Appendix 1.A: Quality Management Expert Meeting Report

IBACOS Expert Meeting Final Report

Quality Management Tools and Integration for High Performance Homes

Prepared by:
Duncan Prahl

November 30, 2010

IBACOS®
| Home Quality + Performance |

Building AMERICA®
U.S. Department of Energy

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Overview

Builders generally use a "spec and purchase" business management system (BMS) when implementing energy efficiency. A BMS is the overall operational and organizational systems and strategies that a builder uses to set up and run its company. This type of BMS treats building performance as a simple technology swap (e.g. a tank water heater to a tankless water heater) and typically compartmentalizes energy efficiency within one or two groups in the organization (e.g. purchasing and construction). While certain tools, such as details, checklists, and scopes of work, can assist builders in managing the quality of the construction of higher performance homes, they do nothing to address the underlying operational strategies and issues related to change management that builders face when they make high performance homes a core part of their mission. To achieve the systems integration necessary for attaining 40%+ levels of energy efficiency, while capturing the cost tradeoffs, builders must use a "systems approach" BMS, rather than a "spec and purchase" BMS. The following attributes are inherent in a systems approach BMS; they are also generally seen in quality management systems (QMS), such as the National Housing Quality Certification program.

- Cultural and corporate alignment
- Clear intent for quality and performance
- Increased collaboration across internal and external teams
- Better communication practices and systems
- Disciplined approach to quality control
- Measurement and verification of performance
- Continuous feedback and improvement
- Whole house integrated design and specification

While there are market leaders who are successful at implementing quality management systems to profitably deliver lowest, first-cost "code" housing, there are very few who have developed quality management systems associated with a holistic systems approach to delivering high performance homes. In an effort to help the industry more widely adopt the technical results from the Building America (BA) program, IBACOS is undertaking an ongoing research project to:

- Characterize the organizational and operational structure of a systems approach BMS and supporting QMS for a profitable company building high performance homes.
- Identify the barriers, level of effort, and costs associated with transformation from a "spec and purchase" to systems approach BMS and QMS, and provide template solutions to these issues for builders to adopt.

In advance of the Expert Meeting, IBACOS provided participants with the following:

- A draft Quality , Environmental, Health and Safety (QEHS) Manual Requirements document that includes recommended structures and processes for a systems approach BMS based on findings

from the examination of past National Housing Quality Award applicants and published operational best practices from publically available sources.

- A list of frequently asked questions (FAQs) and answers related to the high performance home aspects of the draft QEHS Manual Requirements. The FAQ's include a draft set of standardized business metrics for homebuilding companies constructing high performance homes.
- Proposed transformation pathways that provide the order of implementation for builders at various levels of technical and operational sophistication to move toward a systems approach BMS.

Participants were asked to review these materials and bring a list of their best practices and biggest implementation challenges in each of the areas associated with the QMM related to high performance homes.

Meeting Objectives

1. To receive feedback on the format, structure, and content of the draft QEHS Manual Requirements and business metrics. Are these relevant and useful tools for helping companies implement a more comprehensive systems approach to a BMS?
2. To examine the practicality of companies uniformly tracking the standardized business metrics
3. To receive feedback on preliminary transformation plans for implementing a systems approach BMS
4. To identify the current gaps in quality management strategies and business systems using the aggregated experience of the participating experts in order to speed up the process of helping code builders adopt BA technical results throughout their organization
5. To receive feedback on the FAQs related to content, structure, and completeness

Agenda

8:00 – 8:45 am	Introductions and Project Overview
	Duncan Prahl, IBACOS
8:45 – 9:15 am	Presentation of Quality Management Manual Requirements
	Denis Leonard, Business Excellence Consulting
9:15 – 10:00 am	Roundtable Discussion – Quality Management Manual Requirements: Content, Format, Structure, Gaps, and Best Practices
	Facilitators - Duncan Prahl & Michael Dickens, IBACOS
10:00– 10:15 am	Break
10:15 – 10:30 am	FAQs Companion to Quality Management Manual
	Duncan Prahl, IBACOS
10:30 am – 12:00 pm	Discussion of FAQs

	Facilitators - Denis Leonard & Michael Dickens, IBACOS
12:00 – 1:00 pm	Lunch
1:00 – 2:00 pm	Discussion of FAQs
	Facilitators - Denis Leonard & Michael Dickens, IBACOS
2:00 – 2:30 pm	Business Metrics (FAQ D.5 and beyond)
	Denis Leonard, Business Excellence Consulting
2:30 – 2:45 pm	Transformation Roadmaps for Several Company Profiles
	Duncan Prahl, IBACOS
2:45 – 3:00 pm	Break
3:00 – 4:00 pm	Business Metrics and Transformation Roadmaps Discussion: Best Practices and Gaps
	Facilitators - Duncan Prahl & Michael Dickens, IBACOS
4:00 – 4:15 pm	Summary and Next Steps
4:15 pm	Conclude Meeting

Location of the Meeting

Hyatt Regency Pittsburgh Int'l Airport
1111 Airport Boulevard
Pittsburgh, Pennsylvania, USA 15231

Speakers

Duncan Prahl, IBACOS
Denis Leonard, Business Excellence Consulting

Meeting Attendees

The following individuals attended the Quality Management Tools and Integration Expert Meeting:

Name	Company	Name	Company
Frank Alexander	Actus Lend Lease	Mike Mazor	Dow Building Solutions
Erik Anderson	Lutron	Mike McMichael	Zurich Services Corporation
Troy Bickerstaff	Arch Insurance Group	George McRorie	Johns Manville
Glyn Boone	iLevel	Jim Moore	Beazer Homes
Todd Booze	Ideal Homes	Mike Nimon	Wathen-Castanos Hybrid Homes, Inc.
Rob Brooks	iLevel	Serge Ogranovitch	The Potomack Group
Paul Cardis	Avid Ratings	Larry Owen	American Contractors Insurance Group
Bruce Case	Case Design/ Remodeling, Inc.	Duncan Prahl	IBACOS
Ted Cater	Panasonic Home and Environment Co.	Tim Rethlake	Fireside Hearth & Home at Hearth & Home Technologies
Pam Cole	Pacific Northwest National Laboratory	Stacey Rothgeb	NREL
Stephen Crouch	Johns Manville	Charlie Scott	Woodland, O'Brien and Scott
Michael Dickens	IBACOS	Bob Shoemaker	S&A Homes
Randy Folts	Masco Framing Corp.	Dave Steppan	Bayer MaterialScience
John Friesenhahn	Imagine Homes	Colby Swanson	BASF
Michael Gestwick	NREL	Jeff Taggart	NAHB Research Center
Anthony Grisolia	IBACOS	Sam Taylor	US Dept. of Energy
Rob Hammon	ConSol / BIRA	John Tooley	Advanced Energy
Bill Hasselbacher	National Energy Technology Lab	Jennifer Williamson	Pacific Northwest National Laboratory
C.R. Herro	Meritage Homes	Amber Wood	NAHB Research Center
Tom Kenney	NAHB Research Center	Gary Zajicek	Veridian Homes, LLC
Joe King	DuPont		
Alan Laing	Laing Associates		
Jim Lambach	Bayer MaterialScience		
Denis Leonard	Business Excellence Consulting		
Alex Lukachko	Building Science Corp		

Meeting Summary

Introduction and Project Overview

Duncan Prahl opened the meeting with a general discussion of IBACOS' research into Quality Management Tools and Integration. The presentation can be found in **Appendix A**. This overview included a discussion of the past and current work undertaken by the Building America Quality Working Group. A summary of high priority resources for builders either currently under development or proposed for near term development, which are listed in **Appendix B**.

Denis Leonard presented results of research undertaken with past National Housing Quality Award winners that indicates the use of a structured, certified Quality Management System (such as the NAHB Research Center's National Housing Quality program) can lead to superior business performance results and should make high performance homebuilding easier.

Duncan then discussed some of the results of additional research with industry partners and literature sources that indicate a QMS will help structure, define, and coordinate standards and processes, especially in design, construction, and with trade partners; drive the efficiency and effectiveness of design and construction, and make changes in product or processes easier to implement. From this research, IBACOS developed the eight key attributes of homebuilders implementing high performance homes listed earlier in this report, and how these attributes are shared amongst all departments within a cross functional homebuilding company.

This section concluded with a brief presentation of some of the barriers observed by IBACOS to adopting quality management principles in general, and specifically those associated with implementing higher performance homes, research questions, and general work activities undertaken by IBACOS during 2010.

Discussion

This presentation prompted a wide ranging discussion related to the overall scope of the project, and the specific audience it was targeted to. In general, it was felt that Quality Management is useful, however it is generally seen as too daunting a task for most builders to undertake. Several overarching questions emerged from the group:

- Do builders even know they have a problem that Quality Management or higher performance homes can help solve? How do they find out if they have a problem in the first place?
- Can a builder make more money by implementing Quality Management principles combined with Higher Performance Homes?
- Does this combination provide some form of value proposition to the end consumer; or are reduced risk, operational efficiency, profitability, and customer satisfaction the benefits builders should focus on?

Quality Management Manual Requirements

Denis Leonard presented (**Appendix C**) the general structure and content of the QEHS Manual Requirements, which can be found in Appendix D. The rationale behind the QEHS Manual Requirements was to based upon an integration of the following sources:

- NAHB Research Center's NHQ Quality Management System Requirements for Builders
- ISO9001
- ISO14001
- OHSAS18001
- The Malcolm Baldrige National Quality Award (MBNQA) Criteria for Performance Excellence
- The National Housing Quality Award (NHQA)

This information was organized into a manual of required information that a builder should document in order to demonstrate a fully functioning QEHS Management System. The high level sections of the QEHS Manual Requirements are:

- 1.0 General
- 2.0 QEHS System Management
- 3.0 Land Development
- 4.0 Sales
- 5.0 Design
- 6.0 Purchasing
- 7.0 Estimating
- 8.0 Construction
- 9.0 Customer Relations & Warranty
- 10.0 Additional Functional Areas

This topic elicited a fairly lengthy discussion among the participants, which has been captured in the following topic areas:

QEHS Structure

In general, the participants agreed the sections were appropriate, with suggestions to add "Marketing" to Section 4.0, and add "Finance" and "Design Center" as two additional sections. A topic that was brought up is the challenge builders face with a greater reliance on outsourced activities that were once considered a core part of the builder's operations, such as Design and Customer Care / Warranty.

