%	0.7%	4.5%	0.7%	\$72.90
DHW	45.5	42.8	35.6	21.7%	16.8%	3.7%	4.3%	\$60.09
Lighting	23.3	9.5	6.5	72.0%	31.7%	6.3%	1.8%	\$102.06
Appliances and MELs	64.9	65.2	62.2	4.2%	4.5%	1.0%	1.8%	\$16.52
Total Usage/ Savings	264.4	168.1	131.9	50.1%	21.6%	50.1%	21.6%	\$808.25

Table 213. Modeled annual energy and dollar savings for Sage Green Unit C

“Should Meet” Gate Criteria – Marketability

The Portland metropolitan area has seen a considerable downturn in the housing market. Keeping homes marketable during the current housing crisis is a challenge for all builders. Walsh will be utilizing innovative construction methods, a positive relationship with subcontractors and well-negotiated component pricing to offer the homes at Sage Green at competitive market rates. The main focus of Walsh’s marketing message will be the ability of Sage Green homes to be operated at net zero annual energy for conscientious home owners. Walsh believes the combination of excellent energy performance and many healthy home features will give him an edge in marketing Sage Green homes. At the time this report was written, the sale price for these homes is \$225,000.

Walsh has experience bringing high performance homes to the marketplace from his involvement in the New Columbia Project. At New Columbia, 22 federal tax credit homes were built and offered for sale from \$274,900 to \$299,000, which was competitive with code-built homes.

“Should Meet” Gate Criteria -- Builder Commitment

Green One was formed by Walsh with the sole purpose of constructing high quality, high value, low energy homes, and as such, will never build a “code” home. Walsh and his team have become known in the region for delivering high performance homes at competitive market rates.

Walsh’s commitment to building high quality, low energy homes is also apparent in his relationship to his subcontractors.

“If people are working on slim margins and if you ask them to up-end their processes, they see this as one thing, and they are absolutely right--loss. They can’t do it,” says Walsh. “Every one of my subcontractors has to know that their profitability is of paramount importance to me.” By demonstrating this commitment to his subcontractors Walsh is able to maintain productive long-lasting relationships in which innovative building practices can thrive. The results are lower costs and higher energy savings.

“Should Meet” Gate Criteria -- Gaps Analysis

The Sage Green development is currently in a stage of obtaining financing for construction. Obtaining financing for a new residential development project in Portland has become difficult. The downturn in the housing market is tied to a financial crisis within banks that traditionally make construction loans. The result has been much less financing available to builders and much higher scrutiny on the part of banks when evaluating a construction project.

The financing challenges for the Sage Green development have impacted two aspects of the

construction project. First, banks are stipulating the project must be funded in multiple stages with future funding being dependent on demonstrated success of a previous project phase. This requirement will affect the construction schedule and result in less opportunity to achieve unit savings through higher volumes of work. What might have been one or two large jobs constructing many units, will now need to be three smaller jobs constructing six units. The second aspect of the project affected by the financial challenges has been the need to provide much more information to the bank to obtain the loan. Walsh had to put together what amounts to a marketing package, not to sell the units to homebuyers, but to sell the project to the bank.

In future projects, Green One will be prepared to deal with challenges of a tight lending market. It may also be that future projects will experience fewer problems obtaining loans as the housing and financial crisis are resolved.

“Should Meet” Gate Criteria -- Quality Assurance

Green One Construction Services is committed to rigorous quality assurance (QA) practices. Walsh spends considerable time and resources developing new and innovative construction practices and considers a strong QA process to be a key part of evaluating and further improving those processes. While construction has not yet begun at Sage Green, Walsh is already demonstrating his commitment to third-party verification. He has engaged the Energy Trust of Oregon and the Oregon Department of Energy to validate his energy calculations.

All Sage Green homes will be built to the Oregon High Performance Home tax credit standard, which includes third-party verification of construction practices through Northwest ENERGY STAR® Homes Verifier Network. In the state of Oregon, 5% to 10% of all ENERGY STAR® homes undergo a second level of quality assurance by an independent third party. Because projects in the High Performance Home tax credit program make up only a small percentage of the total ENERGY STAR® homes program, 100% of these projects are selected for the additional level of QA. This additional level of review has been true of Sage Green Homes.

Based on this information, Sage Green community development passes the Quality Assurance “Should Meet” criteria.

Subtask 4.2.a – Stage Gate 3: Devoted Case Study (40% Marine Joule Milestone)

Mediterranean Villas --Community Overview

The community described in this case study is Devoted’s Mediterranean Villas community located in Pasco, Washington. The city is located in Building America’s Cold Climate Zone and experiences average annual precipitation of 7.1 inches, 4823 annual heating degree days, and

888 annual cooling degree days.

Devoted Builders was started in 2005 by Fred Giacci and his family. The company has grown to be one of the larger homebuilding companies in the Tri-Cities region of Washington State. In 2006 Devoted decided to build all of its homes to Northwest ENERGY STAR standards and is currently participating in the Department of Energy's Builders Challenge. In 2007 Devoted added Built Green certification to all their homes. Devoted has received the 2008 Builder of the Year Award from the Northwest ENERGY STAR Program for the State of Washington.

Mediterranean Villas will consist of 250 homes when complete. Approximately 200 homes are now complete with at least 30 meeting federal tax credit standards. The 50 homes to still be constructed will be at the tax credit level or beyond. Devoted currently offers eight (8) one and two story floor plans as duplexes, triplexes and single family units ranging in size from 1140 ft² to 2100 ft². All models employ slab-on-grade construction with R-25 ICF walls from the footing to the top plate. All units have attached two-car garages, stucco exterior finish and are marketed as low maintenance, high efficiency, "green" homes to middle class and retiring home owners. Current sale prices range from \$145,000 to \$300,000.

For more information on the Mediterranean Villas community, contact Fred Giacci, Owner, Devoted Builders, at fgiacci@earthlink.net or visit the Devoted Builders website, www.mvtownhouses.com.

Key Results

Devoted Builders' Mediterranean Villas community qualifies as a Building America 40% Community in the Cold Climate Zone based on an energy analysis performed using EnergyGauge, the incremental costs based on builder estimates, and additional information gained first hand from the builder.

Gate Status

An energy analysis performed on a typical Devoted federal tax credit house shows energy savings of 48.5% compared to the Building America Benchmark. Devoted has over 30 of these tax credit homes completed in the Mediterranean Villas. Based on the energy cost savings from EnergyGauge and incremental costs from Devoted Builders, it has been determined that the homeowner expects to see approximately \$934 per year net cost savings versus the Building America Benchmark.

Devoted has been able to keep their homes marketable even in the current housing crisis. Devoted has qualified 100% of their homes to be labeled ENERGY STAR since 2006 and Built Green since 2007 and qualifies all homes for the \$2000 federal tax credit. In addition, Devoted is currently building all of their homes to a level beyond the Building America 40% Cold Climate bench mark and consistently works with their subcontractors to implement new technologies

and practices to further improve performance. Devoted is currently completing two 50% prototypes that include ductless mini-split heat pumps; additional air sealing with spray foam, improved windows ($U=.21$), and real time energy use feedback to increase awareness of MELs. Future improvements anticipate including solar domestic hot water and/or heat pump water heaters; PV ready designs; additional CFLs moving to 100%; and switched circuits to better manage MELs.

“Must Meet” Gate Criteria -- Source Energy Savings

Using EnergyGauge, an energy analysis was performed on Devoted’s Marsala 1772 floor plan. Floor plans and elevations can be found in the final report. The Marsala 1772 plan is a two-story house representative of a typical Devoted house in Washington, with 1772 square feet of finished floor area, three bedrooms, and two bathrooms. The plan was modeled as a federal tax credit home, as are all floor plans offered by Devoted. Two separate simulations were run, one with the BA Benchmark as the reference house, and one with a Washington code house as the reference house. Figure 158 shows the EnergyGauge source energy use graph for the Marsala 1772 floor plan with the BA Benchmark as the reference house. All four cardinal orientations were simulated for both reference homes. Table 214 summarizes the findings of both simulations. The energy savings for Marsala 1772 are averaged over all four orientations and grouped into five main end use categories.

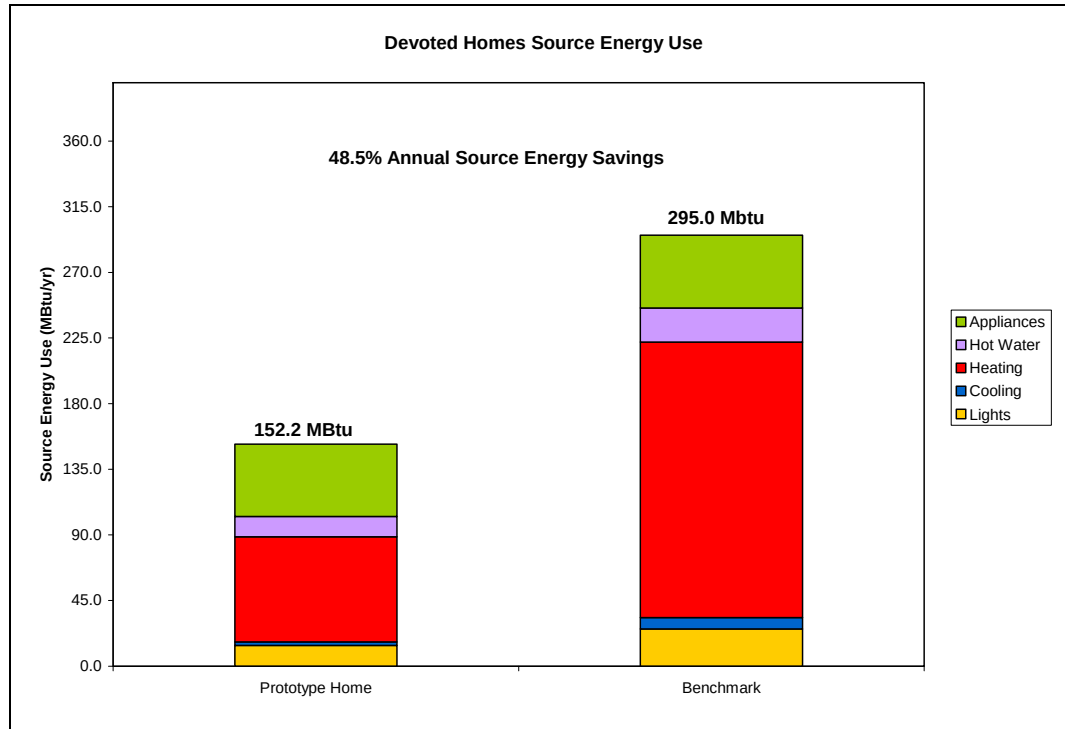


Figure 158. EnergyGauge Source Energy Use
Marsala 1772 with the BA Benchmark as the Reference House

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	Washington Code	Unit "M"	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	188.8	78.2	72.0	61.9%	7.9%	39.5%	3.1%
Space Cooling	7.9	3.3	2.5	68.4%	24.2%	1.8%	0.4%
DHW	23.3	24.8	14.0	40.0%	43.5%	3.2%	5.4%
Lighting	25.5	27.6	14.2	48.5%	48.5%	3.8%	6.7%
Appliances and MELs	50.0	55.5	49.5	1.0%	10.8%	0.2%	3.0%
Total Usage/ Savings	295.6	198.5	152.2	48.5%	23.3%	48.5%	23.3%

Table 214. Source Energy Savings for the Marsala 1772 Floor Plan

As shown in Table 214, a typical Devoted house meets the Building America goal of 40% energy savings in the Cold Climate Zone with respect to the BA Benchmark. The critical above code energy reduction features implemented in order to reach this goal are as follows:

- ENERGY STAR refrigerator, dishwasher, and clothes washer
- 70% hardwired CFL lighting
- 84% EF gas on-demand water heater
- 8.5 HSPF 14 SEER heat pump with 93% AFUE gas furnace backup
- Tested duct leakage less than 6% cfm50 to exterior
- 3.0ACH₅₀ infiltration (typical Devoted home)
- R49 blown-in cellulose insulation in the attic
- R-25 ICF exterior walls
- Heat Recovery ventilation (75% Total efficiency)
- 0.29 U-value windows
- Gas cooking range and clothes dryer (gas dryer stub provided)

Based on the EnergyGauge simulation comparing a typical Devoted house to the BA Benchmark and providing a 48.5% reduction in source energy use, it can be concluded that Devoted Builders' Mediterranean Villas community passes the Source Energy Savings "Must Meet" criteria.

"Must Meet" Gate Criteria -- Market Coverage

Mediterranean Villas will consist of 250 homes when completed. Within the currently 80% complete community are 30 federal tax credit homes (40% above the BA Benchmark). All of the 50 remaining homes to be completed are planned to meet the federal tax credit level or beyond. For a site plan of the Mediterranean Villas community, see Appendix E of the final

report. Based on this information, Devoted Builders' Mediterranean Villas community passes the Market Coverage "Must Meet" criteria.

"Must Meet" Gate Criteria -- Neutral Cost Target

Devoted Builders has been able to keep its costs relatively low while implementing energy efficiency features. They have done this by working with vendors to bring costs down, beginning with the most expensive elements. This effort is largely driven by the recent housing crunch—and it is definitely working. In addition, the 48.5% whole house energy savings provides substantial reduction in energy bills, resulting in few, if any, tradeoffs necessary to reach the neutral cost target. Figure 63 shows the EnergyGauge energy cost graph for the Marsala 1772 floor plan with the BA Benchmark as the reference house. These costs are based on the current utility rates in Pasco, Washington, summarized in **Table 215**, and include both electric and natural gas energy sources.

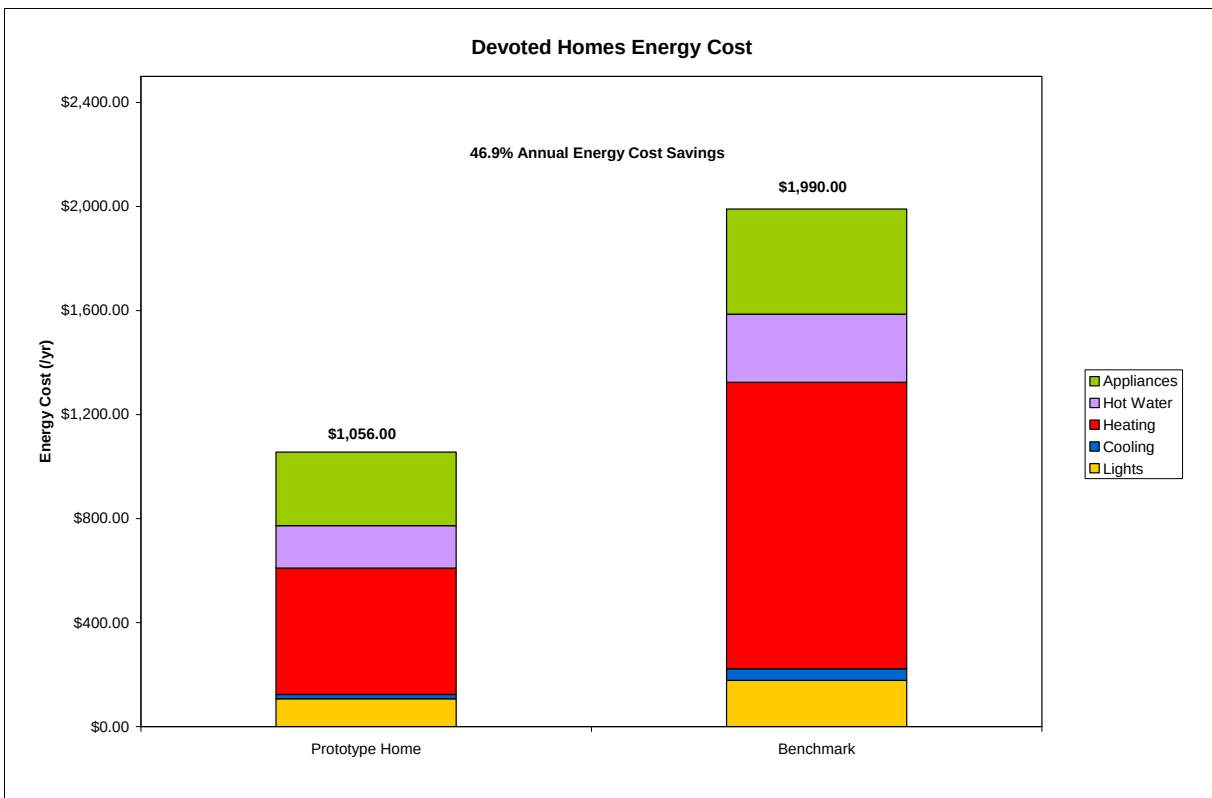


Figure 159. EnergyGauge Energy Cost
Marsala 1772 with the BA Benchmark as the Reference House

Electricity Rate		
	Utility	Big Bend Electric Coop
	Marginal	\$0.065/kWh
	Fixed	\$6.40/month
Natural Gas Rate		
	Utility	Cascade Natural Gas
	Marginal	\$1.02252/therm
	Fixed	\$4.00/month
	City Tax	8.5%

Table 215: Current Utility Rates for Pasco, Washington

The top half of Table 216 adds a column to Table 215 that details the annual utility bill savings of each of the five main end use categories in comparison to the BA Benchmark. Again, these values are averaged over all four orientations. As shown in

Table 216, the annual utility bill savings according to EnergyGauge is \$934.00. It should be noted that this includes no fluctuations in utility rates or inflation.

The bottom half of Table 216 is derived from the builder's first cost (detailed in Appendix D of the final report) for each of the energy efficiency features listed. The builder cost comes from a meeting between BIRA representatives and Devoted's owner. A 10% markup is assumed, the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation is not considered. For the gas cooking range and clothes dryer, it is assumed that there are no additional costs.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	Washington Code	Unit "M"	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	188.8	78.2	72.2	61.8%	7.7%	39.4%	3.0%	\$615.00
Space Cooling	8.0	3.3	2.3	71.6%	31.1%	1.9%	0.5%	\$28.00
DHW	23.3	24.8	14.2	39.0%	42.6%	3.1%	5.3%	\$99.00
Lighting	25.6	27.6	11.4	55.3%	58.6%	4.8%	8.1%	\$71.00
Appliances and MELs	50.1	55.5	48.5	3.2%	12.6%	0.5%	3.5%	\$121.00
Total Usage/ Savings	295.8	198.5	148.6	49.8%	25.1%	49.8%	25.1%	\$934.00

Energy Star Northwest Home					Energy Efficiency Feature		Annual Mortgage Cost vs. Code
					Energy Star Appliances		(\$21.08)
					70% CFL Lighting (ES Requires 50%)		(\$10.54)
					84% EF Water Heater		(\$116.80)
					Improved Duct Sealing, Envelope Sealing, and Testing		(\$100.99)
					R49 Attic Insulation		(\$21.16)
					8.5HSPF/14 SEER Heat Pump		(\$4.39)
					HRV		(\$171.16)
					U= 0.29 Window		(\$50.15)
					R-25 ICF walls		(\$312.64)
					Total Annual Mortgage Cost		(\$808.91)
					Net Annual Cash Flow to Consumer		\$125.09

Table 216. Neutral Cost Analysis for the Marsala 1772 Floor Plan

As shown in Table 216, the net annual cash flow to the homeowner is approximately \$125.09. Based on this information, it is clear that the incremental annual cost of energy improvements is much less than the annual reduction in utility bill costs and Devoted Builders' Mediterranean Villas community passes the Neutral Cost Target "Must Meet" criteria.

This analysis does not include the \$2,000 federal tax credit that Devoted receives for each new home built that achieves 50% energy savings for heating and cooling over the 2004 International Energy Conservation Code (IECC). This stems from Building America's goal of finding sustainable solutions. Since the tax credit that Devoted Builders utilizes expires at the end of 2009, it was not considered appropriate to include this credit. It is important to note, however, that the federal tax credit, along with ENERGY STAR, provides a crucial framework and starting point for builders seeking to build energy efficiently, including Devoted Builders.

"Should Meet" Gate Criteria -- Marketability

Keeping homes marketable in the current housing crisis has been a real challenge for Devoted Builders. The main focus has been faster turnarounds for installation and adoption of energy efficiency/healthy home features as opposed to higher margins. Devoted believes that their differentiation is helping to keep them afloat during this market downswing. Devoted continues to build energy efficient homes.

In future marketing efforts using information from this Building America Study, Devoted would like to be able to quantitatively show homebuyers the energy savings that their house provides compared to a typical Washington code house. Figure 160 and Figure 160 are graphs that BIRA will provide to Devoted Builders to help with this marketing effort.

Based on this information, Devoted Builders' Mediterranean Villas community passes the Marketability "Should Meet" Stage Gate criteria.

For more information on Devoted Builders sales and marketing strategy, contact Jennifer Cowgill through the Devoted Builders website at www.mvtownhouses.com.

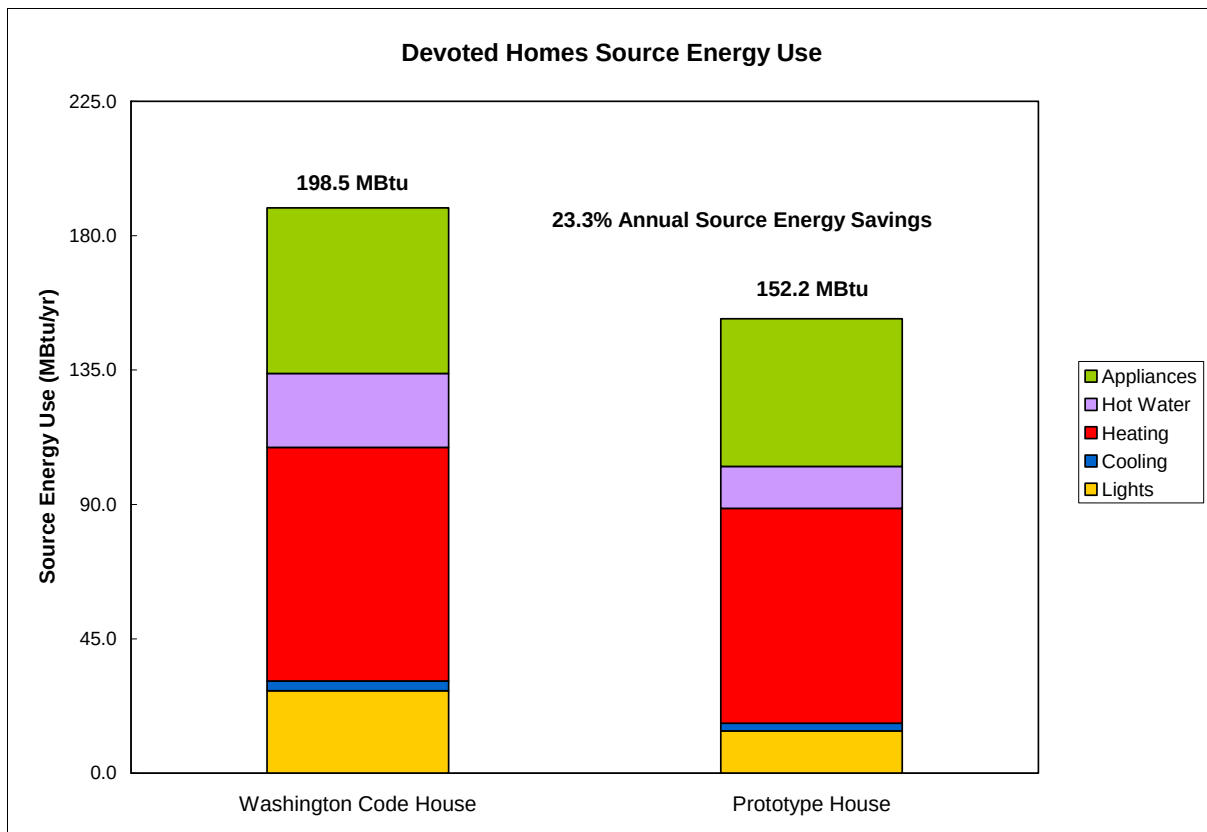


Figure 160. Source Energy Use Marketing Material for Devoted Builders

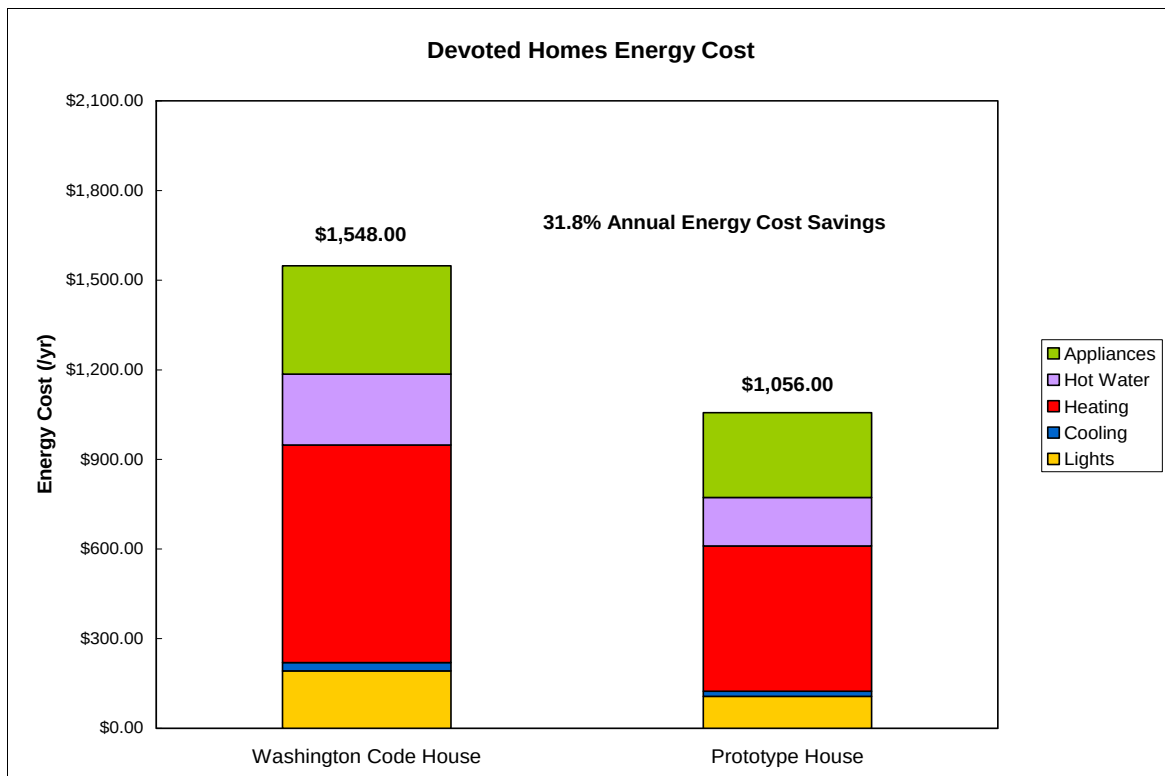


Figure 161: Energy Cost Marketing Material for Devoted Builders

“Should Meet” Gate Criteria -- Builder Commitment

In 2006 Devoted Builders made a commitment to build all of their homes to Northwest ENERGY STAR and federal tax credit standards. They are the only Washington production builder that does this. In 2007 Devoted added Built Green certification to all their homes and in 2009 they will add Builder Challenge labeling.

Devoted Builders has committed significant resources of time and money to educate their staff, subcontractors, and customers about the benefits of building high performance homes. Devoted is always looking to implement “cutting edge” energy savings technologies and sustainable building systems. David Hales, a Building Science Specialist working for Washington State University and a member of the BIRA team, believes that Devoted is “one of the best, because of their 100% commitment to building cost effective, quality, healthy, durable, and energy efficient homes in Washington State.”

They have also trained their sales agents to help them turn technical information into benefits that empower homeowners to make better decisions with respect to energy efficiency. Devoted understands that energy efficiency is not just about individual features but rather an integrated process and commitment to continual improvement.

Based on this information, Devoted Builders’ Mediterranean Villas community passes the

Builder Commitment “Should Meet” Stage Gate criteria.

“Should Meet” Gate Criteria -- Gaps Analysis

Current marketing by the HVAC industry in the Pasco market has created a demand and expectation for a dual fuel heating system in high performance homes. The system consists of a heat pump with a gas furnace for backup. At current fuel costs this system is more expensive to operate and less efficient than a normal heat pump with electrical strip heat backup and costs at least \$1000 more to install. Devoted is now moving away from this system with their 50% prototype.

Devoted has aggressive plans to move to the next level and is currently building 2 homes as prototypes for the 50% Cold Climate Benchmark. Measures included in the prototypes include: bio-spray foam of the ceiling, party walls, attic ductwork and any areas not insulated by ICFs to further reduce air leakage and provide better R-value; triple glazed U=0.17 windows; a high efficiency variable speed mini-split heat pump with inverter technology eliminating the current dual fuel system; and real time energy use feedback to increase awareness of MELs. Future improvements anticipate including solar domestic hot water and/or heat pump water heaters; PV ready designs; additional CFLs moving to 100%; and switched circuits to better manage MELs

“Should Meet” Gate Criteria -- Quality Assurance

Devoted Builders has demonstrated a strong commitment to quality assurance. As part of their Energy Star and federal tax credit standards all homes must pass third party testing and inspections. Inspections include:

- Total duct leakage test at system rough in on every house
- Insulation and thermal by-pass inspection
- On-site confirmation of window U-values
- On-site confirmation of qualifying HVAC and appliance equipment efficiencies
- On-site lighting inspection
- Prior to occupancy at least 10 % of homes are retested to confirm duct leakage to the exterior less than 6% at 50 Pascals and blower door tested to confirm envelope tightness.

Devoted’s process emphasizes coordination with subs who share and support their commitment to producing a superior product and who take pride in maintaining high standards of quality.

Starting in 2009 they will be adding additional inspections for Builder Challenge labeling.

Subtask 4.3 Stage Gate 3 Report: 40% Initial Community Scale Projects in Marine Climate

BIRA evaluated five communities in the Marine Climate Zone to determine if they met the Building America 40% whole house energy savings goal when compared to the Building America Benchmark. The communities were evaluated based on Building America's Stage Gate 3 "Must Meet" and "Should Meet" criteria. Key research partners in this endeavor are David Hales and Michael Lubliner from the Washington State University (WSU) Energy Program and R. Brady Peeks from the Oregon Department of Energy (ODOE).

Key Results

All five communities studied qualify as Building America 40% Communities in the Marine Climate Zone. This assessment was based on energy analyses performed using BEopt 0.8.6, incremental costs based on builder estimates, and additional information acquired first hand from the builders.

Project Overview

Stage Gate 3 evaluates the performance of final production building designs using energy simulations. This report provides a concise summary of communities meeting 40% energy efficiency savings relative to the Building America Benchmark in the Marine Climate Zone while addressing all of Stage Gate 3's "Must Meet" and "Should Meet" criteria. Detailed case studies for each community are available in the task report.

The Northern Marine Climate Zone is distinct from the Southern Marine Climate Zone not only due to increased heating degree days and precipitation, but also due to differing construction practices. Northern Marine builders typically build with 2x6 walls on top of crawlspaces while Southern Marine builders typically build with 2x4 walls on a slab. The five case studies provide details of the five different Northern Marine communities. The reasons for this distribution are thoroughly discussed in the Market Coverage "Should Meet" criteria section of this report. Table 217 lists the five communities studied along with the builders and locations of the communities.

Builder	Community	Location
New Tradition Homes	Landover Commons	Vancouver, WA
Quadrant Homes	Kentlake Highlands	Kent, WA
Ruhoff Home Builders	Crescent Village	Eugene, OR
Schneider Family Homes	Village at Miller's Creek	Burien, WA
Tom Walsh & Co.	New Columbia	Portland, OR

Table 217: 40% Marine Communities

"Must Meet" Gate Criteria -- Source Energy Savings

Builder	Community	Simulated Floor Plan	FFA of Simulated Floor Plan	Source Energy Savings vs. Benchmark	Source Energy Savings vs. Code
New Tradition Homes	Landover Commons	Kent 2264	2250 sq. ft.	44.1%	26.2%
Quadrant Homes	Kentlake Highlands	Olympic 2011	2082 sq. ft.	41.7%	27.5%
Ruhoff Home Builders	Crescent Village	Fidalgo Townhome	2350 sq. ft.	44.1%	34.2%
Schneider Family Homes	Village at Miller's Creek	E381	2019 sq. ft.	47.4%	35.2%
Tom Walsh & Co.	New Columbia	Roseburg 1884	1884 sq. ft.	43.5%	26.2%

Table 218: 40% Marine Source Energy Savings

Table 218 shows the results of an energy simulation performed on a representative home from each community using BEopt 0.8.6.³⁴ As shown, two simulations were performed, one with the Building America Benchmark as the reference house, and one with a local code house as the reference house. When applicable, the simulation was averaged over all four cardinal

³⁴ The chosen plan for a given community represents the median home size of that community and is preferably near 2,000 square feet. For use in best practice guides and the like, it is important the modeled plan is near 2,000 sq. ft. to promote transferable technology pathways to the largest number of new homes and communities constructed throughout the climate zone. Although only one plan was evaluated per community, the home's energy features are universal across all plans.

orientations. As shown in Table 218: 40% Marine Source Energy Savings

, all five communities meet the Building America goal of 40% energy efficiency savings in the Marine Climate Zone relative to the BA Benchmark. Typical energy reduction features implemented at each of the communities in order to reach this goal are as follows:

- Wall insulation
 - R21 batts, 2x6, 16" o.c.
 - R21 batts, 2x6, 24" o.c.
 - R23 BIBS, 2x6, 24" o.c.
- Foundation
 - Vented crawl space, R30 Ceiling
 - Vented crawl space, R37 Ceiling
 - Insulated slab, 2ft R10 Perimeter, R5 Gap
- R49 ceiling insulation/R40 ceiling insulation (vaulted ceilings)
- 0.29 - 0.34 U-value windows
- 3.4 ACH₅₀ - 5.2 ACH₅₀ infiltration
- 92.5% - 94% AFUE furnace
- SEER 13 - 14 air conditioner (if present)
- Ducts in conditioned space
- Domestic hot water
 - 60+% EF gas water heater
 - 81% EF gas tankless water heater
 - 64 sq. ft. closed loop solar DHW
- ENERGY STAR refrigerator, dishwasher, and clothes washer
- 50% - 100% hardwired CFL lighting
- Gas cooking range and/or clothes dryer³⁵

For a complete list of BEopt inputs for each of the simulated houses, see the respective case study.