A major dichotomy inherent in the structure of the QEHS Manual Requirements is the conflicting nature of being organized by individual departments which reinforces a "silo" mentality, while the goal of the QEHS Management System at the company level is to create a more integrated, cross functional organization. While it was agreed that sections broken down by Department made sense to enable each department head to focus on their management area, it would be useful to have a matrix diagram to guide repetitive materials, and show where cross functions from multiple departments are needed. Some of the redundancy in the Manual Requirements may be overcome by developing "General Conditions" for cross

functional activities and then each department has their additional specific activities. The departmental requirements could reiterate individual department goals, as opposed to just in Section 1.11 - Performance Measures.

Presentation of Content

There was a great deal of discussion related to the way this information was currently documented and the ability for builders to realistically access it. There was agreement that the core content was reasonable but "overwhelming" in scope and could "scare a builder off." A builder needs multiple "points of entry" based on specific situations, with the amount of information provided tailored to those situations. A web based environment was suggested as a possible way to structure and access this information, and that there may be a tie to DOE building code information websites. A consideration would be to divide this up into what is absolutely "necessary" and supplement it with what is "appropriate." A greater use of photos, diagrams, and graphics would also help make this information more accessible to builders. In addition, the numbering system seemed to add a level of formality that might want to be reevaluated.

Translating from Requirements to Actual Company Manual

The group also considered the more practical aspects of how a builder would apply this information to their business. It would be helpful to create additional Frequently Asked Questions (FAQ) that generally discuss the process of developing a QEHS Management System and how this set of QEHS Manual Requirements gets translated to a specific builder's operations. There would definitely be value in having a "kit of parts" builders could use in areas to streamline adoption. If a "template manual" was ultimately developed, it was noted that builders have used such templates in the past and simply copied them verbatim, including such language as "Sample Builder" instead of truly customizing it to their company operations. There needs to be a balance between tools that can help a builder jumpstart documentation that supports what is written in the manual (such as recommended processes and procedures, flowcharts, checklists, scopes of work, etc.) and providing text for the manual itself. It was reiterated that it is not IBACOS' goal to develop a comprehensive QMS for an entire company. The goal of the project is to identify and develop support resources and tools in those areas where best practices are needed to successfully execute a high performance home strategy at lowest cost.

A script or narrative guide for each department may help builders and managers translate this into their own specific quality manual. One page fact sheets on "How" and Why" in various areas would probably increase the usefulness and allow builders to go to deeper layers of content.

Gap Assessment

It was noted that a critical piece of QMS development is a gap assessment and upfront company evaluation. Providing tools to builders to be able to undertake such an assessment, along with documentation of best practices, can help at a micro level (the builder wants to solve a specific problem) to the macro level (what is missing organizationally to complete a comprehensive QEHS Management System). IBACOS has developed a Strategic Mapping process that has been undertaken with a number of builders. More formal documentation of this process and creation of tools that allow a builder to do this

assessment themselves could be useful. This is an area where additional FAQ documents were also identified.

Benefits of a QMS

One question posed by the participants was "What is the benefit of a QMS?" Builders in the audience related various experiences, and confirmed that the key attributes IBACOS had identified also benefited their organizations. As a result of discussion at the Expert Meeting, IBACOS has reorganized these key attributes into the following three areas:

1. Cultural and corporate alignment
    a. Clear intent for quality and performance
    b. Disciplined approach to quality control
    c. Continuous feedback and improvement
2. Whole house integrated design and specification
    a. Measurement and verification of performance
3. Better communication practices and systems
    a. Increased collaboration across internal and external teams

It was noted that unless there were clear business benefits (see section on Business Metrics below) that would help a builder improve their business, wholesale adoption of this material was doubtful. Actual case studies showing the transformation of a company with long term business results would be helpful.

Trades & Trade Partnering

The importance of the trade / builder relationship was brought up repeatedly. Participants stated that it falls to the builder to support trades in achieving the goals and standards of the builder. Trades can be the weakest link in the achievement of quality goals in the homebuilding process, but only if the builder is not proactive in engaging them and integrating them in the process of what a builder is doing to meet those quality goals. Builders can get in the way of trades being successful by not having a system to assure the job is ready for the next trade, improper scheduling, and poor scopes of work, all of which can cause rework and warranty issues for the trade.

Many builders in the room stated they have programs to actively bring quality management support to their trade partners. This can be done by individual coaching or by actively engaging them as a team in cross trade communications through meetings or trade councils. One strategy that was effective in getting a trade "on board" is supporting them through an analysis of the cost of rework and warranty due to poor quality when the work is first being performed. Resources for this type of work mentioned include the book "The Dollarization Discipline" by Jeffrey Fox and Richard Gregory, and a recent case study by the NAHB Research center on the "Cost of Quality."

Frequently Asked Questions (FAQ's)

Duncan gave a brief presentation on the rational and development of FAQ's (**Appendix E, F**). Given the lengthy discussion on the introductory and QEHS sections of the agenda, the FAQ discussion was shortened, and restructured. Originally intended to provide be a forum for detailed discussion of each FAQ, the group was instead asked to provide general critique of the structure and organization of the FAQ's, and to elaborate on the "Points of Entry" that would allow builders to begin to access this information. Some of the issues with the FAQ's that were discussed in the previous two sections have been captured here.

FAQ Structure

The group agreed the FAQ content is good, but some seem too lengthy, and may need to be broken down to be more "digestible." Leading the FAQ with relevant QEHS sections made them cumbersome and more difficult for a reader to get to the point. It was suggested that the FAQ's be viewed as the "Why" to do something, the QEHS Manual Requirements the "What" to do about the topic, and the actual procedures the builder undertakes are the "How" to do it.

Points of Entry

The group agreed there is no one way a builder will get to a point that they will be receptive to this information. As such, it was suggested that the FAQ's could be a point of entry, and could be structured either around the building process, or based on a builder's possible need. The information should be structured so that the builder can solve a critical problem or need and gain small victories. The problems or need will likely be a small project or represent low hanging fruit, and can probably quickly show a benefit to some aspect of the builder's organization and bottom line. Once the information has proved useful, additional layers of information should be available for the builder to take the next step towards implementation. There will be right brain (holistic, comprehensive, systems driven) and left brain (rational, objective, component driven) reasons builders will access this information, and the points of entry should allow for both, and create relationships from one to another. Initially, builders will only be capable of developing a few key processes, which may be the first step towards a more comprehensive QMS. The four levels of Quality Assurance in the International Code Council Evaluation Services "Acceptance Criteria For Structural Wood-Based Products" (AC 47) was suggested as one model to review. Possible Entry Points for this information were brainstormed by the participants, and the following list was generated. More detailed information is provides in **Appendix G**.

- Builder wants to drive consistency through Construction Department
- Builder has a proactive Building Science Need - eg. water management, air barrier, advanced framing, HVAC
- Builder has building science related construction quality issues leading to risks and customer dissatisfaction
- Builder is seeking to benchmark current business metrics with other builders
- Builder is looking for market distinction and sales and marketing opportunity

- Builder wants to develop a succession plan
- Builder wants to benchmark their current construction quality and building performance
- Builder wants to grow
- Builder decides to apply for NHQA
- Leadership decides to take company to NHQ Certification

This is not an exhaustive list, and could further be expanded.

Additional FAQ's

It was stated that the FAQ's really represent "Best Practices" and there should be some general explanation of what the FAQ's are for the reader. Through the course of the meeting, the group came up with a number of additional FAQ's that could be useful, which are listed below:

- Where do i start?
- What are the key things to do?
- How long will it take?
- What are the benefits of implementing a qms?
- What is a gap assessment?
- What are some gap assessment tools?
    - IBACOS Strategic Mapping
    - 360^{o} Review to identify plusses and minuses of company
    - NHQA feedback report and self assessment
    - Using industry peers such as a Builder 20 clubs
    - NAHB Business benchmarks (Cost of doing business report)
- How can departmental budgeting prevent the implementation of a Systems Approach and prevent cross functional solution sets?

Other Resources Identified

As part of the FAQ discussion, other resources and tools were identified, and are listed below in general categories:

- Trade Partners
    - Documenting the value of NHQ certification for trades, and strategies to show them that value
    - How to develop and manage successful trade relationships, up to and including trade councils
- Business Best Practices
    - A network for sharing business as well as construction best practices would be useful
    - How to manage the integration and cross training of departmental processes
    - Developing individual or corporate incentives to succeed
    - Having business success case studies
- Business Metrics

- Gather and make accessible business metrics for builders to benchmark within their industry and across other industries – possibly working with building product manufacturers
- Have compelling cost of quality case studies from builders, demonstrating the value of quality management as it relates to high performing homes

Business Metrics

Denis gave a brief presentation on business metrics associated with operational excellence for homebuilders from the Shinn group, and some proposed metrics to be tracked during the implementation of high performance homes (**Appendix H, and Appendix F - FAQ D.5**).

Others metrics the group came up with that could be captured include:

- Safety, number of accidents, days since last accident
- Defect levels at walk through
  - It is critical to define defects clearly
    - When is it noted? Pre Walk? Customer Walk?
    - Per house?
    - Per square foot?
    - Per customer?
- Waste / Scrap
- Immediate feedback on high performance aspects of the home (site supervisors actually do blower door testing on houses and track results as an example)
- Time variance from schedule and cost variance from budget
- Referral rate
- Cost of change and ROI
- Rework

The group discussed the need for a larger national database of these metrics which could help all builders understand what to measure in their businesses, and provide them with reference points as to how they are doing against others. This database could be broken down by region, size of builder, and type of house. It may be that this data could be incorporated into the Building America House database.

Transformation Roadmaps for Several Company Profiles

Duncan presented (**Appendix I**) two fictitious case studies to provide an example of how a builder might use the information developed so far, and a fishbone diagram that was developed to show various points of entry that a builder might experience. The case studies are included in **Appendix J**. Suggestions made to enhance and improve the case studies included having an executive summary and developing them as more interactive learning tools. One example given was to refine the case studies as the backbone of an online tutorial or series of lessons, with each step in the process a different learning module, possibly using video, animations, graphics, and quizzes. It was also noted that almost any item on the flowcharts

could be seen as an entry point for a builder, and perhaps documenting how a builder got to the decision point in the case study should also be flow charted.

Conclusions

Several themes came through from the participants at the meeting. IBACOS has listed these below, in no particular order of importance.

Trade Partnerships and Trade Performance

Trades build houses. Builders manage relationships with and among trades to get the house built. The end product that is delivered to the customer is a direct reflection of the extent to which the builder and trade partners are in alignment with quality goal and building performance standards. As houses are built more energy efficiently, by the builder's choice or code driven increases in energy efficiency, trade partners and their performance becomes a critical factor in the success or failure of the builder's quality goals and associated risks.

Business Best Practices and Metrics

Most builders are in business to make money and satisfy their customers. Many NHQA award winning builders have shown that there is a correlation between satisfied customers and increased profitability. Any change undertaken by a builder is stressful for the entire organization, and perceived as a risk. Change is only undertaken where the leadership of the company sees the financial or customer satisfaction benefits outweigh the risk. To date very little hard data exists that demonstrate how high performance homes contribute to either increased profitability or improved customer satisfaction scores. The risk of change is very high for higher performance homes, however codes are going to be pushing builders to construct higher performance homes. To minimize this risk, business best practices and a broader set of business metrics can be valuable to help give builders models toward which they can move their business.

Points of Entry

Builders will come to high performance from any number of ways. Whether they have identified a need or are required to do so by code, the construction of higher performance homes will require change, and builders need ways to access the information in logical steps and in manageable quantities of information.

Next Steps

IBACOS will be using the results of this meeting to adjust the current work plan for this project, and evaluate how this work is transferable to the retrofit market. A more detailed plan will be provided in IBACOS' 2011 Research Plan.

List of Appendices

Appendix A: Introduction and Project Overview Presentation

Appendix B: Quality Working Group Near Term Work Products

Appendix C: Quality, Environmental, Health and Safety Manual Requirements Presentation

Appendix D: Quality, Environmental, Health and Safety Manual Requirements

Appendix E: Frequently Asked Questions Presentation

Appendix F: Frequently Asked Questions

Appendix G: Points of Entry Diagrams

Appendix H: Business Metrics Presentation

Appendix I: Transformation Pathways Case Studies Presentation

Appendix J: Transformation Pathways Case Studies

Appendix A: Introduction and Project Overview Presentation

Expert Meeting on Quality Management Tools and Integration for High Performance Homes

Duncan Prahl, RA
Sr. Research Associate, IBACOS

Denis Leonard, PhD
Business Excellence Consulting

October 26, 2010
Pittsburgh, PA

Welcome to Picturesque Pittsburgh

Expert Meeting, October 26, 2010

Who's Here?

- 15 seconds each
  - 45 people x 15 = 675 sec / 60 sec per min = 00:11:15
- Name
- Company
- Area of expertise (10 word or so)
- Challenge, barrier, or issue that caused you to show up here today

Why Quality?

- Higher performance in housing will continue to be more prevalent
- Business constraints on homebuilding companies will only increase
- Builders don't individually have the resources to put the business systems in place
- There is a need for plug and play solutions

Building America Quality Working Group

- NAHB Research Center, IBACOS, Building Science Corp.
- Jointly developed 5 year plan
- Key agreement: For Builders to successfully and profitably implement higher performance homes They need:
  - Better integration of operational areas in company
  - Higher level of quality management to assure the right result and limit risk

QWG Near Term Work Products

- 1.0 Best Practices Handbook: *Quality Management for Design, Construction, and Operation of High Performance Homes.*
  - 1.1 Guideline: *Essential Steps: Quality Management for Design and Construction of High Performance Homes.* (primer; quick start guide)
  - 1.2 Procedure: High Performance Quality Management System: *major section of handbook.*
  - 1.3 Guideline: Effective Teaming (including Trade Partnering) and Communication Protocols.
- 2.0 Guideline: Economic and Non-Economic Benefits of Quality, High Performance Building Practices

QWG Near Term Work Products

- 3.0 Design/Construction Documentation Guidelines/References
  - *3.1 Scopes of Work* –Scopes of work would be a key element of the model contractor packages.
  - *3.2 Guideline* -- Development of Quality, High Performance Design/Construction Documentation: Process and Key Elements. Envision a significant expansion of LEED integrated design process.
  - *3.3 Guideline* -- Development of Quality, High Performance Design/Construction Documentation: Effective Graphic Communication, including Detailing High Performance Enclosures.
  - *3.4 Guideline* -- Selection of Suitable Building Products and Materials, and associated QA/QC processes/requirements.
  - *3.5 Quality/Durability Checklist*: Adapted for Builders Challenge.
  - *3.6 Case Studies*: Field Evaluation of Model Trade Design/Construction Document Packages.
  - *3.7 Builders Challenge Guidelines* – Enhance existing documentation with more detailed QM/Design/Construction Documentation Chapters.

Where Are We Now?

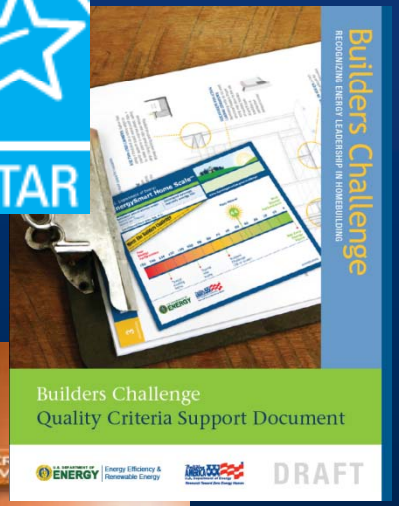
- Technology research
  - 30% savings readily achievable, 40% becoming reality
  - 70% whole house savings on horizon

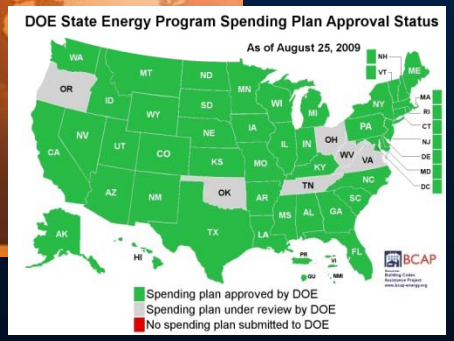
2005 - Ideal Homes builds first "Zero Energy Home" in the U.S. under $200,000

Where Are We Now?

- Operational Excellence & Quality Management is known but not widely utilized
  - Increase productivity: More with same or less
  - Standardize systems and processes
  - Continual improvement
  - Cultural and corporate alignment
  - e.g. Even flow, cycle time, customer satisfaction, return on assets, first time quality, trade relations…

Changes Ahead





- Code push for 30% and 50% savings in 2012 and 2015
- ARRA: 90% Energy Code compliance if accepting funding
- Builders Challenge Quality Criteria
- ENERGY STAR® v.3: Checklists, checklists, checklists
- But….

General Assumption is that Builder Needs "Adult Daycare"

Expert Meeting, October 26, 2010

Execution is Critical

- Increased energy efficiency requires greater attention to detail in design and execution
  - Water management, HVAC design, thermal enclosure, comfort, IAQ