There were two main programs that BIRA partners from the WSU Energy Program and ODOE used as driving forces for aiding builders in implementing these features. The first is Northwest ENERGY STAR®, which all five of the 40% Marine communities qualify for. The second is the \$2,000 federal tax credit that builders can receive for each new home built that achieves 50% energy savings for heating and cooling over the 2004 International Energy Conservation Code (IECC). One key feature aiding each of the 40% Marine communities in reaching the federal tax

³⁵ Using BEopt 0.8.6's multiplier for source to site energy consumption, gas appliances were more source energy efficient for each home and community documented in this report. While electric appliances might use comparable or fewer units of site energy, when multiplied by the multiplier of 3.365 to calculate electric source energy, gas is a better choice. The multiplier for gas is only 1.092 source/site. Example = ((Electricity; 2 units of site energy* 3.365 = 6.73 units of source energy)(Gas; 2 units of site energy* 1.092 = 2.184 units of source energy)

credit level was the decision to move ducts inside conditioned space. This suggestion came from research done by the WSU Energy Program and BIRA. For more information on moving ducts into conditioned space in the Marine Climate Zone, see the case studies for New Tradition Homes and Quadrant Homes. Programs such as Northwest ENERGY STAR® and the federal tax credit provide excellent jumping off points for builders looking to build with energy efficient features.

It is important to note that Northwest ENERGY STAR® has different specifications than the national ENERGY STAR program. These features were developed to work within the framework and climate of the region. The Northwest ENERGY STAR® program has done a tremendous job of raising the bar in the Pacific Northwest while preparing builders to approach Building America with important quality and energy efficiency best practices. (Northwest ENERGY STAR® specifications can be found Appendix A of the task report.)

Quadrant Homes and Schneider Family Homes' represent the lowest and highest source energy savings respectively compared to the Building America Benchmark.

Quadrant Homes has the lowest source energy savings at 41.7%. There are two main drivers for this. First, the Quadrant Homes plan features 0.29 U-value, 0.29 SHGC windows. In heating dominated climates such as the Marine Climate Zone, BEopt is extremely favorable to higher SHGC. Changing the window type on Quadrant Homes' simulated plan to 0.29 U-value, 0.35 SHGC raises the energy savings to 45.3%. Second, the Quadrant Homes plan is one of the smaller plans and also features eight foot ceilings. This provides less opportunity for energy savings.

Schneider Family Homes has the highest source energy savings at 47.4%. This can be largely attributed to the focus Schneider placed on reducing the heating load. Schneider gained their edge in this category with a combination of a very sound R23 BIBS, 2x6, 24" o.c. wall system coupled with 0.34 U-value, 0.35 SHGC windows. This effectively decreased the heating load by 59.9%, more than any other builder. Schneider gained a further edge over most of the other builders by including a 0.81 EF tankless water heater.

Notably, Ruhoff Home Builders also demonstrated many efficiency features that might not receive proper attention due the house's middle-of-the-pack performance of 44.1% savings. Of particular interest was the 64 sq. ft. closed loop solar DHW system, which provided Ruhoff with a 63.3% decrease in the water heating load (for comparison, the Schneider design with its tankless DHW only decreased this load by 36.9%). Removing this system reduces savings to 40.4%. Exhibiting the same wall system and similar window SHGC as Schneider, it is difficult to see why they do not have the highest savings. The answer is that Ruhoff incorporated significantly more glazing into their design (31% of conditioned floor area compared to Schneider's 14.6%). Early simulations using more conservative glazing around 18% showed potential energy savings closer to 50%. These results will certainly be taken into consideration when working toward the 50% Marine Joule Milestone.

Based on the BEopt simulations comparing typical homes from each community to the BA Benchmark and providing greater than 40% reduction in source energy use, it can be concluded that all five communities pass the Source Energy Savings “Must Meet” criteria.

“Must Meet” Gate Criteria -- Market Coverage

Builder	Community	Total Number of Homes in Community	Number of 40% Homes by April 2008	Number of 40% Homes by September 2008	Number of 40% Homes Sold
New Tradition Homes	Landover Commons	94	7	≥ 10	≥ 7
Quadrant Homes	Kentlake Highlands	310	9	≥ 10	≥ 9
Ruhoff Home Builders	Crescent Village	24	16	24	≥ 8
Schneider Family Homes	Village at Miller's Creek	37	28	28	≥ 25
Tom Walsh & Co.	New Columbia	46	22	22	≥ 20

Table 219: 40% Marine Market Coverage

It is important to note that Quadrant Homes, the largest builder in the Puget Sound region, offers their Building America energy package (branded as Energy Sound), as an option in all of their communities. As of June 2008, Quadrant had begun construction on 86 Energy Sound homes across all communities, representing 10% of all homes currently under construction. Quadrant Homes expected well over 100 by the end of 2008. These were successful and Quadrant Homes adopted these BA improvements in all their homes by 2010.

Based on the information found in Table 219, it can be concluded that all five communities pass the Market Coverage “Must Meet” criteria.

“Must Meet” Gate Criteria -- Neutral Cost Target

Builder	Community	Simulated Floor Plan	FFA of Simulated Floor Plan	Annual Utility Bill Savings vs. Benchmark	Annual Mortgage Cost vs. Code	Net Annual Cash Flow
New Tradition Homes	Landover Commons	Kent 2264	2250 sq. ft.	\$990.61	(\$290.24)	\$700.37
Quadrant Homes	Kentlake Highlands	Olympic 2011	2082 sq. ft.	\$951.02	(\$159.67)	\$791.34
Ruhoff Home Builders	Crescent Village	Fidalgo Townhome	2350 sq. ft.	\$1,204.69	(\$885.22)	\$319.47
Schneider Family Homes	Village at Miller's Creek	E381	2019 sq. ft.	\$1,143.68	(\$313.08)	\$830.60
Tom Walsh & Co.	New Columbia	Roseburg 1884	1884 sq. ft.	\$943.60	(\$191.45)	\$752.15

Table 220: 40% Marine Neutral Cost Target

Table 220: 40% Marine Neutral Cost Target

shows the annual utility bill savings for each community relative to the BA Benchmark provided by BEopt 0.8.6. These costs are based on the current utility rates in each of the community locations and include both electric and natural gas energy sources. It should be noted that this includes no fluctuations in utility rates or inflation.

Table 220 also provides the incremental annual mortgage cost versus a typical code house that homebuyers at each of these communities may experience. All of the 40% Marine builders have been able to keep their first costs relatively low while implementing energy efficiency features. In fact, all of the builders have been able to keep their incremental costs at less than \$4,000 per home, excluding Ruhoff Home Builders who spent \$6,500 on the SDHW system alone. Quadrant Homes has the lowest incremental cost relative to the other builders because many of the features implemented on their houses reaching the 40% level are implemented on their standard houses as well and were not considered. This includes moving ducts into conditioned space. Quadrant Homes also has a very efficient building process and the ability to negotiate with suppliers for lower costs.

All of the incremental annual mortgage costs are derived from the builder's first cost, obtained through meetings between BIRA representatives and representatives from each of the builders. A 10% markup is assumed and the cost is converted into an annuity assuming a 7% loan over 30 years. Inflation is not considered. A detailed breakdown of these costs can be found in each of the respective case studies.

As shown in Table 220, the net annual cash flow to the homeowner for each community is at least \$300. Based on this information, it is clear that the incremental annual cost of energy improvements for all communities is much less than the annual reduction in utility bill costs and that all five communities pass the Neutral Cost Target “Must Meet” criteria.

This analysis does not include the \$2,000 federal tax credit that all of the builders receive for each new home built that achieves 50% energy savings for heating and cooling over the 2004 International Energy Conservation Code (IECC). It also does not include state and utility incentives from Northwest ENERGY STAR® or other programs that the builders use. This methodology stems from Building America’s goal of finding sustainable solutions. Since the federal tax credit expires at the end of 2008, it was not considered appropriate to include this credit. It is important to note, however, that the federal tax credit, along with Northwest ENERGY STAR®, provides a crucial framework and starting point for builders seeking to build energy efficiently.

“Should Meet” Gate Criteria -- Marketability

Keeping homes marketable in the current housing recession has been a real challenge for all five Marine builders. To overcome this challenge, there were several common threads involving the marketability of each of the five 40% Marine communities. One item that was common to many of the smaller builders, such as Tom Walsh & Co. and Schneider Family Homes, was the use of outside sources as driving forces for marketing efforts. This includes programs such as Built Green, Northwest ENERGY STAR®, Earth Advantage, and independent realtors. In the cases where the community studied was part of a larger community (Ruhoff Home Builders and Tom Walsh & Co.), the builders utilized the developer and other entities involved in the marketing of the community as a whole. Several of the communities featured articles in various magazines and newspapers. These materials can be found in the respective case studies.

Another common thread among the five builders was the use of efficient building practices to keep costs down. The most extreme case is Quadrant Homes, who can build homes in exactly 54 days. Builders believe that keeping costs low while implementing energy efficiency features attracts budget-conscious first-time buyers looking to buy at a low cost and to keep their utility costs down. Builders such as Ruhoff Home Builders believe that educating potential buyers on energy efficiency features is critical to promoting this low-cost thinking.

New Tradition Homes conducted a unique survey to support the belief that their differentiation with energy efficiency measures is helping to keep them afloat during this market downswing. This survey indicated that 95% of homebuyers show at least some desire to have high performing homes and that energy efficiency is the second most desirable feature among energy and non-energy features. With this information in hand, New Tradition continues to build energy efficient homes at a price comparable to code homes. Although they have smaller margins than their competitors, New Tradition is selling more units.

Quadrant Homes has a unique marketing strategy that is working for them. Quadrant allows customers to visit one of their two, 12,000 square foot showrooms that allow homeowners to make selections on features ranging from carpeting to bathroom accessories. Customers can also select energy efficiency features at these showrooms, which Quadrant successfully markets as the only features that pay the customer back. After leaving the showroom, homeowners can visit Quadrant's website and log in with a secure username and password to select the features they would like to use from the comfort of their own home.

One important way BIRA can support builders in the Marine Climate Zone is with marketing support, especially in the current market downturn. BIRA has created and shared both source energy and energy cost saving graphs with each builder. The graphs provided to Quadrant Homes can be found in Figure 162 and Figure 163. In addition, Figure 164 shows a comparison of energy costs between a Washington code house, a Quadrant code house, a Quadrant Northwest ENERGY STAR® house, and a Quadrant Energy Sound house (40% energy efficiency savings compared to the Building America Benchmark). Figure 164 shows that not only is the Quadrant Energy Sound house cost-effective compared to the Building America Benchmark; it is also cost-effective compared to a Quadrant code house. It is clear that even Quadrant's base design is a very energy efficient home. This displays the value of having a tight envelope and moving the furnace and ducts inside conditioned space.

Several of the 40% Marine builders plan to use the graphs provided by BIRA in current and future marketing efforts. Additionally, BIRA created a "one-sheet" that highlights several projects in the Pacific Northwest. This can be found in Appendix A of the task report. Overall, these five builders see their energy efficient homes as an important differentiation tool in the down housing market. This differentiation can be the difference between selling homes and not selling homes.