Code

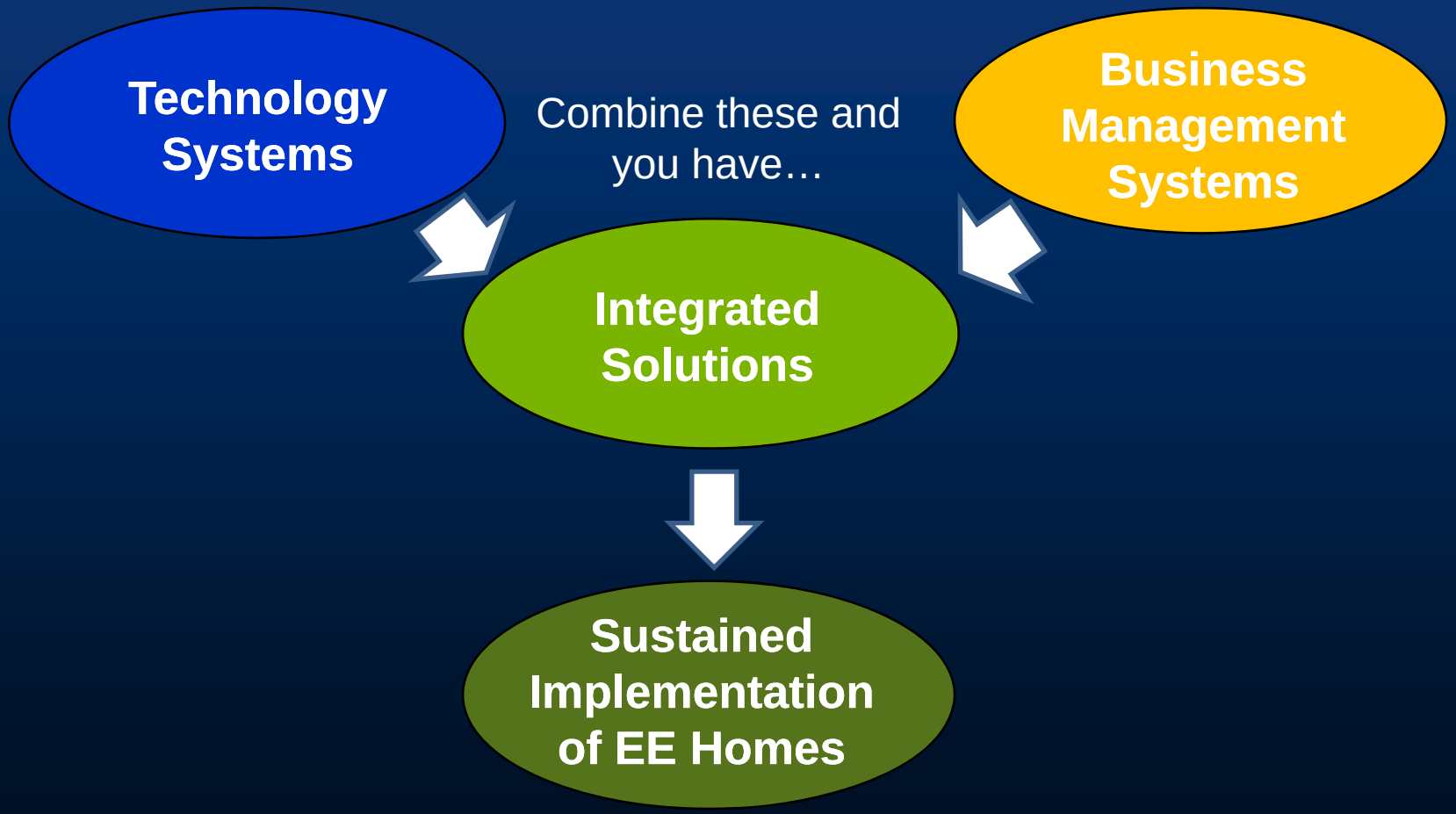
30% - Builders Challenge, ES 2011

50% +

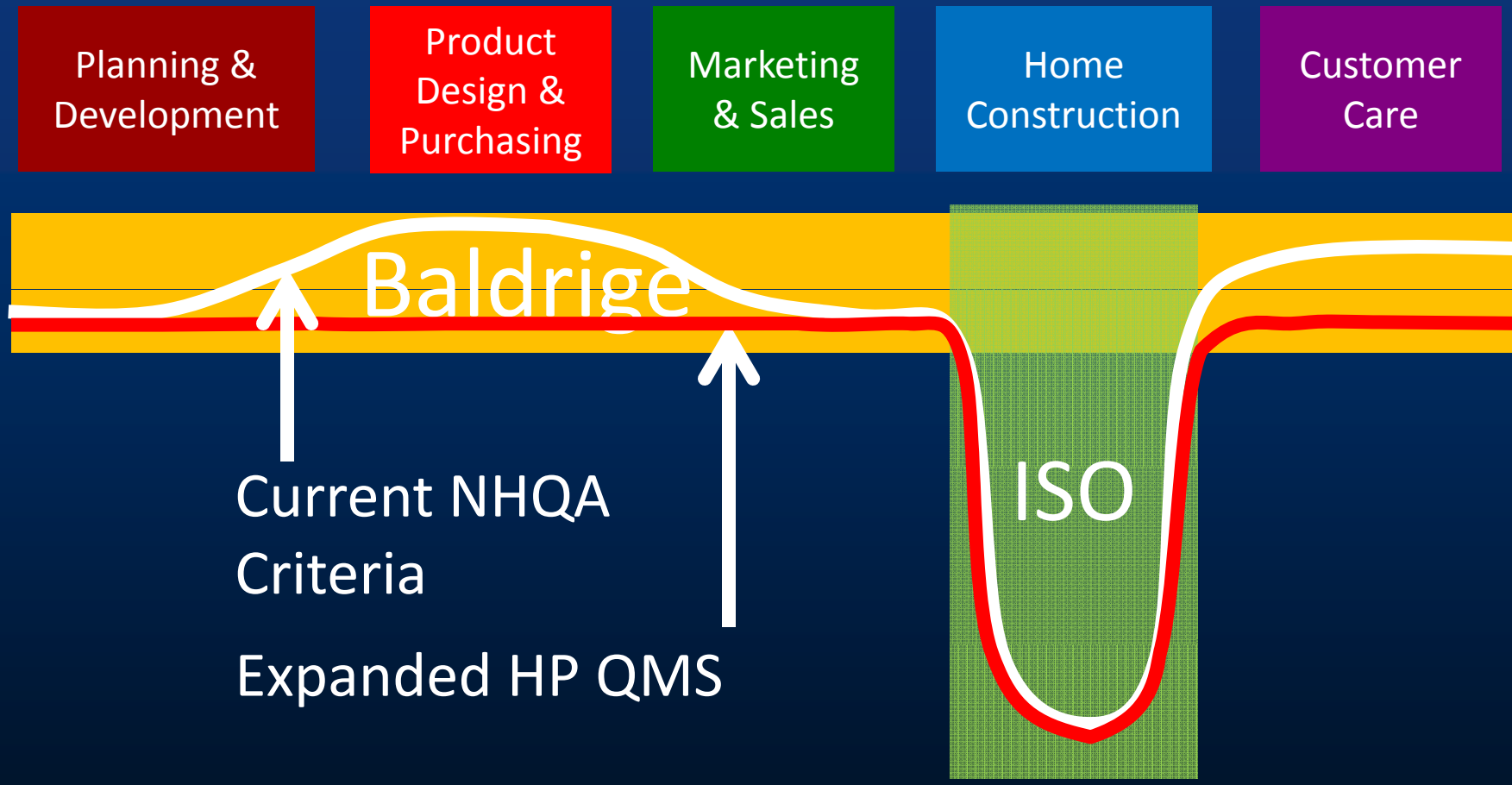
Merging of Energy Efficiency and Quality Management

Part of the solution is…

The other part of the solution is…



Quality Models: ISO vs. Baldrige Criteria



Two Quality Strategies

ENERGY STAR Qualified Homes
National Builder Option Package

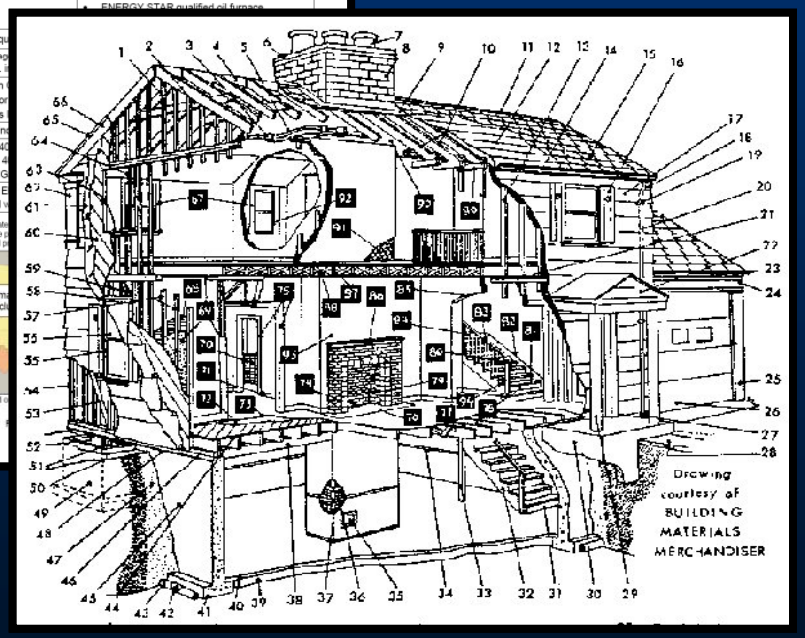
The requirements for the ENERGY STAR Builder Option Package (BOP) are specified in the table below.
To qualify as ENERGY STAR using this BOP, a home must meet the requirements specified, be verified and field-tested in accordance with the HERS Standards by a RESNET-accredited Provider, and meet all applicable codes.

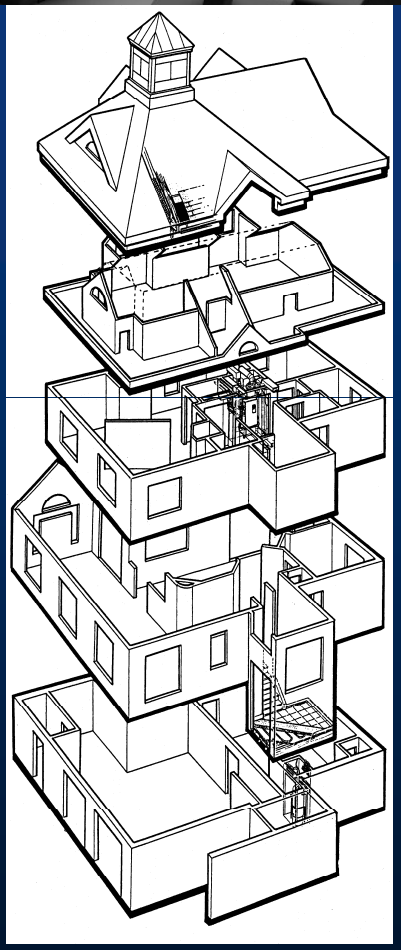
	Hot Climates [1] (2004 IRC Climate Zones 1,2,3)	Mixed and Cold Climates [1] (2004 IRC Climate Zones 4,5,6,7,8)
Cooling Equipment (Where Provided)	Right-Sized [2]: • ENERGY STAR qualified A/C *(14.5 SEER / 12 EER)*; OR • ENERGY STAR qualified heat pump [3] *(14.5 SEER / 12 EER / 8.2 HSPF)*	Right-Sized [2]: • 13 SEER A/C; OR • ENERGY STAR qualified heat pump [3] *(14.5 SEER / 12 EER / 8.5 HSPF)*
Heating Equipment	• 80 AFUE gas furnace; OR • ENERGY STAR qualified heat pump [2,3] *(14.5 SEER / 12 EER / 8.2 HSPF)*; OR • 80 AFUE boiler; OR • 80 AFUE oil furnace	• ENERGY STAR qualified gas furnace *(90 AFUE)*; OR • ENERGY STAR qualified heat pump [2,3] *(See Note 3 for specifications)*; OR • ENERGY STAR qualified boiler *(85 AFUE)*; OR • ENERGY STAR qualified oil furnace
Thermostat [3]	ENERGY STAR qu	
Ductwork	Leakag R-6 min. i	
Envelope	• Infiltration [6,7] (ACH50): 7 in (• Insulation levels that meet or • Completed Thermal Bypass	
Windows	ENERGY STAR qualified win	
Water Heater [13,14]	Gas (EF): 4 Electric (EF): 4 Oil or G	
Lighting and Appliances [16,17]	Five or more E ceiling fans equipped w	

Note: Due to the unique nature of some state codes and/or climate California, Hawaii, and the Pacific Northwest to continue to define p requirements of the national program or the regionally-developed p

Clim (Incl

Map is for illustrative purposes only and is based o





"Spec and Purchase"

"Systems Approach"

IBACOS | Home Quality + Performance |

Best Practices Research Alliance

Expert Meeting, October 26, 2010

Building Company Organization

Planning & Development

Product Design & Purchasing

Marketing & Sales

Home Construction

Customer Care

Systems Approach:
Integration for High Performance & Quality Management

Spec and Purchase

Study of Management System Impact on Builders of High Performance Home

- Total population of 59 NHQA-winning builders
- Studied a sample of 21 (36%)
- Compared analysis of two builder groups
- 14 ENERGY STAR/Green Standard builders
- 7 non-ENERGY STAR/Non-green ‘traditional’ builders
- Builder performance evaluated using NHQA scoring results from in-depth expert desk and site visit reviews
- 19 of the builders in the study had won NHQA Gold, Silver, or Honorable Mention
  - Other two (one in each group) were considered future winners if they reapplied
- Mix of small, medium, and large builders

High Performance &Traditional Builders

- 14 currently ENERGY STAR/Green Standard builders
  - 9 certified to NAHBRC third-party audited QMS
  - 1 had a third-party trade monitoring system
  - 4 had no formal documented QMS
- 7 non-ENERGY STAR/Non-green ‘traditional’ builders
  - 3 were certified to NAHBRC third-party audited QMS
  - 1 had its corporate office certified to ISO9001 third-party audited
  - 2 had no formal documented QMS

Performance Impact

- Organizational size had no impact
- In both high performance (HP) and traditional groups, the lowest performing builders were those that did not have a certified QMS
- Those builders that had a third-party independently audited and certified QMS had the best performance

Those without QMS Certification

- The traditional uncertified builders were weakest in:
  - Construction Quality
  - Trade Relationships
  - Business Results
- The HP uncertified builders were also weaker in those areas BUT had two additional low performing areas:
  - Performance Management
  - Human Resources

Low Performance Areas for HP Uncertified Builders

- The HP uncertified builders were specifically weakest in:
  - Performance Management
    - How you develop, manage, measure, and improve your key processes
  - Human Resources
    - How you support superior work performance
    - How you ensure organizational alignment
  - Construction Quality
    - Education and reinforcement of quality standards
  - Trade Relationships
    - Integration of trades in building a better company
  - Business Results
    - Business operating results
    - Employee satisfaction and turnover rates
    - Supplier and trade satisfaction

Weaknesses can be Resolved thorough the Strengths of QMS

- This study shows that the use of a certified QMS will improve business performance and make HP homebuilding easier, since the focus of a certified QMS is the following:
  - Process Management
  - Work Performance
  - Organizational Alignment
  - Reinforcement of Quality Standards
  - Integration of Trades
  - Measures and Metrics

Additional Market Scan

- Looked at builders associated with Building America, NHQA, EVHA, Builders Challenge, ENERGY STAR, Professional Builder Magazine Builders of the Year, Hanley Wood Best Builder
- Management systems help structure, define, and coordinate standards and processes , especially in design, construction, and with trade partners
- Drive the efficiency and effectiveness of design and construction
- Easier to implement changes in product or processes

Results: Key Attributes of HP Builders

1. Cultural and corporate alignment
2. Clear intent for quality and performance
3. Whole house integrated design and specification
4. Measurement and verification of performance
5. Better communication practices and systems
6. Increased collaboration across internal and external teams
7. Disciplined approach to quality control
8. Continuous feedback and improvement

Relationship Between Key Attribute To Functional Areas

	Planning & Development	Product Design & Purchasing	Marketing & Sales	Home Construction	Customer Care
1. Culture					
2. Intent					
3. Integrated Design					
4. Measurement					
5. Communication					
6. Team Collaboration					
7. Quality Control					
8. Cont. Improvement					

Barriers to High Performing Homes that Quality Management Can Help Overcome

- Don’t know where to start
- Inability to change organizational culture
- Improper planning
- Lack of continuous training
- Incompatible organizational infrastructure
- Isolated/Silo departments

Research Questions

- What are some “systems approach” models of Quality Management?
- How does a builder get from where it is to one of those models?
- What do builders need to accelerate the change?
- What does it take to make the change ($$$, effort, manpower)?
- What are the financial and business benefits, and how can those be measured?

IBACOS 2010 Research Activities

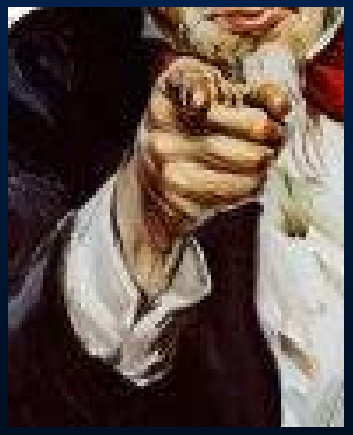
1. Characterization of best-in-class practices from NAHBRC Quality Certified Builders, NHQ award applicants and winners, and others
2. Lead development of standardized business metrics
3. Coordinate collection of BMS data from existing BA Teams, Builders Challenge builders, or BA research builders
4. Lead development of model characteristics for companies with a systems approach
5. Develop strategies for adoption of systems approach QMS – Pathways to Quality and Higher Performance Housing
6. Expert Meeting: “Quality Management Tools & Integration” October 26, Pittsburgh, PA

Are We on Track?

Expert Meeting, October 26, 2010

Meeting Agenda

- This Morning
  - Presentation and Discussion of QEHS Manual Requirements
  - Presentation and Discussion of FAQs
- Lunch
  - Presentation and Discussion of FAQs (cont.)
  - Metrics / Pathways
- What We Want from You
  - Open and Honest Critique
  - Your Best Ideas & Practices
  - Your Biggest Challenges
  - Additional Areas of Need



Appendix B: Quality Working Group Near Term Work Products

1.0 Best Practices Handbook: *Quality Management for Design, Construction, and Operation of High Performance Homes.*

The electronic handbook will summarize (or incorporate) and reference (link to) the following more comprehensive documents. The documents listed below would also be stand alone documents. Supporting the development of these and other products, a number of research activities and studies will be conducted. Many of the guidelines listed here are aimed at both the professional and university construction management field.

1.1 Guideline: *Essential Steps: Quality Management for Design and Construction of High Performance Homes.* (primer; quick start guide)

1.2 Procedure: High Performance Quality Management System: *major section of handbook.*

1.3 Guideline: Effective Teaming (including Trade Partnering) and Communication Protocols.

2.0 Guideline: Economic and Non-Economic Benefits of Quality, High Performance Building Practices (including equations, sample problems, key parameters, etc.).

3.0 Design/Construction Documentation Guidelines/References

3.1 Scopes of Work –Scopes of work would be a key element of the model contractor packages.

3.2 Guideline -- Development of Quality, High Performance Design/Construction Documentation: Process and Key Elements. Envision a significant expansion of LEED integrated design process.

3.3 Guideline -- Development of Quality, High Performance Design/Construction Documentation: Effective Graphic Communication, including Detailing High Performance Enclosures.

3.4 Guideline -- Selection of Suitable Building Products and Materials, and associated QA/QC processes/requirements.

3.5 Quality/Durability Checklist: Adapted for Builders Challenge.

3.6 Case Studies: Field Evaluation of Model Trade Design/Construction Document Packages.

3.7 Builders Challenge Guidelines – Enhance existing documentation with more detailed QM/Design/Construction Documentation Chapters.

Training Materials: A longer term set of products will support trade and builder training, including quality, high performance construction management curricula, “hot spot training”, high performance construction best practices, etc. These products would be validated and revised through a pilot training program. Performer: QM WG [Training materials and training will be for builders, trades, and universities.]

Appendix C: Quality, Environmental, Health and Safety Manual Requirements Presentation

QEHS Manual Requirements

Denis Leonard. PhD
Business Excellence Consulting

October 26, 2010

Pittsburgh, PA

QEHS Integrated Management System

- Integrated Management System based on an integration of the principles and content from:
  - NAHB Research Center's NHQ Quality Management System Requirements for Builders
  - ISO9001
  - ISO14001
  - OHSAS18001
  - The Malcolm Baldrige National Quality Award (MBNQA) Criteria for Performance Excellence
  - The National Housing Quality Award

Quality Management Systems

Expert Meeting, October 26, 2010

Quality Management System

- ISO9001:2008
  - Quality Management System (QMS)
  - Focus on Process
  - Continuous Improvement
  - Corrective and Preventive Action

Safety Management System

- OHSAS18001:2007
  - Safety Management System
  - Focus on safety standards
  - Zero accidents
  - Continuous Improvement

Environmental Management System

- ISO14001:2004
  - Environmental Management System (EMS)
  - Focus on Environmental Issues
  - Continuous Improvement

Integrating Management Programs

Department	Quality (ISO 9001)	Safety (OSHA14001)	Environmental (ISO 18001)	Integrated
Home Construction	X			X
Marketing & Sales	X			X
Home Construction		X		X
Customer Care	X			X
Home Construction			X	X