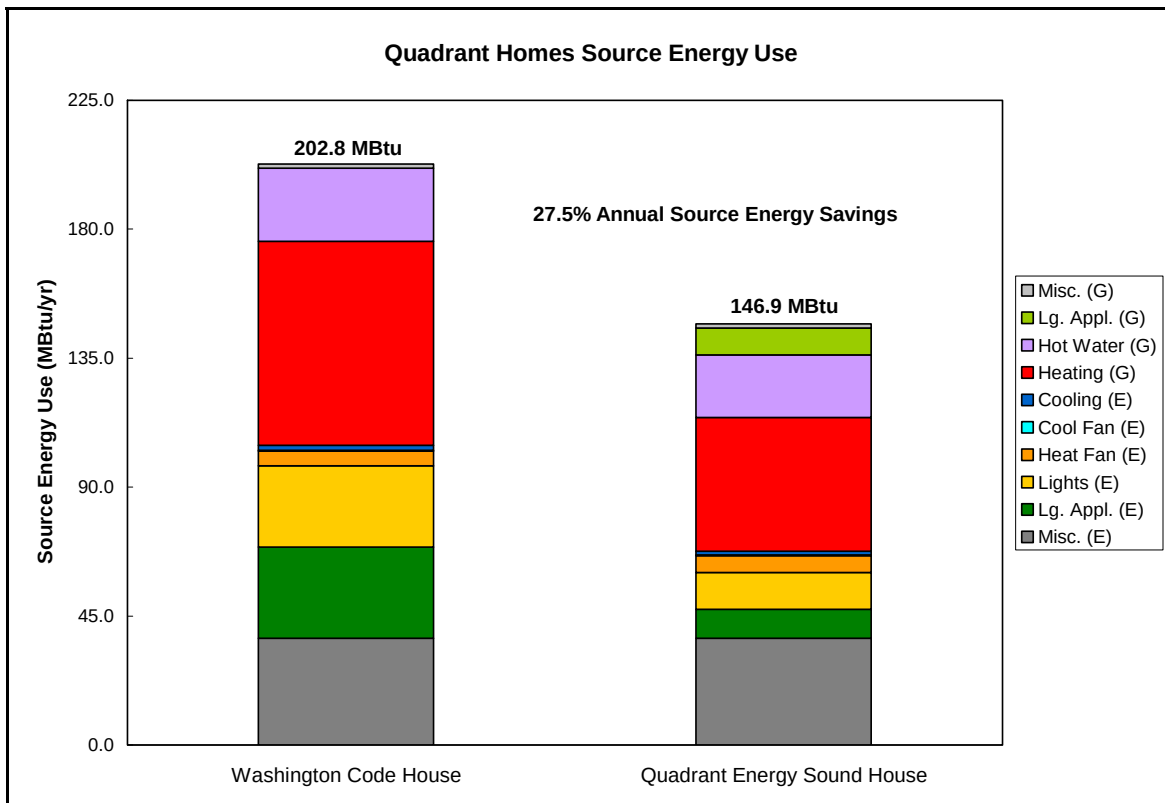


Figure 162: Source Energy Use Marketing Material for Quadrant Homes

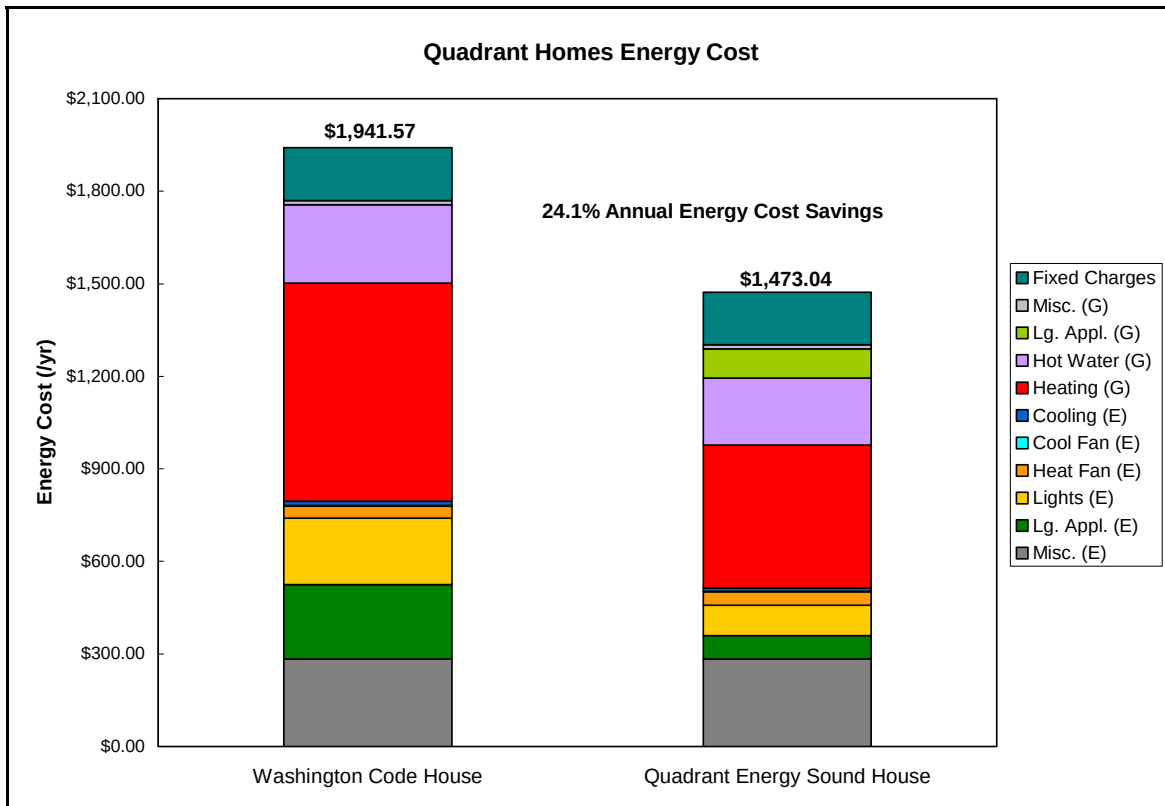


Figure 163: Energy Cost Marketing Material for Quadrant Homes

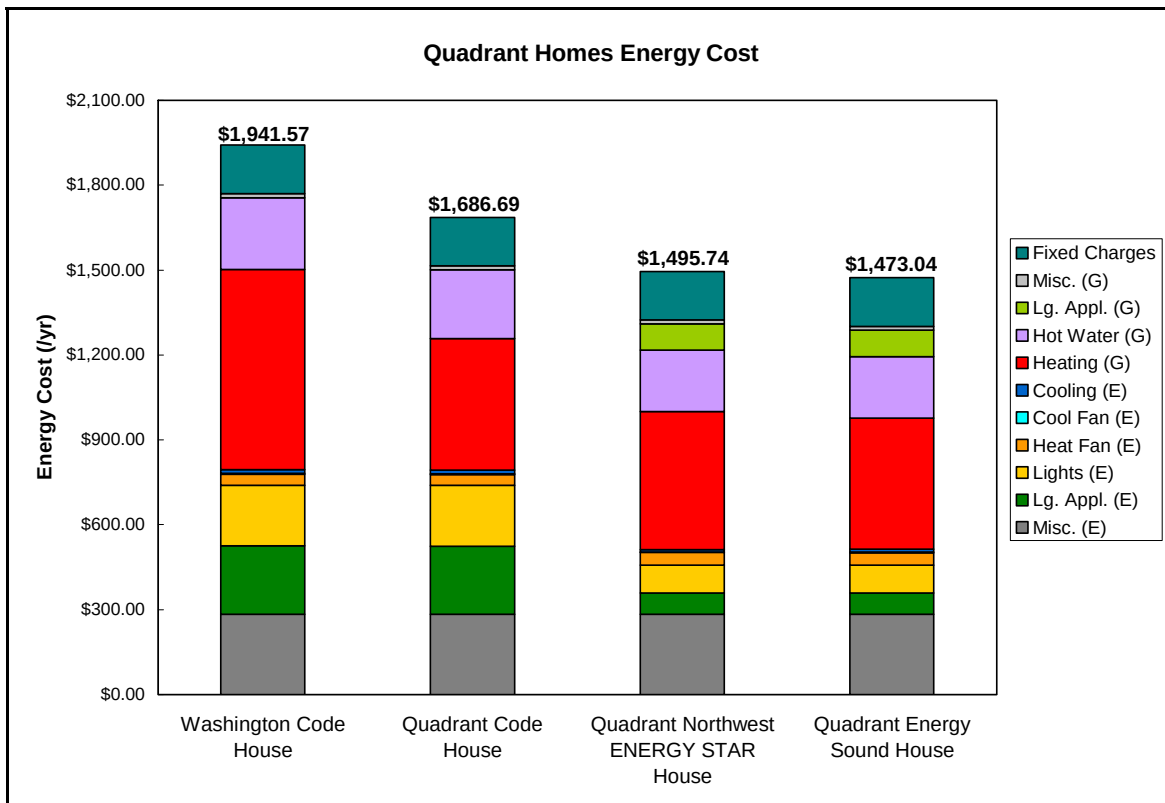


Figure 164: Energy Cost Comparison Marketing Material for Quadrant Homes

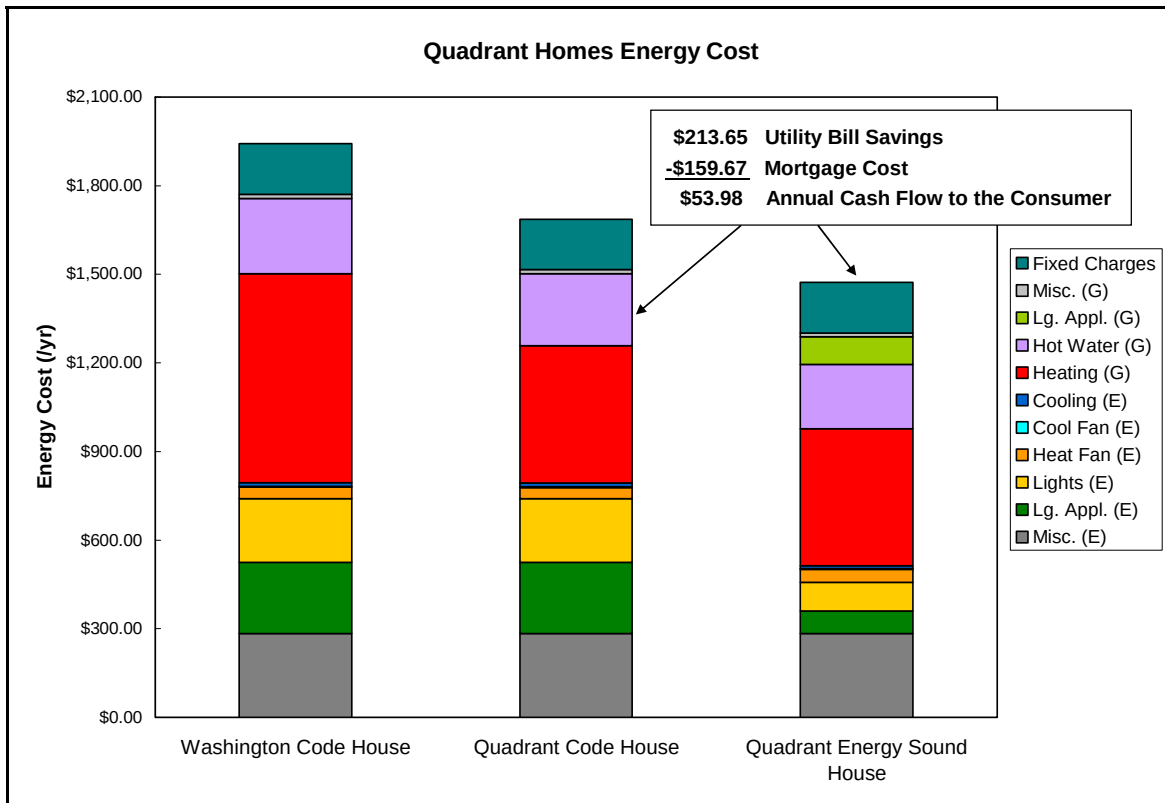


Figure 165: Cost Effectiveness Marketing Materials for Quadrant Homes

“Should Meet” Gate Criteria -- Market Coverage

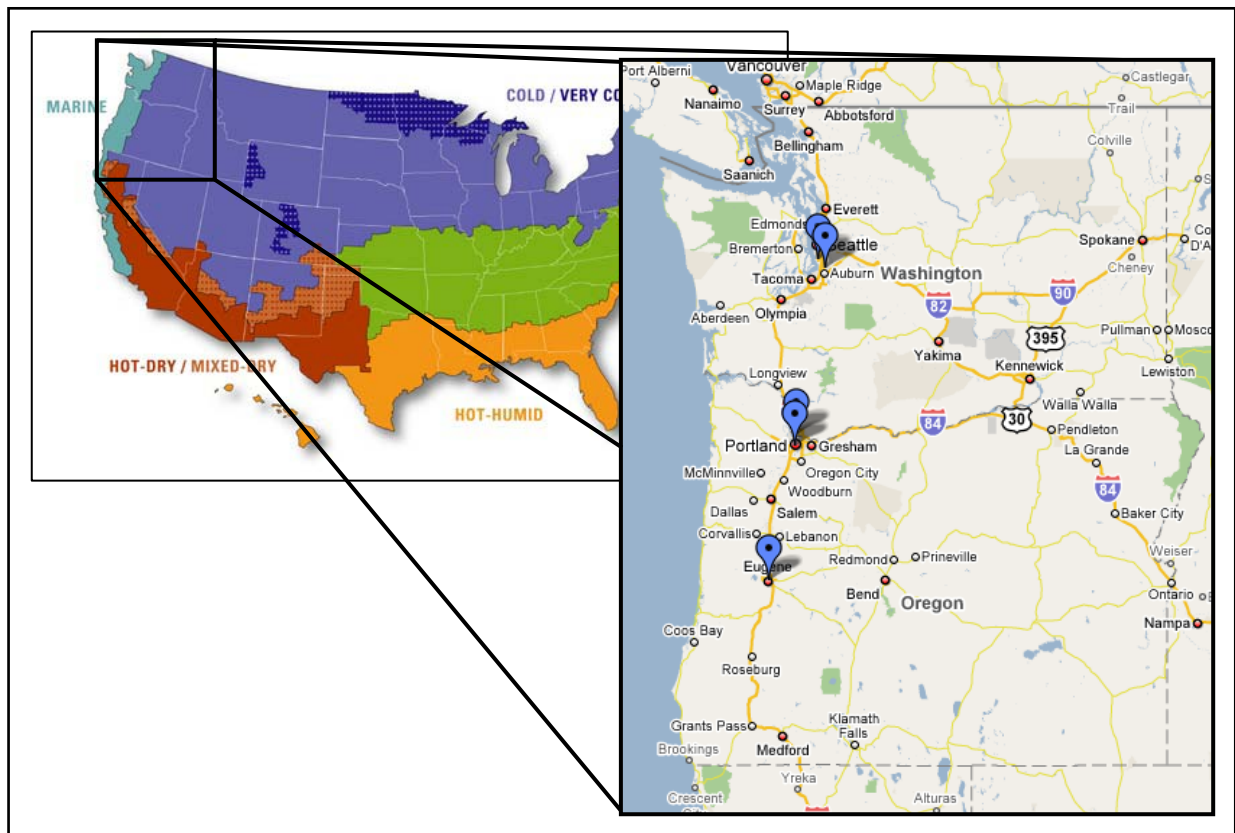


Figure 166: 40% Marine Community Distribution

As Figure 166 shows, all five of the 40% Marine communities are located in the Northern Marine Climate Zone. BIRA chose to target communities in this region not only because Seattle and Portland are two of the largest housing markets in the Marine Climate Zone, but also due to the large number of energy-conscious builders in the Pacific Northwest. In addition, the housing markets in both Oregon and Washington have not been hit nearly as hard as the housing market in California by the recent market downturn. This is shown in Figure 167. According to the US Census Bureau, the number of housing permits granted in 2007 to California builders was 55% less than the same number in 2004. This is in comparison to Oregon, which saw only a 26% decline, and Washington, which saw only a 17% decline from their 2004 numbers. It is for these reasons that BIRA, through the WSU Energy Program, sought builders in the Pacific Northwest for the 40% Marine milestone.

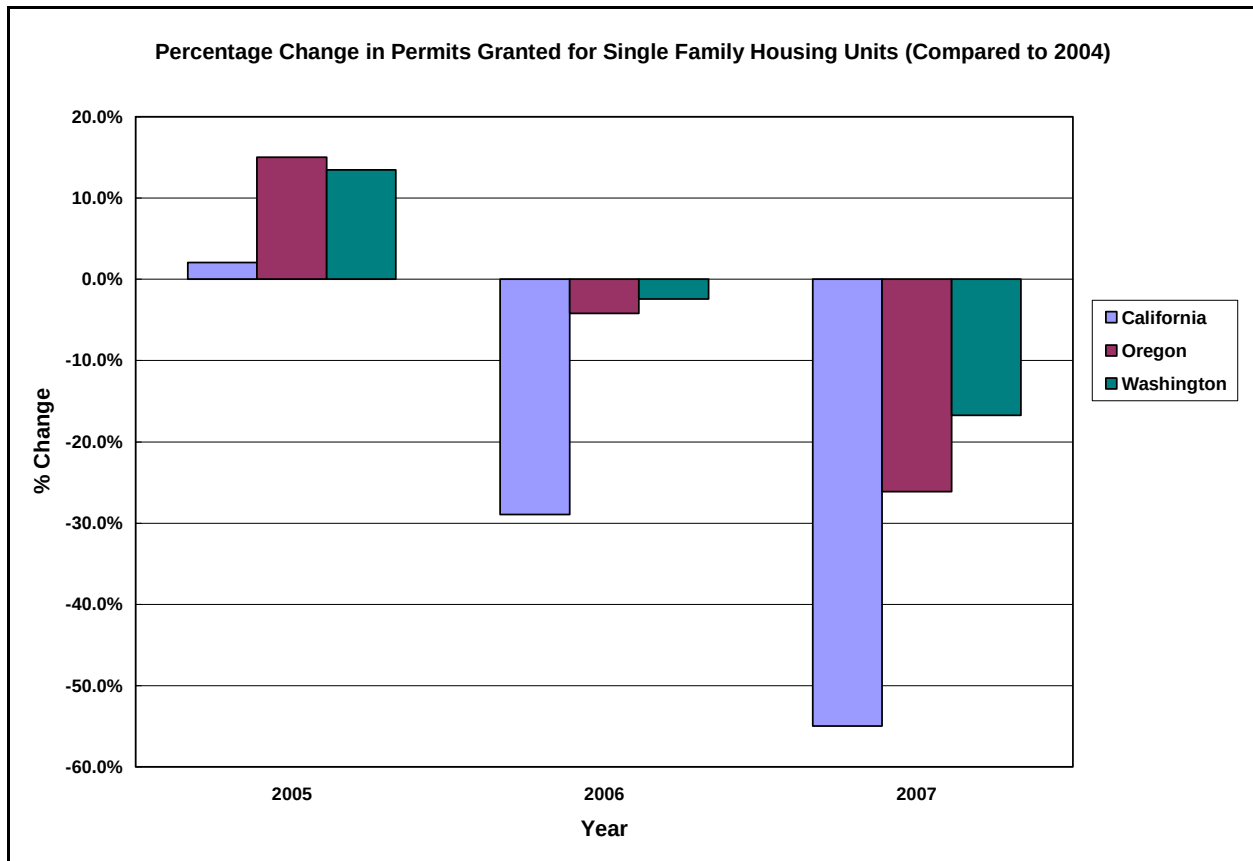


Figure 167: Housing Permits Comparison for California, Oregon, and Washington

In order to account for the fact that no communities in California were studied, BIRA performed simulations on a 30% Marine community in California to determine what features would need to be added for the community to reach 40% energy efficiency savings compared to the BA Benchmark. The simulated house used is a typical house found in Clarum Homes' Hamilton Park community located in Menlo Park, California. The as-built, 1,985 square foot house has energy savings of 35.2% versus the BA Benchmark averaged across all four cardinal orientations and has the following features:

- R13 batts, 2x4, 16" o.c. + 1" foam
- Uninsulated slab foundation
- R38 ceiling insulation
- 0.35 U-value windows
- 6.0 ACH₅₀ infiltration
- 90% AFUE furnace
- SEER 13 air conditioner
- R-4.2 ducts
- 82% EF gas tankless water heater
- ENERGY STAR® refrigerator, dishwasher, and clothes washer

- 50% hardwired CFL lighting
- Gas cooking range and clothes dryer

Because the Marine Climate Zone around the San Francisco Bay Area is heavily heating dominated, BIRA believed it would be best to apply improvements to the heating system first. Three improvements were decided upon to implement in the Hamilton Park simulation:

- R15 batts, 2x4, 16" o.c. + 1" foam
- 94% AFUE furnace
- Ducts inside conditioned space

These three features alone increased the savings to 41.2% above the BA Benchmark. A complete list of BEopt inputs and results for both the 30% and 40% simulations can be found in the task report.

Of the three features listed, moving ducts into conditioned space would be the biggest challenge for California builders, who typically place ducts in the attic. Although moving ducts into conditioned space would be the best option, builders not willing to make this change in their design could also bury their ducts in insulation in the attic. This is a more common practice for California builders. Savings levels using this method are very similar to ducts in conditioned space due to the fact that the Southern Marine Climate Zone is more mild than the Northern Marine Climate Zone. Other regionally appropriate options in the Southern Marine Climate Zone to reach the 40% savings levels include increasing the amount of fluorescent lighting or adding a solar domestic hot water system.

"Should Meet" Gate Criteria -- Builder Commitment

All five of the 40% Marine builders show continuing interest in building energy efficient homes and communities. One qualifier for this statement common to many of the builders is the fact that they would like to see energy efficiency measures and programs that fit within their business model and show tangible benefits to their company. The best example of this occurring is Quadrant Homes' decision to put ducts inside conditioned space on all of their homes.

While working with the WSU Energy Program to redesign their homes and achieve the \$2,000 federal tax credit level, it became evident to Quadrant that moving ducts inside conditioned space was the best option. Following this conclusion, Quadrant representatives met with their HVAC subcontractor, Bob's Heating, to design a new system. Quadrant was able to bring their supply ducts within the building envelope while also putting the furnace in a mechanical closet on the second floor. This practice benefits Quadrant by decreasing costs with shorter uninsulated duct runs and the purchase of smaller furnaces. It also increases quality by getting subcontractors out of the crawlspace and into a work environment that is not only easier to work in but also much more easily inspected. In this way, bringing ducts inside conditioned

space was a move that not only made sense in energy efficiency, but also in terms of Quadrant's business model. Quadrant now includes ducts inside conditioned space on all of their designs, including homes that do not include optional energy efficiency measures.