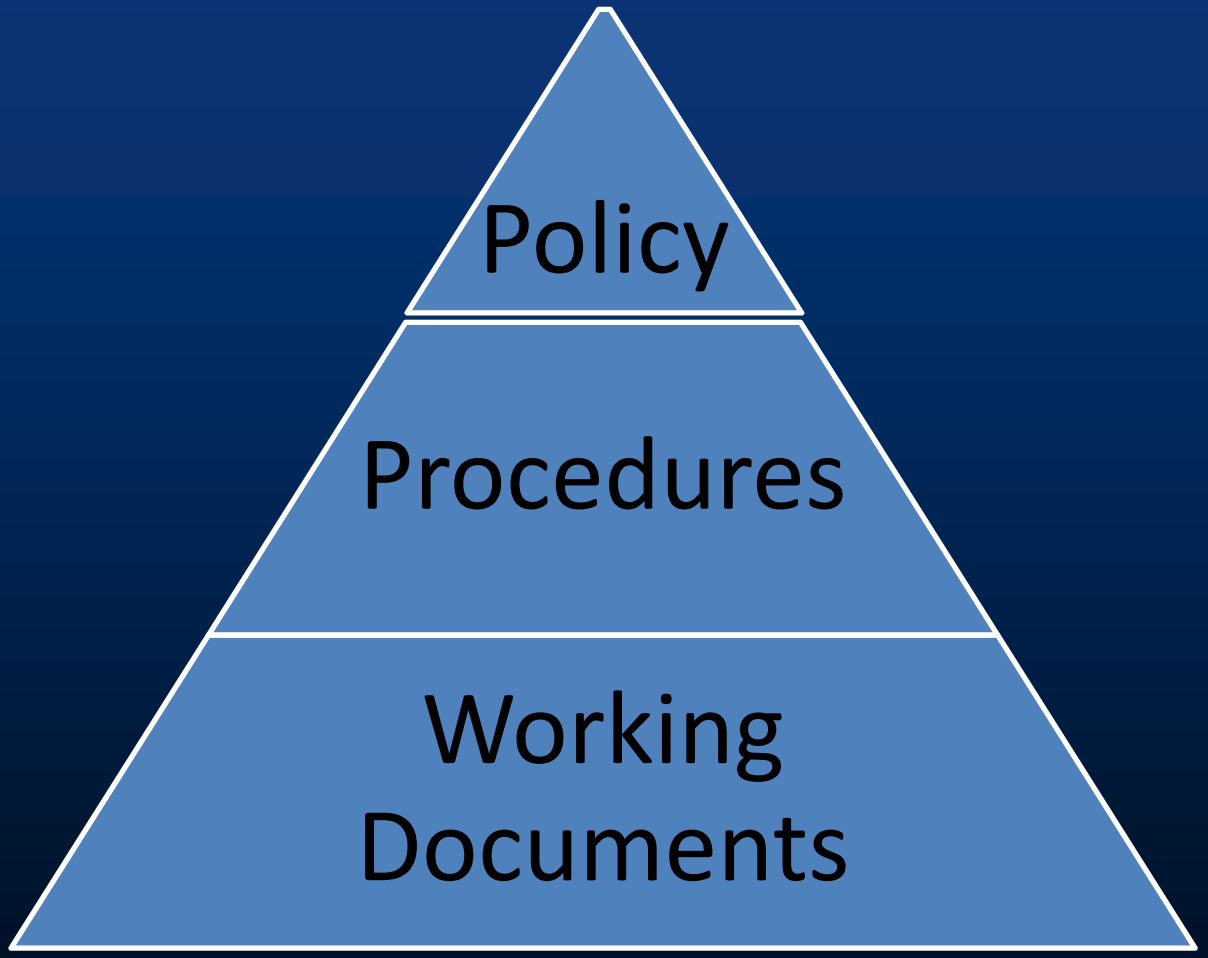
Benefits of an Integrated Management Systems QEHS

- Avoid Replication
  - Merge Audits (Quality/Safety/Environmental)
  - Saves Costs and Time
  - Involves everyone, achieving alignment of goals/objectives/practices and performance

Principles of ISO Standards & Quality Awards

- Principles
- Customer Focus
- Leadership
- Involvement of People
- Process Approach
- System Approach to Management
- Continual Improvement
- Factual Approach to Decision Making
- Mutually Beneficial Supplier Relationships

Conceptual ISO Structure



QEHS Requirements Details

- 1.0 General
- 2.0 QEHS System Management
- 3.0 Land Development
- 4.0 Sales
- 5.0 Design
- 6.0 Purchasing
- 7.0 Estimating
- 8.0 Construction
- 9.0 Customer Relations & Warranty
- 10.0 Additional Functional Areas

1.0 General

- Scope
- Leadership
- QEHS Statement
- QEHS Manual
- QEHS Responsibilities
- Organizational Chart
- Personnel
- Training
- Communications
- Customer Feedback
- Performance Measures
- Process Flow

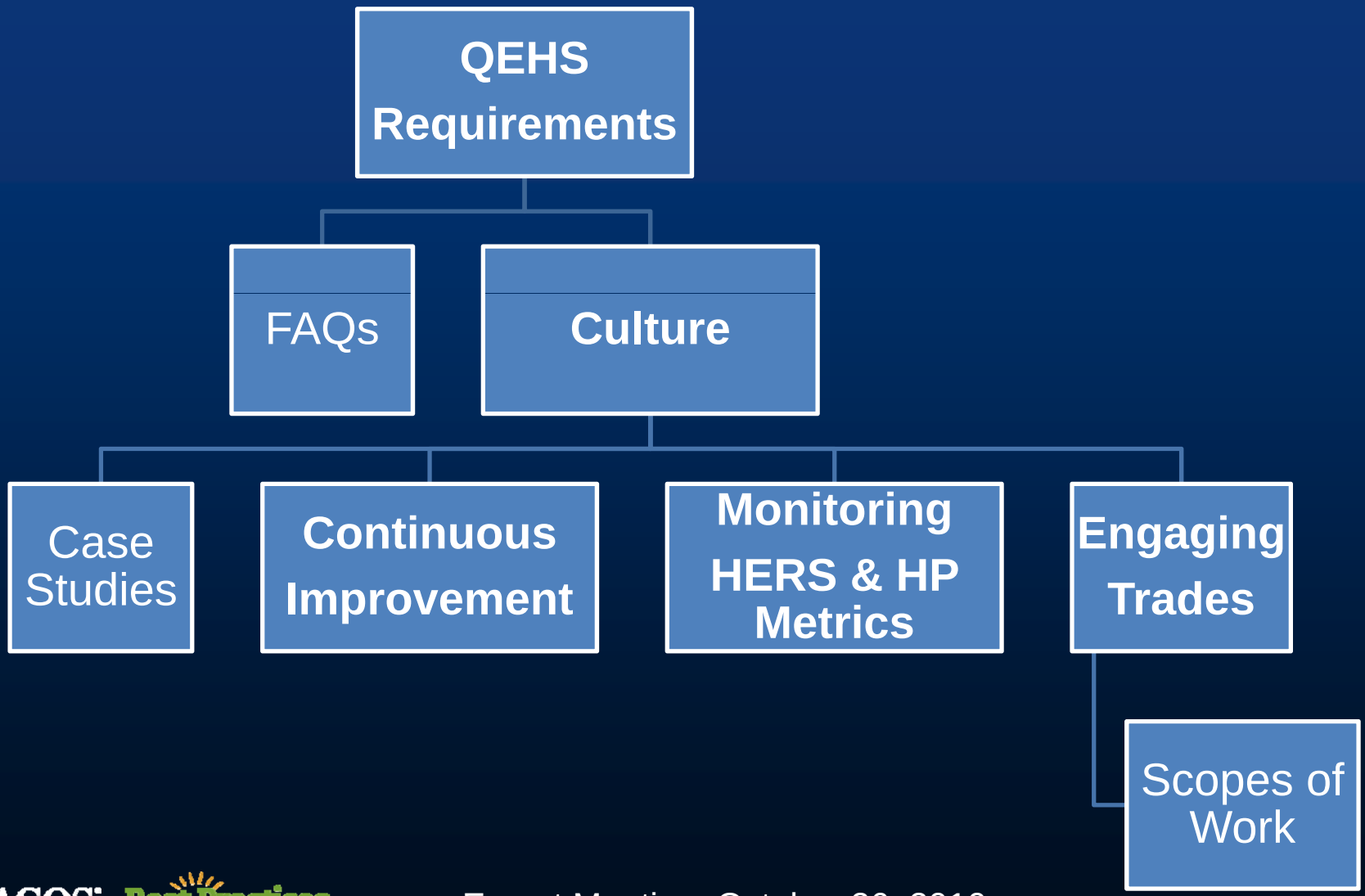
2.0 QEHS Management

- QEHS Committee
- Audits
- Annual review
- QEHS System Changes
- Document Control
- Record Keeping
- Update of Reference Documents

General Operations Sections (3 – 10)

- Policies & Procedures
- Operations and Inspections
- Continual Improvement

Tip of the Iceberg



QEHS Discussion

- Is the general structure of the document useful? What would you change?
  - Do we have the right Departments
  - Streamline to reduce redundancy?
  - Keep as is to enable departments to focus on each area?
  - Require operational integration of functions and departments?
- Should there be more “help” within the document?
  - Include FAQ’s or cross reference in the document?
  - Develop Example for a “Case Study” builder?
- Problems you encountered developing a Quality Manual and System that could be addressed in this document?

Appendix D: Quality, Environmental, Health and Safety Manual Requirements

Quality Management for High Performance Homes

DRAFT Quality, Environmental, Health & Safety (QEHS) Management System Requirements v.1

Prepared by:
Duncan Prahl

In collaboration with:
Denis Leonard, Business Excellence Consulting
NAHB Research Center

October 26, 2010

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INTRODUCTION

This set of integrated Quality, Environmental, Health and Safety (QEHS) Management System Requirements has been developed as a proposed restructuring of the NAHB Research Center's National Housing Quality: Quality Management System Requirements for Builders 6/10/08© to include elements of the following:

- ISO9001:2008
- ISO14001:2004
- OHSAS18001:2007
- The Malcolm Baldrige National Quality Award (MBNQA) Criteria for Performance Excellence 2009-2010
- The National Housing Quality Award 2010
- The IBACOS Green BluePrint
- Concepts from Six Sigma as well as concepts from other QEHS tools and approaches.

This QEHS Management System Requirements draws heavily from the NAHB Research Center's National Housing Quality: Quality Management System Requirements for Builders, and if implemented it is anticipated that a builder could receive NHQ Certification.

In this document, wherever QEHS is used it refers to the Quality, Environmental, Health and Safety aspects of the organization's processes. Environmental refers to complying with environmental regulations, reducing environmental impacts as a result of operations, and all the aspects involved in building energy efficient, safe, durable, comfortable, high performing homes. The intent of these requirements is to define the major elements of a practical, effective, and integrated Quality, Environmental, Health and Safety Management System to help home builders achieve superior operational results while efficiently and effectively building high performance homes.

This QEHS works at the tactical level of an organization, below the strategic level helping to manage and coordinate the daily running of the business and each department. The QEHS refers to other documents and operational tools such as checklists that are used in the field each day, to attain the specifications set for the houses to be built. See chart below.

These requirements also fit with the 8 principles of ISO9000:2008 and are developed to align with the philosophies and objectives of most QEHS award programs including the National Housing Quality Award.