Although an ideal situation, this example shows how Building America can work with builders to show them the benefits of implementing energy efficient features. Other builders, such as Schneider Family Homes and Tom Walsh & Co., are willing to implement energy efficiency measures that provide benefits such as quality, easier construction, or marketing support. This is one reason why Schneider chose Built Green to spearhead their marketing efforts. In addition, many of the builders say they are open to implementing features such as open-web trusses to bring ducts into conditioned space more effectively (if they haven't already implemented these) or external foam insulation.

Ruhoff Home Builders and New Tradition Homes both show exceptional commitment to energy efficient building. Chad Ruhoff, owner of Ruhoff Home Builders, authored a courtesy whitepaper detailing what it means to produce a well-built, high performance home (available in the Crescent Village case study). New Tradition Homes has committed to building all of their homes to Northwest ENERGY STAR® and Earth Advantage standards. In addition, New Tradition is one of very few builders to have their own building science team, a fact that demonstrates a true dedication to continuously building more energy efficient homes.

Ultimately, all five builders show that they are at the very least committed to building at current Building America levels. If BIRA can continue to work within each builder's business model, future communities will feature designs that meet the next set of Building America goals.

"Should Meet" Gate Criteria -- Gaps Analysis

The five builders in this study used 2x6 walls with either R21 batt insulation or R23 BIBS insulation. Some builders used 16" o.c. framing while others used 24" o.c. framing. One option that none of these builders explored in the communities studied was the use of external foam insulation. This feature alone would have a significant impact on the R-value of the walls by providing a thermal break between the studs and the outside air. Builders such as Ruhoff Home Builders have shown interest in using this type of insulation but say they are nervous about water infiltration issues between the foam and the rest of the wall system. BIRA is looking to leverage its relationship with another builder, Schneider Family Homes, to help teach builders such as Ruhoff how external foam insulation can be installed successfully in the Marine Climate Zone. Schneider Family Homes has already successfully implemented external foam on a community they built in Washington.

One other gap in the designs of New Tradition Homes and Tom Walsh & Co. is their implementation of ducts inside conditioned space through the use of drop-downs and soffits. Although a viable practice, New Tradition Homes estimates that it is three times more

expensive than comparable methods. Both Tom Walsh and New Tradition say they are willing to consider using open-web trusses to implement ducts in conditioned space, a method used by Ruhoff Home Builders, Quadrant Homes, and Schneider Family Homes. This design allows subcontractors the flexibility to run plumbing, electrical, and ductwork easily between floors, with little to no “trade damage” or “trade fighting.”

One caveat to the use of open-web trusses in the Pacific Northwest involves code issues in Washington. According to Washington code, insulation must be in contact with the surface it is insulating. In both Quadrant and Schneider’s open-web truss design, insulation between conditioned space and the garage would, in some cases, go around the ducts and other objects in the open-web trusses, resulting in a code violation. WSU Energy Program staff is currently working to identify both air sealing details and code language prohibitions to this approach. (This issue is discussed in Task 1.6)

Another common thread among builders was a lack of trust or dependence on incentive programs. Tom Walsh believes incentives are a good idea, but that qualification requirements should be simpler if agencies are looking to promote energy efficiency. Many Northwest builders feel that they cannot count on tax credits such as the \$2,000 federal tax credit that expires at the end of 2008 and build energy efficiently for other reasons. However, incentives such as the federal tax credit can entice builders that wouldn’t normally change their building practices to do so. Quadrant Homes faced their own unique issues involving the federal tax credit that are discussed in the case study on their Kentlake Highlands community.

“Should Meet” Gate Criteria -- Quality Assurance

The five builders studied all have similar quality control and quality assurance practices. All five of the communities studied are Northwest ENERGY STAR® certified and must adhere to the quality control protocols specified by this program. The WSU Energy Program administers quality assurance and quality control for Northwest ENERGY STAR®, which is very important for BIRA’s success in the region. Builders such as Ruhoff Home Builders continuously provide quality control training to their subcontractors and superintendents. Tom Walsh & Co., Ruhoff Home Builders, and Quadrant Homes all pride themselves on their fast building process, which requires exceptional planning and timing. Because these issues are taken care of before construction begins, their superintendents can focus on quality construction. All five of the builders show a strong dependency on their superintendents for quality control, who is often a family friend or a long-time employee.

There are several other quality assurance practices common to the five 40% Marine builders. Both Schneider Family Homes and Quadrant Homes feature an extensive home warranty for each of their homes to ensure that any mistakes that are made are fixed at no cost to the homeowner. Tom Walsh & Co. and New Tradition Homes both hire separate contractors for tasks such as window sealing and flashing or special weatherization procedures. Quadrant Homes has representatives from the WSU Energy Program test between 5% and 10% of the

homes in their communities for quality assurance.

With the huge success that the five 40% Marine builders have had with moving ducts into conditioned space, the WSU Energy Program is taking steps to ensure that builders hoping to follow in their footsteps will perform a high quality installation. First, they are working at the state and national levels to integrate duct testing and location requirements into code. Second, they are exploring infrared and blower door tests as potential quality assurance evaluation tools for checking rim leakage when duct are placed in-between floors. This ongoing work by the WSU Energy Program, operating under BIRA, will have a significant impact on expanding the practices found in this report to other builders in the Marine Climate Zone.

Subtask 4.4 Stage Gate 3: Initial Communities Update Report - Multiple Climates

Stage Gate 3 evaluates the performance of final production building designs through analyzing a community of homes, primarily for energy consumption. For a community to be eligible for this gate, at least ten houses must be constructed using the Building America strategy for the particular milestone being tested. The objective of this report is to provide a concise summary of communities that will meet this requirement and are being, or likely will be, used for Stage Gate 3 research. Details regarding each community's climate, location and expected savings level as well as when BIRA expects to perform the research are included, providing a tool by which BIRA can gauge current research progress and provide an informal timeline for when future Building America Joule milestone research is expected.

BIRA has focused its efforts in the Cold, Marine, and Hot/Dry climates that predominate the western states. Research has recently been completed at the Stage Gate 1A level for 40% Cold, 50% Hot/Dry and 50% Marine. Because of this, BIRA holds particular interest in communities that are expected to perform at the 40% level in Cold and 50% in Hot/Dry and Marine Climates. However, BIRA has not shied away from the opportunity to be involved with projects that expect to perform beyond these levels or in other climates.

BIRA completed its analysis of five 40% Marine communities in Washington and Oregon. The results were positive, showing that community scale projects were cost effective and marketable at the 40% level. Two of the builders included in that reporting, Ruhoff Home Builders and Tom Walsh & Co., have future communities being included in this report for the 50% Marine milestone. This continued push from these two building partners toward continual performance improvement, despite the economic downturn, demonstrates not only their commitment to energy efficiency, but also the competitive edge that it gives them in the market.

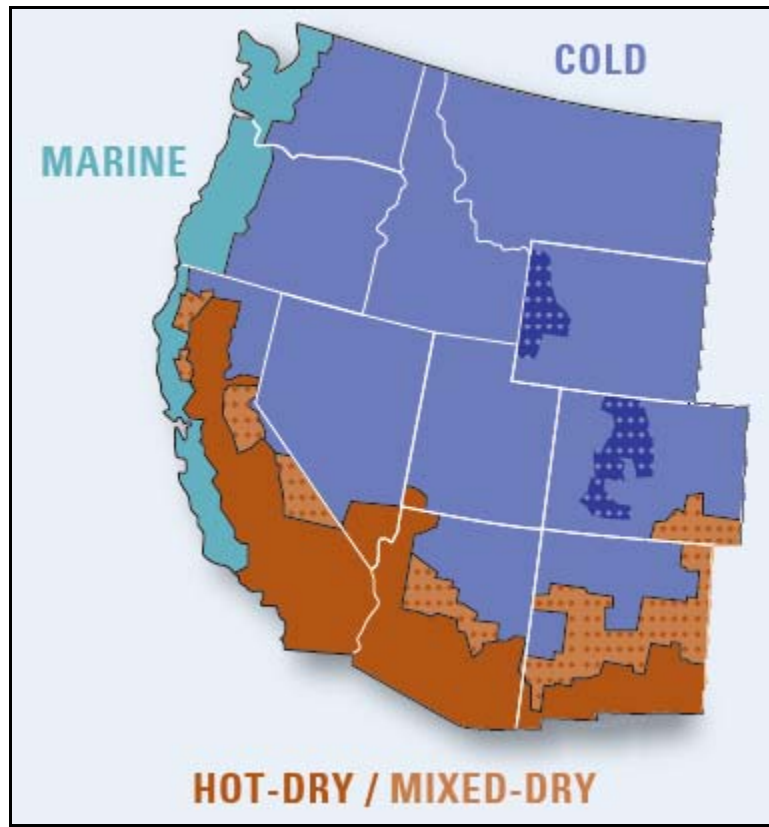


Figure 168: Climate Zones of the Western US

BIRA arranged for twenty-five community-level projects, spanning four climate zones for analyses during the anticipated five-year project period. Redundancy in each climate zone was viewed as a benefit as the market conditions did not guarantee that all projects would proceed as planned. Due to the sudden closure of this Building America project, there was not time nor budget to track these projects during their multi-year build-out. Thus the disposition of many of these community-scale projects is not reported due to lack of time and budget to collect the pertinent information.

Cold Climate

City of Park City, UT (Developer)

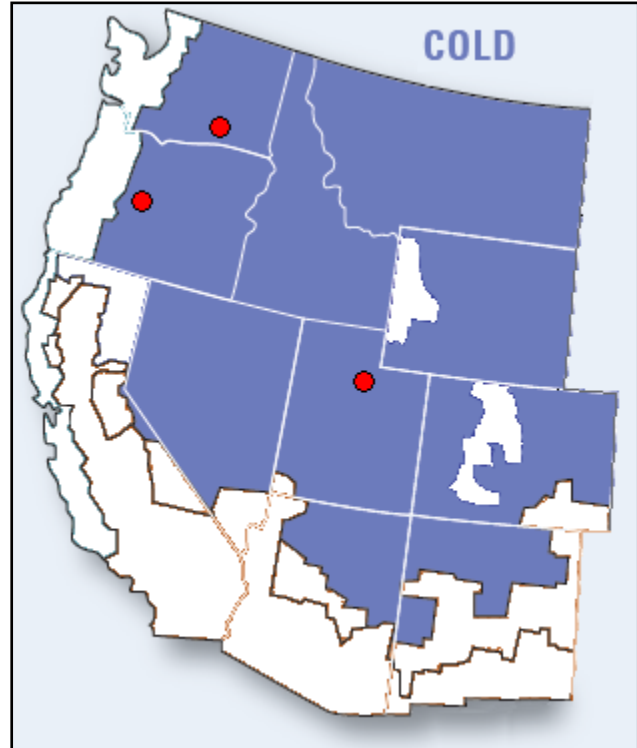
Community: Snow Creek

Location: Park City, UT

Expected Savings Level: > 50%

Status: 13 homes have been completed.
Analysis and reporting began in 2009.
Problems found and documented with GSHP due to installation issues.
Problems corrected and data collection started late 2010. Insufficient data to analyze by end 2010

Unique Features: Some of the houses will have PVT, remaining will have PV and SDHW. All will have GSHP, SIPS or equivalent and Passive Solar Heating.



Devoted Home Builders

Community: Mediterranean Villas

Location: Pasco, WA

Expected Savings Level: >40%

Status: 37 homes have been completed with another 8 homes currently under construction. Final build out will be 70 homes. Stage Gate 3 case study report for 40% Cold Joule Milestone to be coordinated with Cold Climate lead, BSC.

Unique Features: All ICF walls, duplexes, affordable homes at \$200,000, tankless water heating, HRV, 2.5 ACH50, 8.5 HSPF Heat pump.

Oregon DOE High Performance Home builder partner (new project)

Community: TBA

Location: Bend, OR

Expected Savings Level: >40%

Status: Initial Construction, BIRA working with OR DOE to develop and assess research opportunity

Unique Features: York air-to-water, low temperature heat pump, very promising COPs 3+, Oregon ENERGY STAR builder since 2004.

Artistic Homes

Community: Hart Valley

Location: Aztec, NM

Expected Savings Level: >50%+ (Net-ZEHs)

Status: This project is in the design stage. Construction is expected to begin in mid-2010. Final build out will be 500 homes. Analysis and reporting can begin in late 2010.

Unique Features: High performance EE, Ducts in conditioned space, Solar Electric and thermal, and OVE Framing.

Salt Lake County Affordable Housing

Community: Webster School Cottages

Location: Salt Lake City, UT

Expected Savings Level: 50%

Status: 3 homes have been completed with another 2 homes currently under construction. Final build out will be 16 homes. Analysis and reporting can begin in 2009.

Unique Features: Solar Thermal, and OAsys 2- Stage Evaporative Cooler.

GEOS

Community: GEOS Community

Location: Arvada, CO

Expected Savings Level: 50%+

Status: Final build out will be 80 homes. Analysis and reporting scheduled for 2010; project still on hold.

Unique Features: Solar Thermal, GSHP, and OAsys 2-Stage Evaporative Cooler.

Hot/Mixed-Dry Climate

K Street LLC

Community: O Bel Sole

Location: Lancaster, CA

Expected Savings Level: 59%

Status: Currently 17 homes have been completed. Final build out expected to be 42 homes. Utility bill analysis and reporting on existing and remaining homes will begin in 2010. Unique Features: Utility/Home End-Use Monitoring, Triple Glazed Windows, 100% Solar PV.

DMB (Developer)

Community: MPG

Location: Albuquerque, NM

Expected Savings Level: >50%

Status: Construction was expected to begin in late 2009. Final build out will be 12,000 homes. Project put on hold due to problems in residential new construction market.

Unique Features: Utility/Home End-Use Monitoring, Sustainable Green Community, Smart Grid.

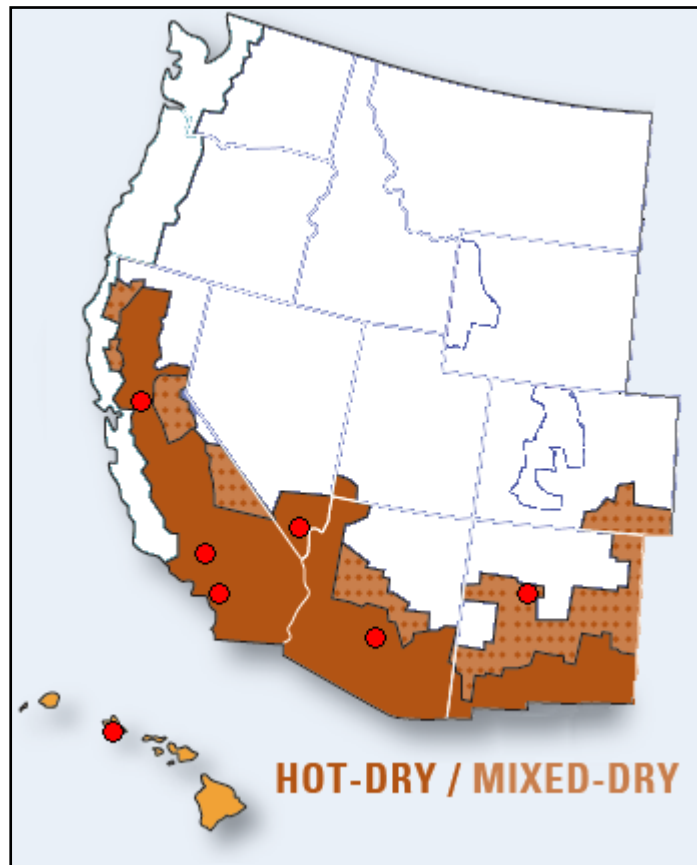
I-Build

Community: TBA

Location: Hurricane, UT

Expected Savings Level: >50%

Status: This project is in the design stage. Construction is expected to begin in late 2009.



Final build out will be 227 homes. Analysis and reporting can begin in 2009.

Unique Features: High performance EE, SIP walls, Solar Electric, Solar Thermal, and devices to reduce plug loads will be installed.

Rancho Mission Viejo (Developer)

Community: The Ranch

Location: Mission Viejo, CA

Expected Savings Level: >50%

Status: Construction was expected to begin in 2010, but due to the collapse of the residential new construction market, the project was put on hold. The final build out will be 1,170 homes in phase 1, and is now (2010) expected to begin in 2011 or 2012. Total build out is expected to be 14,000 in the next 20 years. Analysis and reporting began in 2008.

Unique Features: Utility/Home End-Use Monitoring, Sustainable Green Community, Neighborhood Electric Vehicles (NEVs), Smart Grid. This community may be a cornerstone project for California PUC and IOU energy efficiency program administer Sempra Utilities (SCG and SDG&E).

Habitat for Humanity

Community: TBA

Location: Alamogordo, NM

Expected Savings Level: >50%

Status: This project is in the design stage. Construction is expected to begin in 2010. Final build out will be 43 homes. Analysis and reporting can begin in late 2010.

Unique Features: High performance EE, Ducts in conditioned space, Solar Electric, and Solar Thermal.

PepperViner

Community: Sunny Pointe

Location: Tucson, AZ

Expected Savings Level: >50%

Status: This project is in the design stage. Construction is expected to begin in late 2009. Final build out will be 267 homes. Analysis and reporting can begin in 2010.

Unique Features: High performance EE, Ducts in conditioned space, Solar Electric, and Solar Thermal.

Coldwell Banker

Community: TBA

Location: Davis, CA

Expected Savings Level: >50%

Status: This project is in the design stage. Construction is expected to begin in late 2009. Final build out will be 29 homes. Analysis and reporting can begin in 2010.

Unique Features: High performance EE, Solar Electric, and Solar Thermal.

Forest City (Developer)

Community: Mesa Del Sol

Location: Albuquerque, NM

Expected Savings Level: 40% - 50%

Status: BIRA is working with developer who is looking into Builders Challenge (see Forest City Hawaii Project). There are some developer issues holding the process up.

Unique Features: 1000's of homes at build out. Mesa Del Sol is planned to be a model sustainable community with support from the State, Sandia National Lab and BIRA.

Newland Communities

Community: TBA

Location: Phoenix, AZ

Expected Savings Level: >50%

Status: Construction on hold in 2010 due to market turn-down.

Unique Features: Houses will be constructed using all off-the-shelf features.

City of Henderson, NV (Developer)

Community: TBA

Location: Henderson, NV

Expected Savings Level: >50%

Status: Community Analysis and reporting expected to begin in 2010, but put on hold due to market problems.

Unique Features: Houses will be constructed using all off-the-shelf features. The community is being driven by the City of Henderson. BIRA will work with the city and the chosen builder to integrate BA design protocols.

Artistic Homes

Community: Anasazi Ridge, Sundance Estates and Yucatan Del Este

Location: Albuquerque, NM

Expected Savings Level: >50%

Status: 80 homes have been completed with another 20 homes currently under construction. Final build out will be 600 homes. Analysis began in 2009. Limited data showed that homes performed well, but with market downturn, builder reduced construction and future plans.

Unique Features: Houses will be constructed using all off-the-shelf features.

Zero Energy Net Homes (SMUD Project)

Community: Elliott Homes – goal shifted from zero net energy to 80% reduction in energy use compared with CA Title 24 code, and no more than 1kW demand during summer peak demand/ peak-cooling periods..

Location: Sacramento, CA

Expected Savings Level: >50%

Status: Community Analysis and reporting began in 2010. Home designs meet SMUD 80% goal, and meet BA goal, exceeding 50% savings level

Unique Features: Houses will be constructed using innovative features (e.g., PVT). One of the goals is to have the house draw no more than 1 kW during system peak period – homes use just over 1kW at peak, but are larger than first anticipated. Considered a success – builder adopted these designs as standard for all homes going forward in 2011.

Marine Climate

Howland Homes

Community: Issaquah
Highlands

Location: Issaquah, WA

Expected Savings Level: >50%

Status: No homes have been completed with four homes currently under construction. Final build out will be 10 homes. Community analysis was anticipated to begin in 2009, but pushed to 2010 due to market turn-down



Unique Features: Community Geo-exchange, High Efficiency Heat Pumps, PV, double stud walls, hydronic heating.

Project website: <http://www.z-home.org/>

Tom Walsh

Community: TBA

Location: Portland, OR

Expected Savings Level: >50%

Status: Community Analysis and reporting was anticipated to begin in 2009, but pushed to 2010 due to market turn-down.

Unique Features: Building off 40% technology package, introducing foam sheathing.

Ruhoff Home Builders

Community: Wiley Creek

Location: Eugene, OR

Expected Savings Level: >50%

Status: 2 duplexes have been completed with 6 more currently under construction. Final build out will be more than 10 buildings. No budget for further analysis.

Unique Features: Project with be building on 40% BA work with solar DHW, exterior foam sheathing

New Tradition Homes

Community: Serena Estates

Location: Vancouver, WA

Expected Savings Level: >50%

Status: Final build out will be 10 homes. No budget for further analysis.

Unique Features: Analysis of various crawlspace designs, and ducts in conditioned space.

The WJM Studio

Community: Mirror Lake Highlands

Location: Federal Way, WA

Expected Savings Level: >50%

Status: The project is in the design stage. BIRA has benchmarked the plans. Final build out will be 24 homes. No budget for further analysis.

Unique Features: Analysis of various crawlspace designs, SIP walls and roofs, and ducts in conditioned space.

Hot/Humid Climate

Forest City

Community: Military Housing

Location: Oahu, Hawaii

Expected Savings Level: 40% and 50%

Status: Expected build out is over 2000 homes by 2014. BIRA is working with DOE and Forest City on phases 2, 3 and 4 to integrate Builders Challenge into development of military housing. Final build out for phases 2, 3 and 4 is 2,000+ homes. Currently 1,000 homes have been completed.

Unique Features: Steel framing, Solar Electric, Thermal. There are interesting challenges related to who receives benefits and who pays costs of energy upgrades in military setting.



Task 5: Stage Gate Final Project Closeout

In Budget Period Two, the BIRA team completed one Stage Gate Final Project Closeout report for the O Bel Sole! Estates community based on the Building America's (BA) Stage Gate Final Project Close Out Criteria.

In BP3, the BIRA team was not tasked with any final project closeout reports.

O Bel Sole! Estates

This report is the final project closeout evaluation of the O Bel Sole! Estates project based on the Building America's (BA) Stage Gate Final Project Close Out Criteria. It documents the performance of an occupied BA community using energy simulations, targeted utility bill analysis and feedback from project stakeholders. BIRA has investigated and identified the benefits and lessons learned from this project for homebuilders, homebuyers, utilities, and other stakeholders to understand the collective benefits that near-zero energy homes offer.

Key Results

The O Bel Sole! Estates community, currently at 66.7% whole house energy savings (WHES), relative to the BA Benchmark, is an example of smart design, improved construction practice, and high efficiency, "off-the shelves" equipment. This building strategy has allowed the cost neutrality target to be exceeded with approximately \$1,457.58 annual cost savings for the homeowner.

Gate Status

O Bel Sole! Estates meets and exceeds the Stage Gate Closeout Criteria. K Street East LLC, owner and developer of the O Bel Sole! Estates, has demonstrated a strong commitment to quality assurance and quality control by continuously building, testing, training, and fine-tuning all facets of their company. At the time of this evaluation report, there are six homes sold, five are in escrow and two are under contract. Current homeowners at Lots 18, 35 and 39 at O Bel Sole! are saving money due to their low electric bills which includes the hot summer months.

Conclusions

K Street East LLC's continuing dedication to improve designs, in spite of difficulties from the housing and financial markets, will most certainly create an opportunity for them to build a community that achieves greater than 50% whole house energy savings in the future. Although K Street East LLC has had difficulties selling the homes due to the tightening credit market, they are moving forward to complete their last two construction phases.

Lancaster – Location, Demographics, Housing Market Data

Lancaster, California is located in Los Angeles County in Southern California. While Lancaster is in Los Angeles County, its geography is much closer to that of Las Vegas. The population of Lancaster has grown dramatically since its incorporation in 1977. Since that time the city's population has grown from an estimated 37,000 to an estimated 145,074 residents in 2009³⁶. Lancaster and Palmdale, a neighboring city of similar size, form the core of census designated urban area of approximately 475,000 people.

Lancaster is in a semi-arid climate, experiencing an average of less than 8 inches of rainfall per year and year-round sunshine. Typical of its “high desert” location (Lancaster's elevation is 2,500 feet above sea level) there are wide temperature swings throughout the day and throughout the year. The average high temperature in August is 95 degrees Fahrenheit; the average low temperature in December is 29.

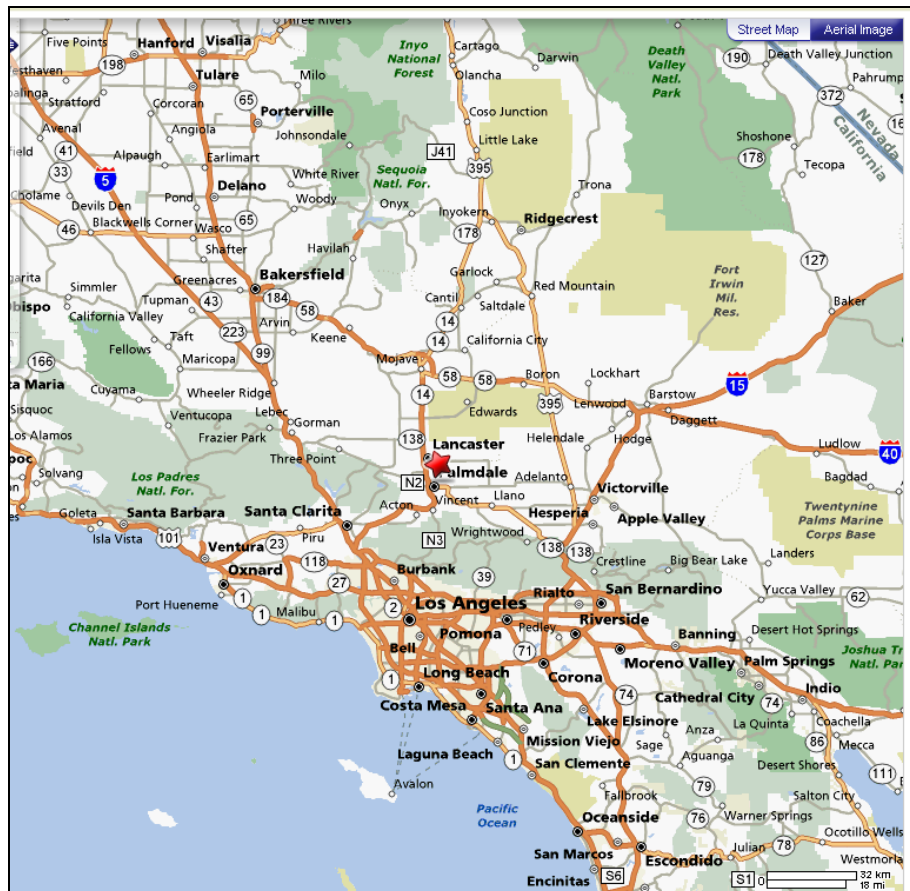


Figure 169: O Bel Sole – Lancaster Area Map

The housing market in California has, without hyperbole, deteriorated to unseen levels. The

³⁶ [California Department of Finance 2009 Population Estimate](#)

Construction Industry Research Board, which provides monthly data based on housing permit activity, indicated in their June 2009 report that recent activity is at the lowest level it has seen since it began tracking data over fifty years ago. In 2005, the State of California had 155,000 single family homes begin construction; in 2008, there were permits for 33,000 single family homes. The projected data indicates that the state will see even lower levels of activity in 2009.

Partnerships/History

The owner and developer of the project is K Street East LLC, a small, progressive builder of single-family, multi-family and non-residential projects. In an effort to lead the way in the greater Los Angeles valley, they proposed the O Bel Sole! Estates project, which would be the first 100% solar community in the region. They are one of the best examples of a Building America builder in Lancaster, California (Hot/Mixed-Dry Climate Zone).

In 2007, K Street was approached to participate in variety of above code programs by ConSol, including the Building America program. ConSol had also partnered with Architectural Energy Corporation (AEC) in 2005 on a contract with the California Energy Commission (CEC.) AEC has been awarded Contract No. 500-04-024, "Utility-focused Market Model for Zero Energy New Homes," by the CEC to undertake research activities as part of their Public Interest Energy Research (PIER) Program. Subsequent to AEC being awarded that contract, the California Public Utilities Commission approved the California Solar Initiative, as part of this initiative; the CEC is managing a 10-year \$400 million dollar program known as the New Solar Homes Partnership. SunPower provided the PV solar panels for the project as well as consulting services.

O Bel Sole! is in the service territory of Southern California Edison (SCE), and was also enrolled by ConSol in SCE's Demand Response Evolving Technologies Program. In addition, the homes were also planned to achieve ENERGY STAR and California Green Builder Certification.

The figure below is the site map for the O Bel Sole project.

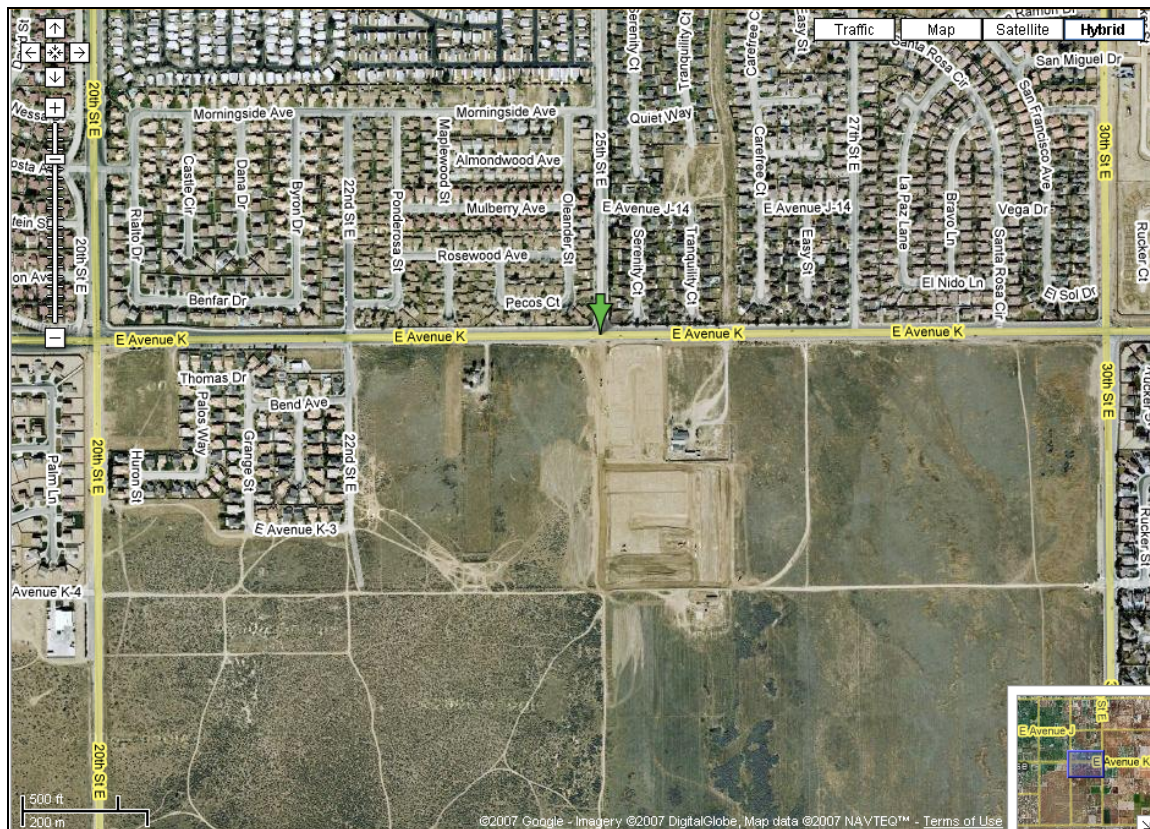


Figure 170: Aerial View of O Bel Sole Site

Homes and Community Overview

The O Bel Sole community by K Street LLC plans to build 41 homes in three different plans. Each plan type (A, B and C) has three different elevations with varying roof lines and facades. Floor plans for each of the three plans can be found in Appendix B of the final report. The energy efficiency measures of the houses were upgraded to the maximum level per K Street LLC. For example, K Street LLC increased the wall insulation from R-19 wall to R-21, upgraded window products from dual pane to triple pane and upgraded the HVAC system from 92% AFUE and 14 SEER to 95% AFUE and 16 SEER.

All of the homes meet federal tax credit standards. The two-story, four to five bedroom homes are built with R21, 2x6, 16"o.c. construction, priced between \$405,000 and \$445,000³⁷, and are generally targeted at middle class homeowners looking to upgrade to a high quality, energy efficient home. The community is provided electricity and natural gas by Southern California Edison and Southern Cal Gas.

³⁷ http://www.obelsole.com/New_Solar_PowerGreen,_Exciting_Lancaster_Homes_listings/index.shtml

“Must Meet” Gate Criteria -- Source Energy Savings

Using BEopt 0.8.7, an energy analysis was performed on K Street’s Plan B floor plan. Floor plans and elevations can be found in the report. The Plan B floor plan is a two-story house representative of a typical K Street house, with 3,218 square feet of finished floor area, five bedrooms, and four and a quarter bathrooms. Two separate simulations were run: one with the BA Benchmark as the reference house, and one with a California 2005 Title-24 code house as the reference house. Figure 171 shows the BEopt source energy use graph for the Plan B floor plan with the BA Benchmark as the reference house. All four cardinal orientations (North, South, East and West) were simulated for both reference homes. Table 221 summarizes the findings of both simulations. The energy savings for Plan B are averaged over all four orientations and grouped into five main end use categories.