- ISO9000:2008 Principles:
  - Customer Focus
  - Leadership
  - Involvement of People
  - Process Approach
  - System Approach to Management
  - Continual Improvement
  - Factual Approach to Decision Making
  - Mutually Beneficial Supplier Relationships

This manual of requirements is organized as follows:

1. General – Describes general organizational information about the company.
2. QEHS Management System Management – Describes how the QEHS management system is controlled and updated within the company.
3. Land Development Operations – Describes the QEHS Policies and Procedures, Ongoing review of the QEHS, and Continual Improvement for the Land Development department of the company
4. Sales Operations - Describes the QEHS Policies and Procedures, Ongoing review of the QEHS, and Continual Improvement for the Sales department of the company.
5. Design Operations - Describes the QEHS Policies and Procedures, Ongoing review of the QEHS, and Continual Improvement for the Design department of the company.
6. Purchasing Operations - Describes the QEHS Policies and Procedures, Ongoing review of the QEHS, and Continual Improvement for the Purchasing (Trade Partner master contract level) department of the company.
7. Estimating Operations - Describes the QEHS Policies and Procedures, Ongoing review of the QEHS, and Continual Improvement for the Estimating (house by house level) department of the company.
8. Construction Operations - Describes the QEHS Policies and Procedures, Ongoing review of the QEHS, and Continual Improvement for the Construction department of the company.
9. Customer Relations Warranty and Service Operations - Describes the QEHS Policies and Procedures, Ongoing review of the QEHS, and Continual Improvement for the Warranty and Service department of the company.
10. Additional Functional Areas - Describes the QEHS Policies and Procedures, Ongoing review of the QEHS, and Continual Improvement for the other functional areas of the company.

These requirements have been broken down into these functional areas, however if a company chooses to combine functions (for example, Design and Purchasing, or Purchasing and Estimating, or Warranty and Service Operations is part of Construction Operations) then these sections can be combined. Sections should also be deleted if they are not applicable to a company (i.e. a company does not undertake Land Development).

It must be emphasized that this document sets forth the requirements that should be integrated into a QEHS Management System Manual. It does not include the actual operational policies and procedures. This document spells out the requirements that the system should include if a builder chooses to get certified (i.e. NAHB Research Center NHQ Certification, ISO certification, etc.) or decides to apply for a quality award such as the Malcolm Baldrige National Quality Award or the National Housing Quality Award.

Quality, Environmental, Health & Safety (QEHS) Management System Requirements

1.0 GENERAL

1.1 Scope

The QEHS manual shall define the scope of the housing products and services provided by the builder and the geographic region served by the company.

1.2 Leadership

Senior management shall provide demonstrated leadership to the company's QEHS, environmental, health and safety (QEHS) initiatives. This shall include setting policy and performance expectations, communicating to the organization the importance of QEHS, the environment, safety and meeting customer expectations, providing resources, and
reviewing the effectiveness of the Management System. A fundamental aim of leadership is the full integration of QEHS which inherently includes a focus on integrated design approaches, and applying integrated problem solving, implementation and measurement systems.

1.3 QEHS, Environmental And Safety Statement

There shall be written statement(s) by senior management that describe(s) the company's commitment to QEHS, the environment and safety that also addresses customer's expectations. This should have a direct link to the company vision and mission statement. The statement(s) will commit the entire organization to continuous improvement, achieving measurable business performance metrics, and a safe workplace and shall be communicated to all stakeholders, customers, suppliers, trade partners, and employees.

1.4 QEHS Manual

The company shall develop, document, and maintain a controlled, QEHS Management System that promotes continual improvement. The QEHS Management System shall be defined in a manual. The system shall define or reference the company's policies, processes, procedures, and documents that assure that customer expectations and company standards are met. The company shall provide ready access to the most current versions of the pertinent QEHS Management System documents to those personnel needing them. The QEHS Management System will include the functional areas of land development, sales, design, estimating, purchasing, construction and customer relations/warranty.

1.5 QEHS Responsibilities

QEHS responsibilities shall be established for all employees including accountability for adhering to QEHS Management System policies and procedures. The QEHS Management System manual shall outline the major responsibilities of the senior manager responsible for the
company-wide QEHS Management System. Each operating area or functional area included in the QEHS Management System of the company shall have a designated representative with responsibility for managing the QEHS Management System in their area. Management responsibilities shall include

ensuring that all employees have an awareness of the QEHS Management System and the QEHS commitment, are following those portions of the system appropriate to their job, and understand the importance of the system.

1.6 Organization Chart

There shall be a company organization chart showing position titles and names and reporting relationships of all functional positions. The senior manager(s) responsible for QEHS, Environment and Safety shall be identified on the organization chart.

1.7 Competent Personnel

Personnel in each functional area shall be qualified and competent to fill assigned positions. Each functional area shall develop and maintain job descriptions that define the responsibilities and qualification requirements of all positions key to meeting customer expectations and/or the QEHS of the "as built" house and the safety of the jobsite operations. At least one employee who is generally available at the job site shall have completed an approved OSHA 10-Hour Construction Industry Outreach Training.

1.8 Training

A program of training for all personnel involved in meeting new homebuyer expectations shall be implemented. This training shall address new employee orientation/training, functional area orientation/training, and training in the technical requirements of the positions, and operation of the company's QEHS Management System. Training will also include a focus on basic principles of quality management, tools and techniques.

1.9 Corporate Communications

Procedures shall be implemented to assure communication exists between all areas of the company and the trade partners of the company. This includes identification of and communication to other functional areas to address recurring non-conformances in QEHS. There shall be procedures implemented to communicate with new home buying customers and to manage their expectations.

1.10 Customer Feedback

The company shall establish and implement procedures to evaluate customer satisfaction with the company's work. This assessment shall be conducted at least annually and shall identify overall satisfaction as well as satisfaction with the functional areas of the company that come in contact with the new home buying customer. This will include move in and one year customer satisfaction scores. These customer satisfaction scores will be shared with all builder employees. The results of this assessment shall be considered in analyzing the effectiveness of the QEHS Management System and initiating changes to the system. These procedures shall be documented and records kept of the customer feedback.

1.11 Performance Measures

The company shall establish performance measures and goals that are indicative of the effectiveness of the QEHS Management System. These shall be defined, documented, and quantified for each functional

area covered by the company's QEHS Management System. Progress towards meeting these goals shall be documented and reported quarterly to the management of the various functional areas.

1.12 Company Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the overall company and their relationships to each other. Each sequence shall include all major planning, work, and QEHS assurance activities. Flowcharts are recommended where possible to assist with articulating the sequence.

2.0 QEHS MANAGEMENT SYSTEM MANAGEMENT

2.1 QEHS Management Committee

A QEHS management committee shall be established and at a minimum shall consist of the QEHS Manager/coordinator, a representative for each functional area, and a senior management representative. This committee shall meet periodically to review the regular operation of the QEHS Management System, review the results of any internal audits and discuss opportunities for improvement. Minutes of the committee meetings shall be documented.

2.2 Internal Audits

The company shall conduct internal audits at periodic intervals to assess effectiveness of the QEHS Management System. The company QEHS management committee, or similar group, shall provide the oversight of planning, conducting, and reporting results of internal audits of the departments covered under the QEHS Management System to assure that the policies and procedures are being met. The auditor shall be trained and independent of the functional area
being audited. Results of these audits shall be documented. Deficiencies in the operation of the QEHS Management System will be identified and actions to correct any nonconformance shall be taken in a timely manner and further documented. Frequency and scope of internal audits shall be sufficient to assure the effectiveness of the QEHS Management System, but shall be conducted at least twice each year.

2.3 Annual Management Review

At least annually the QEHS management committee shall review the operation and effectiveness of their respective systems with the senior management of the company. This annual review shall include a summary of the internal and external audits of the activities of each functional area of the company, performance measures, customer feedback, trade partner and supplier feedback, complaints, and recommendations from the QEHS department representatives. The annual review shall also include assuring compliance with these requirements, setting new annual goals, and addressing needed changes to the management system. Records shall be maintained for each review. The records shall be in sufficient detail to disclose the participants; significant issues; conclusions; recommendations; and planned changes. The aim is to ensure that the QEHS Management System is working to the satisfaction of the leadership and management of the organization, the annual review is the opportunity to make significant changes to make the QEHS Management System and it functioning more effective and efficient.

2.4 Certification

If the builder wishes to gain and sustain Certification of the QEHS management System, then the QEHS Management System shall be evaluated by and approved auditor of the certifying body to assess compliance with its requirements. This evaluation shall occur in accordance with the audit guidelines of the certifying body to verify the continuous effective operation of the QEHS Management System.

2.5 QEHS Management System Changes

The company shall have a documented procedure for approving and incorporating changes and improvements to the QEHS Management System. Individual functional area QEHS Management System changes must be approved and integrated into the overall company QEHS Management System.

2.6 Document Control

The company shall document the procedure for updating and controlling the QEHS Management System documents to assure they are current. The company shall have procedures for assuring that obsolete documents cannot be used. These documents include the QEHS manual, reference documents, and supporting procedures.

2.7 Record Keeping

The company shall establish and document a procedure to define the controls for the retention of records and shall specify which records shall be kept and for how long. Further, it shall specify how records are disposed of once they have matured beyond the retention period. Records shall be maintained at least for a period of time consistent with the state's statute of repose.

2.8 Update Of Referenced Documents

The company shall provide a procedure that assures applicable codes; regulations; industry standards; company standards; or manufacturer's instructions are reviewed for changes, and the references for each in the QEHS program are updated annually at a minimum. The company shall effectively communicate any changes to key personnel and appropriate trade partners. Any such changes are to be incorporated into the builder's QEHS Management System, as needed.

3.0 LAND DEVELOPMENT OPERATIONS

3.1 Land Development Operations QEHS Policies And Procedures

3.1.1 Scope of the Land Development Operations

The Land Development operation shall define the scope of its operations including, whether this is a separate department from Construction Operations. The scope of operations shall also define what conditions must be met to affect "turnover" of developed lots to Construction Operations.

3.1.2 Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the Land Development Operation of the company. This sequence shall include all major work with agencies, local government as well as interactions with other company departments including construction. The process shall include all necessary checkpoints to assure the finished lots meet the requirements of Construction Operations.