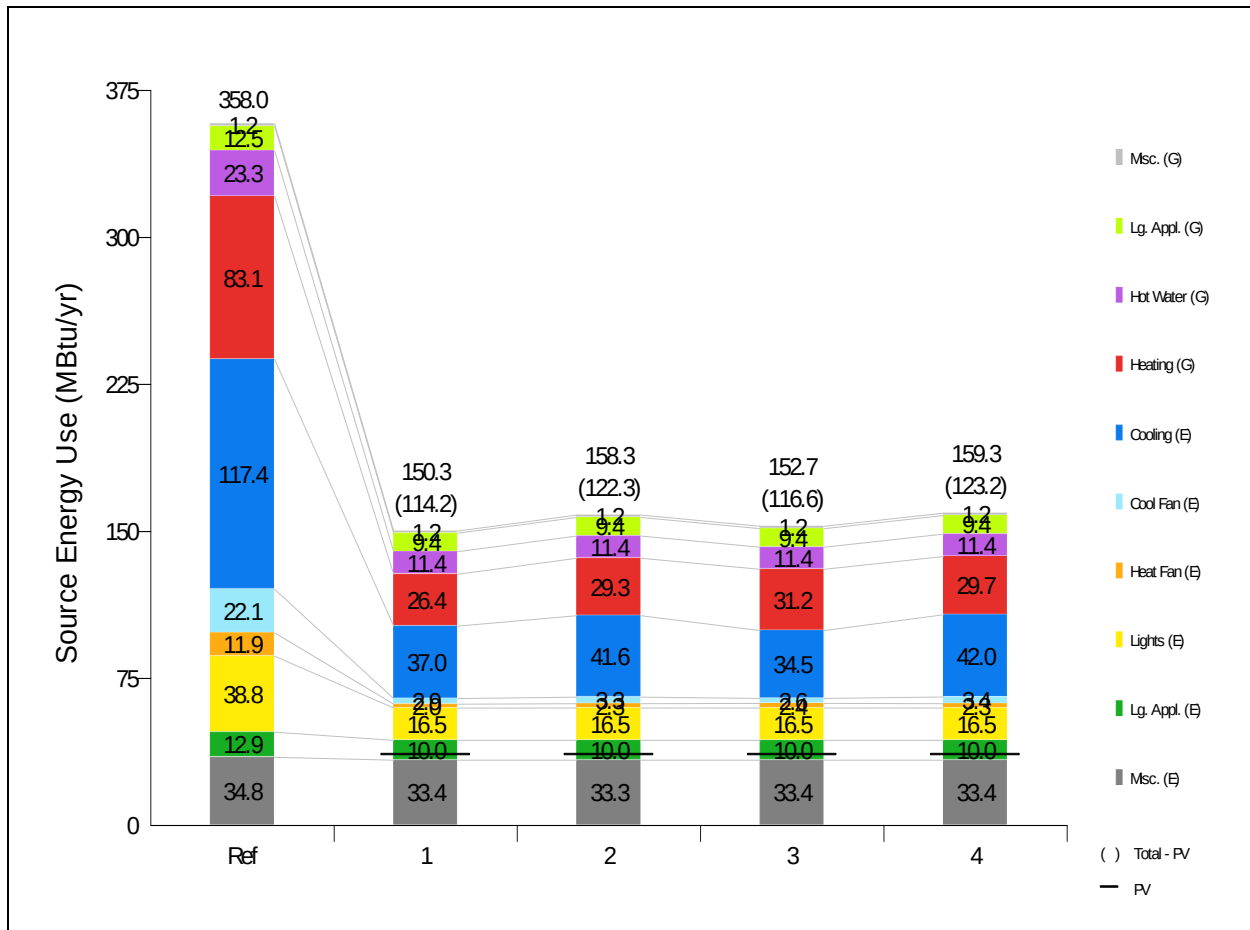


Figure 171: BEopt Source Energy Use
Plan B with the BA Benchmark as the Reference House

Description	Annual Source Energy			Estimated Source Energy Savings			
	Benchmark	California Code Home	Plan B 3218	Percent of End Use		Percent of Total	
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code
Space Heating	95.0	74.3	31.4	66.9%	57.7%	17.8%	16.3%
Space Cooling	139.5	92.2	41.8	70.0%	54.7%	27.3%	19.2%
Direct Hot Water	23.3	21.2	11.4	51.1%	46.2%	3.3%	3.7%
Lighting	38.8	16.5	16.5	57.5%	0.0%	6.2%	0.0%
Appliances and MELs	61.3	58.8	54.0	11.9%	8.2%	2.0%	1.8%
Photovoltaic	0.0	0.0	-36.1	n/a	n/a	10.1%	13.7%
Total Usage/Savings	358.0	263.0	119.1	66.7%	54.7%	66.7%	54.7%

Table 221: Source Energy Savings for the Plan B Floor Plan

As shown in Table 221, a typical O Bel Sole! house with the federal tax credit package meets the Building America goal of 50% energy savings in the Hot/Mixed-Dry Climate Zone with respect to the BA Benchmark. The critical above-code energy efficiency features implemented in order to reach this goal are as follows:

- 80% hardwired CFL lighting
- 82% EF tankless gas water heater
- 2.1 SLA infiltration
- R49 blown-in cellulose insulation in the attic
- R21 batts insulation in the walls
- R30 fiberglass batt insulation above the garage
- 94% AFUE furnace
- 16 SEER AC unit
- R8 duct wrap with attic ducts buried in ceiling insulation
- 0.33 U-value windows (worst case, most windows have 0.20 U-value)
- Gas cooking range and clothes dryer (gas dryer stub provided)
- 2.6 kW DC PV system

Based on the BEopt simulation estimated source energy savings of 66.7% WHES with respect to the BA Benchmark, the O Bel Sole! Estates community passes the Source Energy Savings “Must Meet” criteria.

“Must Meet” Gate Criteria -- Neutral Cost Target

K Street has been able to keep its costs marketable while implementing energy efficiency features. They have done this by working with vendors to bring costs down, beginning with the most expensive elements. This effort is largely driven by the recent housing crunch. In addition, the 66.7% WHES provides substantial reduction in energy bills, resulting in few, if any, tradeoffs necessary to reach the neutral cost target. Figure 172 shows the BEopt energy cost graph for the Plan B floor plan with the BA Benchmark as the reference house. These costs were based on the current utility rates in Lancaster, California, summarized in Table 222, and include both electric and natural gas energy sources. SCE utilizes a tiered rate structure for three generation categories: delivery, water generation and electrical generation. This could not be modeled in BEopt, so an average rate (\$0.097 per kWh) was computed based on average kWh used per month, per tier.

Rebates for the homes include \$400 for the tankless water heaters, from Southern California Gas, \$2000 energy efficiency rebate from Southern California Edison for being a TIER II home, a \$2000 energy efficiency federal tax credit to the builder, a \$2000 Federal solar tax credit to the homeowner, and a \$2/watt (\$5,200 total) PV buy-down rebate from California. The buy down was incorporated into the cost of the PV system. This totals \$11,600 in rebates per home.

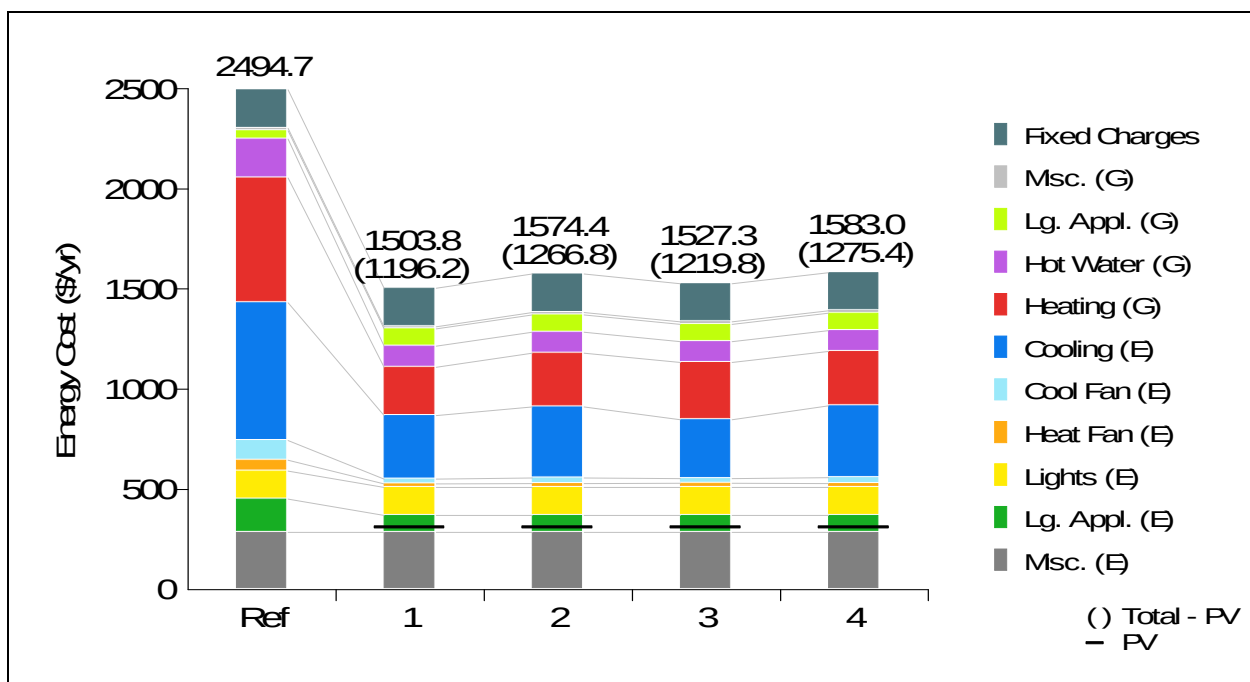


Figure 172. BEopt Energy Cost
Plan B with the BA Benchmark as the Reference House

Electricity Rate		
	Utility	Southern California Edison
	Marginal	0.097938
	Fixed	\$8.00/month
Natural Gas Rate		
	Utility	Southern California Edison
	Marginal	\$1.0/therm
	Fixed	\$5.00/month

Table 222. Current Utility Rates for Lancaster, California

The top half of [Table 223](#) adds a column to [Table 221](#) that details the annual utility bill savings of each of the five main end use categories in comparison to the BA Benchmark. Again, these values are averaged over all four orientations. As shown in [Table 223](#), the annual utility bill savings according to BEopt is \$2,178.02 compared to a BA Benchmark home. It should be noted that this includes no fluctuations in utility rates or inflation.

The bottom half of [Table 223](#) is derived from the builder's first cost for each of the energy efficiency features listed. The builder costs were gathered from Jennie Stabile, president of K Street East LLC. The cost is converted into an annuity assuming a 7% loan over 30 years. Inflation is not considered.

Description	Annual Source Energy			Estimated Source Energy Savings				Annual Utility Bill Savings
	Benchmark	California Code Home	Plan B 3218	Percent of End Use		Percent of Total		
End Use	(MBtu/yr)	(MBtu/yr)	(MBtu/yr)	vs. Benchmark	vs. Code	vs. Benchmark	vs. Code	vs. Benchmark
Space Heating	95.0	74.3	31.4	66.9%	57.7%	17.8%	16.3%	\$576.06
Space Cooling	139.5	92.2	41.8	70.0%	54.7%	27.3%	19.2%	\$832.93
DHW	23.3	21.2	11.4	51.1%	46.2%	3.3%	3.7%	\$109.30
Lighting	38.8	16.5	16.5	57.5%	0.0%	6.2%	0.0%	\$190.32
Appliances and MELs	61.3	58.8	54.0	11.9%	8.2%	2.0%	1.8%	\$64.34
PV	0.0	0.0	-36.1	n/a	n/a	10.1%	13.7%	\$214.54
Total Usage/ Savings	358.0	263.0	119.1	66.7%	54.7%	66.7%	54.7%	\$2,178.02
				Energy Efficiency Feature				Annual Mortgage Cost vs. Code
				80% CFL Lighting				(\$9.58)
				82% EF Tankless Water Heater (x2)				(\$119.75)
				Improved Duct Sealing, Envelope Sealing, and Testing				(\$35.93)
				Radiant Barrier				(\$42.79)
				R30 Above Garage insulation				(\$8.22)
				R21 Wall Insulation				(\$11.98)
				R49 Attic Insulation				(\$26.75)
				95% AFUE Furnace				(\$39.92)
				16 SEER (12.5 EER) A/C unit				(\$63.87)
				Highly Efficient Windows				(\$31.93)
				Pipe Insulation Water Distribution				(\$11.98)
				2.6 kW DC PV System				(\$1,243.85)
				Rebates and Incentives				\$926.10
				Total Annual Mortgage Cost				(\$720.44)
				Net Annual Cash Flow to Consumer				\$1,457.58

Table 223. Neutral Cost Analysis for the Plan B Floor Plan

As shown in Table 223, the net annual cash flow to the homeowner is approximately \$1,457.58. Based on this information, it is clear that the incremental annual cost of energy improvements is much less than the annual reduction in utility bill costs and K Street O Bel Sole! Estate community passes the Neutral Cost Target “Must Meet” criteria.

Should Meet” Gate Criteria -- Quality Control Integration

K Street East has demonstrated a strong commitment to quality assurance and quality control. They have aggressive inspection and third-party verification protocols to ensure that everything is properly installed and working. All the models are inspected and tested at rough and final stages, and production homes are tested/inspected at 1:7. BIRA has worked with the city officials to ensure that their inspection protocols are up-to-date to verify everything is meeting compliance measures. One area of quality control that K Street East has exceptional control over is their HVAC installation. Their long-term relationship with their HVAC subcontractor, BMI, and the high quality of their installations has allowed HVAC system call backs to avoid the Top-Ten call back categories.

Under the CEC Zero Energy New Homes program, SCE is interested in monitoring the peak kW draw. Preliminary energy simulations using the BESTEST-certified Micropas³⁸ energy analysis software shows a peak reduction of up to 50% kW (from 9 kW to 4 kW), based on a Title-24 compliant home. This estimate was based on SCE’s DEER peak calculation methodology. The reduction suggested that SCE could serve more homes with existing underground infrastructures, or could reduce infrastructure costs in similar future projects. Although there is a concern about harmonic distortions within the grid due to the PV generations, other similar solar projects’ yield was negative. SCE has already planned to replace the current meters with smart meters to measure the peak kW draw from this project in the near future.

In 2007, K Street East LLC made a commitment to build all of their homes to the California Energy Commission’s (CEC) Zero Energy New Homes Program. Due to marketing success and as a champion of energy efficiencies, K Street East LLC continues to build phases 2 and 3, totaling 24 additional homes. Jennie Stabile has been very satisfied with the positive responses she has received on her community and plans on building energy efficient communities in the future.

K Street East LLC has committed significant resources of time and money to educate their staff, subcontractors, and customers about the benefits of building high performance homes. Their commitment to energy efficiency is evident by the amount of building science training that K Street East LCC staff has received. K Street East LCC continuously builds, tests, trains, and fine-tunes all facets of their company. This team commitment helps differentiate K Street East from other production builders.

K Street East LLC has also taken a proactive approach to educating the community and local

³⁸ Micropas is a product of Enercomp, Inc.

jurisdictions through their state-of-the-art homes. Numerous curious individuals stop by the community to learn about the energy efficient features installed in the homes, and the advanced building science techniques used to achieve such a high level of energy efficiency.

Should Meet” Gate Criteria -- Marketability

Despite the housing market downturn, K Street East LLC continues to move forward with construction. The homes are targeted at the upgrading homeowner looking to invest in a long-term solution for their housing needs. However, the builder is having a difficult time selling the homes, specifically qualifying people for financing due to the tight credit market.

As the first 100% solar home community in the area, traffic at O Bel Sole! Estates remains strong. Many people are taking the opportunity to see the advantages of having a PV system on the roof, as well as the savings produced by tankless water heaters and advance home design. The community has been marketable to the point where construction will not be further delayed and plans for the next 17 homes of Phase Two have begun.

Based on current marketing information, the O Bel Sole! community passes the Marketability “Should Meet” criteria.

K Street East’s marketing efforts used information from the Building America community study to quantitatively show potential homebuyers actual energy bills and the energy savings these homes provide when compared to a typical California 2005 Title-24 code house. Figure 173 and Figure 174 are example graphs that BIRA provided to K Street East to assist with this marketing effort.

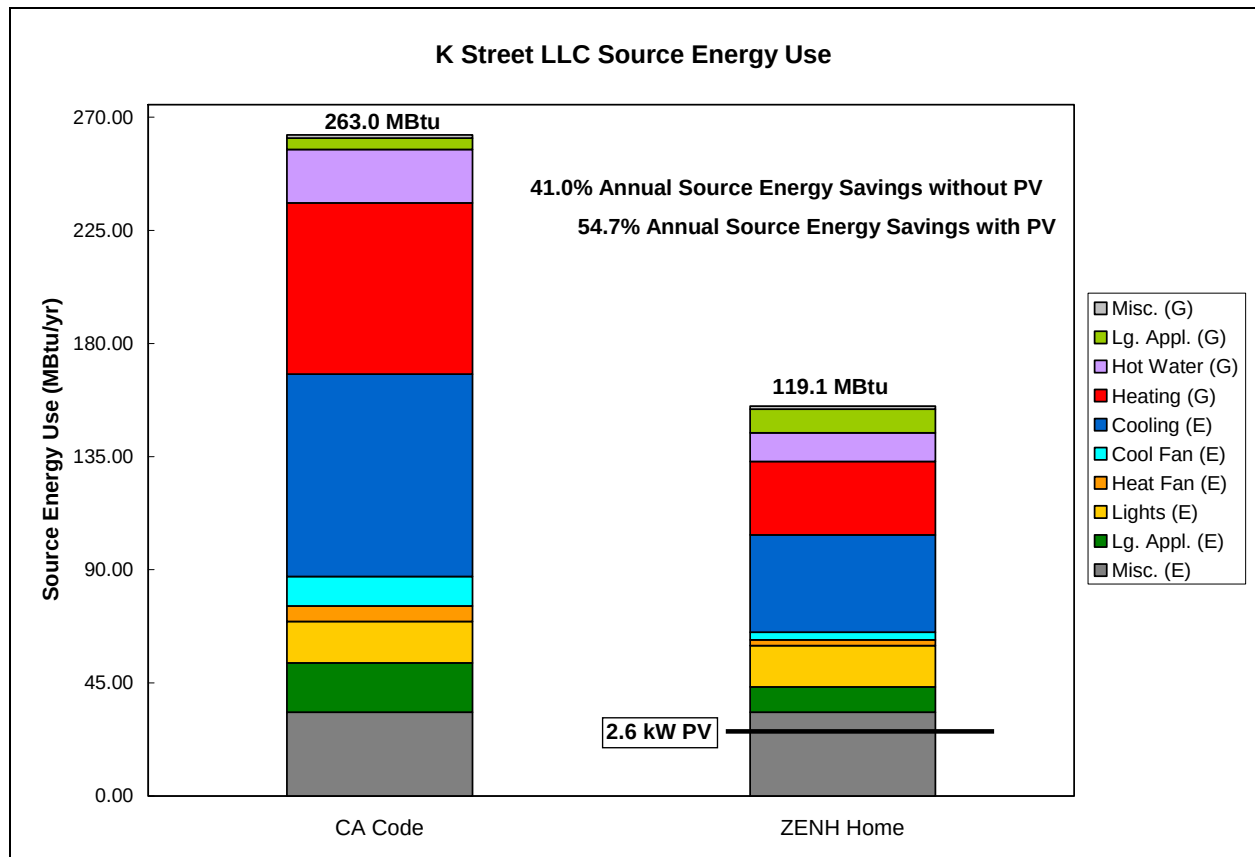


Figure 173. Source Energy Use Marketing Material for K Street

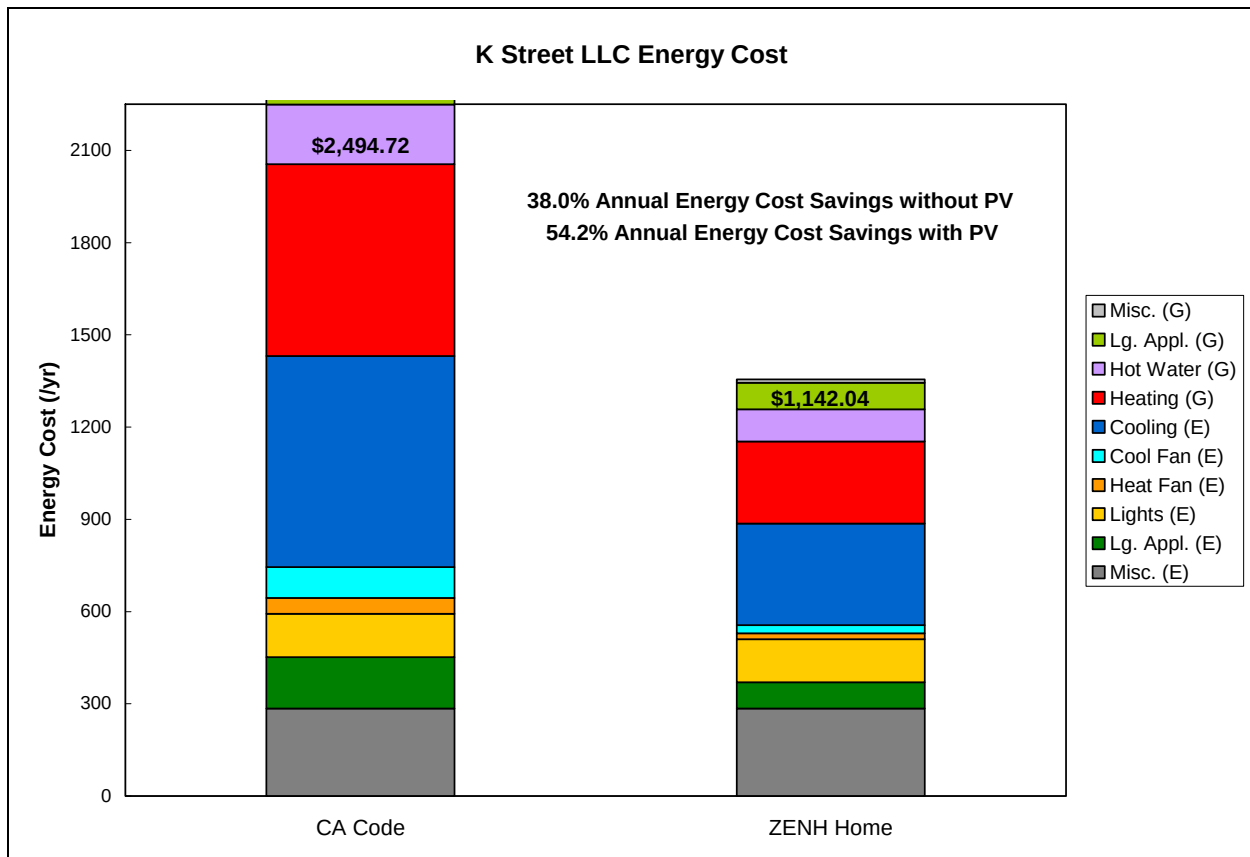


Figure 174. Energy Cost Marketing Material for K Street

Should Meet" Gate Criteria -- Builder Commitment

Jennie Stabile, the owner of K Street East, LLC remains committed to building energy efficient homes and committed to building homes with PV solar. While the lack of sales volume has been disappointing, interest in the O Bel Sole! project has been high. The greatest challenge from a sales standpoint has been difficulties in qualifying individuals for financing.

K Street East LLC hoped that their participation in the Building America program would create product differentiation and increase the interest levels in their homes. In a recent conversation with Jennie Stabile, she commented that this has absolutely been the case. Ms. Stabile believes she could have sold these homes three to four times over were it not for difficulties with the financial market. She also believes builders who are not building energy efficient homes with solar are missing out on an opportunity and noted how much energy could have been saved had builders embraced such practices during the last housing boom.

K Street East LLC received a wide variety of design and marketing assistance from ConSol, AEC, SunPower, and Southern California Edison, under the PIER program. On October 4, 2007 a grand opening event was held following the completion of the model homes. The speaker list for the event included representatives from the California Energy Commission, Southern

California Edison, the City of Lancaster, SunPower, and K Street.

In conjunction with the grand opening, ConSol and other partners provided K Street with sales agent training to familiarize the sales agents with the features and benefits included in the O Bel Sole! homes. Jennie Stabile indicated that she and the other sales agents were successful in presenting these benefits, which were so significant that the majority of homebuyers understood immediately the savings potential of buying an O Bel Sole! home.

During the construction of the production homes, the process proceeded relatively smoothly. There were some delays caused by a disagreement between K Street and the installing HVAC contractor, ultimately a new sub-contractor was brought in to the project. There were no issues noted with the installation of window, insulation, tankless water heater, or the solar panels. ConSol provided training to many of the subcontractors on installation best practices, and SunPower had a representative on sight during many of the city's solar panel inspections to address any potential issues that might come up.

Jennie Stabile's biggest regret for the project is not pressing ahead sooner for the completion of the first phase. There was a delay in construction of several months that prevented the homes from being completed before the credit markets tightened. She has few regrets, however, about the decision to build a high performing home. Overall, K Street East LLC is glad of their decision to participate in the Building America program and will continue to build high performance homes.

Based on this builder's proactive energy efficiency practices and continued commitment at the O Bel Sole! community, K Street East LLC passes the Builder Commitment "Should Meet" criteria.

Should Meet" Gate Criteria -- Home Owner Satisfaction / Energy Bills

Energy Bills Savings

Current homeowners at Lots 18, 35 and 39 at O Bel Sole! are saving money due to their low electric bills, including one hot summer month, June 2009. Gas bills were difficult to obtain from the utility company and were not included in this analysis. In addition, ConSol was not able to obtain additional electric bills beyond June 2009 due to difficulties with the utility and homeowners. Below are the available actual and simulated electric bills.

Month 2009	Lot 35 - Electric Bill		Lot 39 - Electric Bill		Lot 18 - Electric Bill	
	Simulated	Actual	Simulated	Actual	Simulated	Actual
January	N/A	N/A	\$44.14	\$43.26	\$44.14	\$54.96
February	N/A	N/A	\$30.61	\$27.27	\$30.61	\$42.14
March	N/A	N/A	\$26.06	\$5.98	\$26.06	\$14.34
April	\$15.97	\$22.31	\$15.97	\$1.83	\$15.97	\$0.89

May	\$27.17	\$38.44	\$27.17	\$1.77	\$27.17	\$1.78
June	\$57.00	\$0.92	\$57.00	\$1.71	\$57.00	\$1.04

Table 224: Actual Electric Bills

Energy Efficiency Performance and Benefits

In addition, each of the 41 homes will incorporate the following features, and benefits of each feature are listed below:

1. **R-49 attic insulation with radiant barrier** – higher insulation levels reduce heat gain in summer and reduce heat loss in winter. Radiant barrier at the inside of the roof reduces solar gain and keeps the attic cool.
2. **R-21** - higher insulation levels reduce heat gain in summer and reduce heat loss in winter.
3. **Low air infiltration rate** - Tight building envelope helps minimize outside/inside air from entering/exiting the home. With lower infiltration of unconditioned air and exfiltration of conditioned air, less conditioning is required, making the home more efficient. Homes with low air infiltration/exfiltration are often quieter and cleaner.
4. **Triple pane non-metal frame windows with spectrally selective glass with U- factor and Solar Heat Gain Coefficient no greater than the following:**

	U-value	Solar Heat Gain Coefficient (SHGC)
Slider	0.20	0.22
Single Hung	0.20	0.22
Fixed	0.16	0.24
Patio Dr	0.33	0.34
French Dr	0.40	0.40

These types of glazing help increase the comfort level of the home by reducing solar insulation into the house. In the summer, spectrally selective glass lets in visible sunlight while blocking 80% of both the infrared and ultraviolet solar energy that drives up cooling costs and degrades curtains, window treatments, carpeting and furnishings. In the winter, these glazing products offer reduced heating costs by reflecting room-side radiant heat back into the room³⁹. In hot climates this type of glazing typically enables builders to reduce the size of air conditioners and decrease other building energy related features.

5. **Engineered System with Heating Ventilating and Air Conditioning (HVAC) efficiencies of: 95% AFUE for furnace/16 TXV SEER for AC with thermal expansion valve (TXV)** – Licensed mechanical engineers size and select HVAC systems, design duct sizes and register locations. The final product of these engineered systems will have properly sized and balanced HVAC systems

³⁹ Supplemental Catalogue for Cardinal IG: LoE² Glass Products “The Choice for Year-Round Energy Savings and Comfort”

with correct duct sizes and placement of registers to assure that conditioned air will be evenly distributed throughout the whole house and provide improved efficiency and comfort. The TXV is a metering device for refrigerant flow into the evaporator of an air conditioner. A TXV improves efficiency.

6. **R-6 duct buried in insulation, and with tight duct and ACCA Manual D designed by a licensed mechanical engineer** – Duct leakage can have a significant impact on HVAC performance, household infiltration/exfiltration rates, moisture levels in the house, water heater and furnace safety, and overall occupant comfort. A tight duct system is one that does not leak more than 6% of the fan airflow (at 50 Pascal). Excessive air leakages in duct systems make HVAC systems work harder, using more time and energy to cool or heat the home due to insufficient air delivery. This results in higher energy bills and less comfort for homeowners/occupants, which often triggers callbacks. Duct leakage typically occurs at:
 - o Poorly fitted and improperly sealed joints and seams in the ductwork
 - o Disconnected and partially disconnected boot connections
 - o Holes in the ducts
 - o Use of improperly sealed building cavities for supply and return ducts
 - o Poor connections between room registers and register boots
 - o Poorly fitted air handler doors, filter doors and air handler cabinets
 - o Tight duct systems increase forced air distribution efficiency, resulting in improved comfort and lower utility bills for homeowners. Tight duct is required to be tested by a third party.
7. **Tankless water heater with an Energy Factor (EF) of 0.82.** R-4 insulation on all trunk lines. This includes any hot water lines located in concrete slabs or underground - A tankless water heater has high efficiencies. Hot water is heated on demand and has no storage tank.
8. **Gas dryer stub** – A stub is provided to encourage the use of gas dryers, which are less expensive to operate than electric.
9. **All-fluorescent lighting as per the CA 2005 Lighting Standards**
10. **Photovoltaic System** – 2.3 kW DC and 2.6 kW DC and 2.8 kW DC building integrated PV system (BIPV). The 2.3 kW DC system produces 3225 kWh/year, the 2.6 kW DC system produces 3646 kWh/year, and the 2.8 kW DC system produces 3926 kWh/year. The BIPV system not only produces electricity, but is also aesthetically pleasing by blending in with the roof. Note: majority of the PV systems are installed on the west orientation to capture most sunlight late in the afternoon since the system peak hour falls on the same time.

Should Meet" Gate Criteria -- Gaps Analysis

K Street had very few problems in the installation of the energy efficient features during construction. Prior to construction start, pre-planning and coordination meetings were held between subcontractors and jurisdiction officials to educate them on the features they would be installing and the procedures for proper inspection and commissioning. The jurisdiction officials had never seen some of the components being installed into the homes (e.g., tankless water heaters and the PV system), so they did not have protocols to inspect and approve their

installations.

Miscommunications with the PV subcontractor almost lead to an undersized system. The original plan was for a 2.3 kW AC PV unit. The subcontractor mistook it for a 2.3 kW DC unit, so a compromise was made for a 2.3 kW, 2.6 kW and 2.8 kW system for the small, medium, and large plan sizes, respectively. Post installation, there were problems qualifying for the California State PV rebates because the system did not complete a proper final inspection since such protocols did not exist for the local jurisdiction prior to this community. BIRA worked with the city to develop these protocols and the city jurisdiction officials were able to complete the final inspection, resolving the problem.

K Street is also strongly considering moving to 100% CFL lighting using screw-in CFLs for the remaining fixtures. Although not a long-term solution, this would certainly increase the energy savings at a small cost. In the future, K Street plans on working with Building America to continue to develop increasingly efficient homes that further reduce heating and cooling loads.

Task 6: Post-Stage Gate Results, Best Practices Documentation and Resource Development

Subtask 6.1 Review & Provide Feedback to Best Practices drafted reports by PNNL & ORNL

BIRA's support of Best Practices Documentation and Resource Development is an ongoing, dynamic process. BIRA strives to respond thoughtfully and quickly to the requests of PNNL and ORNL, and has strong relationships and lines of communications with key personnel at each lab.

BIRA continues to support Task 6 objectives through its work with PNNL, ORNL, NREL and the DOE. Much of BIRA's work in this area has been in tandem with other deliverables, such as Stage Gate Research Reports. For instance, the Marine 40% Joule report and case studies were designed, implemented and reported on in a manner that facilitated the needs of the aforementioned parties. Ryan Kerr, BIRA, worked with PNNL to align Gate reports with their needs for Best Practices/Builders Challenge Guides. An example of this alignment was the inclusion of high resolution pictures to the Gate reports. These pictures can be used directly for the PNNL guides, an important element of the Guides historically. Much of the 40% Marine Joule work will pay dividends as PNNL develops the updated Marine Climate guide, of which BIRA will strongly support. BIRA has also received positive feedback from NREL on the organization of the G3 reporting. As Building America's approach (e.g. Gate Reporting, Builders Challenge) evolves, it is increasingly important that the teams work closely with each other, labs and the DOE to leverage activities and ensure alignment with reporting goals.

BIRA has also worked closely with the DOE, namely Chris Early and Lew Pratsch, to ensure gate reports serve the needs of the DOE. One DOE need is to develop a memo to the Office of Management and Budget reporting criteria important toward determining Building America goal fulfillment and future funding needs. As with PNNL, BIRA worked with the DOE both while outlining reports but also intermittently during research and reporting. Ryan Kerr worked with Chris Early in development of BIRA's Marine Climate update presentation at a DOE Quarterly Meeting. Again, this coordination was aimed at meeting the needs of multiple stakeholders and ensuring Chris and the DOE had the information they needed for their internal deliverables.

BIRA has a strong relationship with ORNL, collaborating on several projects. BIRA has developed several marketing pieces that were designed with input from the DOE and ORNL (Pat Love). The latest is a 'one pager' that discusses BIRA's research in the Pacific Northwest, especially as it relates to the Marine Joule (See Appendix A of the Pacific Northwest Highlights "one-sheet"). BIRA has also worked with ORNL to promote and implement the Builders Challenge.

Other work BIRA has done that promotes Task 6 includes; reporting on heat pump commissioning protocols and analyzing their appropriateness for inclusion in BA guides, contributing analysis and data for a DOE sponsored international case study on efficiency and

renewables, integrating Builders Challenge protocols and messaging into Cold, Marine and Hot Mixed/Dry projects and offering technical and market research and perspective on Builders Challenge criteria to DOE staff and consultants. BIRA sees several large scale Builders Challenge opportunities in Utah and Hawaii. These projects are being coordinated with Christine Barbour, Ed Pollack and other important DOE, contractor and lab personnel.