3.1.3 Codes and Regulations

Procedures shall be implemented to assure that all applicable codes, and governmental regulations are identified and complied with. The company shall have access to all applicable codes.

3.1.4 Company Standards

Company standards shall be documented to define the requirements for workmanship, including tolerance requirements, industry standards, construction procedures, and material specifications. These company standards shall be included in scopes of work or other agreed upon document(s). When a conflict exists between local practice and other requirements (e.g., industry standards, manufacturer's instructions, etc.), there shall be a procedure for allowing exceptions while maintaining QEHS. There shall be a procedure to require that all equipment used in the construction process requiring calibration is properly calibrated and maintained.

3.1.5 Manufacturer's Product Installation Instructions

The Land Development Operation shall develop, document, and implement procedures for obtaining and maintaining current copies of all installation/application instructions. Land Development Operations shall ensure that all products are properly installed.

3.1.6 Trade Partner and Supplier Contract Documents and Scopes of Work

Procedures shall be implemented to prepare and review the subcontracts and construction documents specific to the work of each trade utilized by the Land Development Operation to assure that builder requirements and typical home buyer expectations will be met. Trade contracts, scopes of work, or other documents shall include mutually agreed upon job ready conditions and procedures to follow when these conditions are not met. Trade contracts shall also include provisions requiring the trade partner to comply with all environmental and safety regulations and provide their accident prevention plan to the company. Trade partners shall be required to periodically report to builder management on non-compliance of job ready conditions at the builder's various communities.

3.1.7 Land Development Documents

Procedures shall be implemented to review all Land Development documents to assure that the expectations of the agencies, Design Operations and Construction Operations are appropriately defined and managed. These procedures shall assure that these documents and materials are confirmed to be correct at least annually.

3.1.8 Land Development Operation Policy

Procedures shall be developed, documented, and implemented for: soliciting and managing all aspects of Land Development operations and the company's QEHS commitment. This includes negotiating and completing Land Development contracts; defining the approval authority for the various Land Development decisions; confirming any agreements reached; communicating the company's job site safety procedures to the excavation and other relevant trades. The Land Development operation shall maintain current copies of these procedures. These procedures shall be reviewed at least annually and updated as needed.

3.1.9 Scheduling

Procedures shall be established for determining and communicating all schedules and any schedule changes between the agencies, Construction Operations and trades.

3.1.10 Approval and Selection of Trade Partners, Materials, and Other Support Services

Procedures shall be established and implemented for review, approval, selection, and monitoring of:

3.1.10.1 Trade partners;
3.1.10.2 Materials and suppliers; and
3.1.10.3 other support services.

These procedures shall include a review of QEHS performance, warranty history, and their safety record. An approved vendor list shall be maintained of all suppliers, trade partners and support services. This list shall be reviewed at least annually.

3.1.11 Version Control

Procedures shall be established and implemented to assure that the current version of Land Development contracts, warranty documents, and other materials are utilized in the Land Development operation. When more than one version of the company's Land Development documents exists, all Land Development personnel shall understand the proper use of those different versions of the documents.

3.1.12 Confirmation of Land Development Process Completion

There shall be a procedure that secures confirmation that each step in the Land Development process has been completed. This procedure shall address when and under what conditions new information or action is required by Land Development and Construction.

3.2 Land Development Operations QEHS Review

3.2.1 Final Document Review

The Land Development operation shall develop and implement a document review procedure prior to filing a completed Land Development contract or plat. Any non-conformances to the Land Development policy and procedures shall be recorded. Corrections shall be completed and documented in accordance with the Land Development completion policy.

3.2.2 Corrective Preventive Action

Errors or deviations from the Land Development process shall be corrected in a timely fashion and in such a way as to assure the QEHS of the completed work. These deviations and their correction shall be documented. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated.

3.2.3 Inspections

Various inspections will be conducted by Land Development Operations to ensure construction activities comply with codes, regulations, scopes of work, manufacturer's instructions, and company standards. Consistent with the builder's experience with each trade partner, the frequency and detail of these inspections shall be sufficient to ensure compliance. Construction operations will develop checklists and/or other documentation for recording the inspection results. The inspection criteria shall be consistent with the company standards and scopes of work. Items requiring corrections shall be recorded, corrected, and their status documented. The Land Development Operation shall take steps to ensure any item requiring correction is not covered up before the correction is completed and documented. The QEHS Management System shall document the inspection process, including who performs the inspection; what is inspected; when and where it is inspected; and the process for recording and storing inspection documentation. The personnel conducting inspections will be trained in the inspection and documentation process.

3.2.4 Job Ready Inspection

The Land Development Operations shall ensure the worksite is prepared for the work of the next trade to begin via an inspection consistent with agreed upon job ready requirements. If a trade or support service firm is required to begin work when the job ready conditions are not met, the Land Development Operations will ensure that the proper procedure is followed. Deviations from the job ready conditions shall be recorded on the job ready inspection record.

3.2.5 In-Process Inspections

Activities and work done in the Land Development Operation shall have in-process inspections to assure that the builder's QEHS policy and procedures are being followed. These inspections shall be documented. Items requiring correction shall be documented, corrected, and confirmed prior to the covering or concealment of any trade's completed work. The inspection criteria shall be consistent with the company standards and scopes of work.

(Note: If an NHQ Certified trade contractor provides the builder with a copy of their inspection reports, this will satisfy this requirement for work of that trade provided the builder maintains a copy of this inspection document and periodically verifies the accuracy of the trade contractor's inspection.)

3.2.4 Final Inspection

Each completed house shall have a final inspection. Any non-conformance(s) to the builder's documented standards for completed work shall be recorded. Corrections shall be completed and documented.

3.2.5 Inspection Records

Records shall be maintained of all code compliance, third-party inspections, company QEHS inspections, and the correction of noted non-conformances.

3.2.6 Review Records

The Land Development Operation shall document internal reviews of Land Development contracts in progress and completed Land Development. Records shall be maintained of all Land Development process reviews.

3.3 Land Development Operations Continual Improvement

3.3.1 Preventive Actions

The Land Development Operation shall define and implement on-going actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. When appropriate these actions shall include recommendations of changes in Land Development procedures or documents. The effectiveness of the corrective actions shall be evaluated. When identified QEHS issues have not been eliminated, the plan shall be reassessed and additional appropriate actions initiated.

3.3.2 Land Development Operations Training

A program of training for all employees involved in Land Development shall be implemented. This training shall include identified opportunities for improvement that leads to continual improvement on department specific metrics and reducing recurring issues in the Land Development operation. This training shall also include both task specific skills and training in the operation of the company's QEHS Management System. Suggestions for and coordination of the training subjects from other operational areas in the company may be utilized to meet some of the requirements of this section. Land Development operations staff will be trained on the use of approved documents and procedures for assuring a complete and accurate Land Development documentation process that meets the expectations of the new home buying customer. Land Development personnel shall be trained on any different versions of the company's Land Development documents and when those different versions apply. Land Development personnel shall be trained on applicable industry practices and safety regulations.

4.0 SALES OPERATIONS

4.1 Sales Operations QEHS Policies And Procedures

4.1.1 Scope of the Sales Operations

The sales operation shall define the scope of its operations including, whether employees or independent realtors typically perform new home sales functions, when the handover occurs from Sales Operations, Construction Operations , or to the Warranty and Service Operation and also define the customer selections and options process.

4.1.2 Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the sales operation of the company. This sequence shall include all major outreach, advertising, and external communications needed to develop sales traffic; sales personnel approach to potential home buyers; writing, processing, and approving sales contracts; customer selections, options, and change orders; clearing contingencies, including financing; and communicating details of the new home to the construction operation. The process shall include all necessary QEHS checkpoints to assure a satisfied new home buyer.

4.1.3 Sales Documents

Procedures shall be implemented to review all sales documents and marketing materials documents to assure that the expectations of the new home buyer customers are appropriately defined and managed. These procedures shall assure that these documents and materials are confirmed to be correct at least annually.

4.1.4 Sales Operation Policy

Procedures shall be developed, documented, and implemented for: soliciting and managing sales inquiries; communicating the company's sales offerings and the company's QEHS commitment to the new prospect or new home buyer; negotiating and completing sales contracts; defining the approval authority for the various sales decisions; confirming any agreements reached with new home purchasers; communicating the company's job site safety procedures to the customer; obtaining customer concurrence at prescribed points in the new home construction process; tracking the sales process through contract, selections, contingency removal, home completion, and new home closing; determining the level of prospective customer satisfaction with the marketing and sales process; determining the level of new home buyer satisfaction with the marketing and sales operation; and identifying future steps to improve the marketing and sales process. The sales operation shall maintain current copies of these procedures. These procedures shall be reviewed at least annually and updated as needed to improve customer satisfaction with the sales and marketing process.

4.1.5 Scheduling

Procedures shall be established for determining and communicating all schedules and any schedule changes between the Construction Operation and new home buyer customers.

4.1.6 Version Control

Procedures shall be established and implemented to assure that the current version of sales contracts, warranty documents, and marketing materials are utilized in the sales operation. When more than one version of the company's sales or marketing documents exists, all sales personnel shall understand the proper use of those different versions of the documents. Procedures shall be established to ensure that the most current documents (including options, selections,
and change orders) relating to the sale of a specific house are the actual documents available to, and referenced by all employees and trade partners.

4.1.7 Confirmation of Sales Process Completion

There shall be a procedure that secures the home owners confirmation that each step in the sales process has been completed. This procedure shall address when and under what conditions new information or action is required by either the new home buyer customer or any company personnel.

4.2 Sales Operations QEHS Review

4.2.1 Final Document Review

The sales operation shall develop and implement a document review procedure prior to filing a completed sales contract or a completed new home purchase. Any non-conformances to the sales policy and procedures shall be recorded. Corrections shall be completed and documented in accordance with the sales completion policy.

4.2.2 Corrective Preventive Action

Errors or deviations from the sales and marketing process shall be corrected in a timely fashion and in such a way as to assure the QEHS of the completed work and the satisfaction of the new home buyer customer. These deviations and their correction shall be documented. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated.

4.2.3 Review Records

The sales operation shall document internal reviews of sales contracts in progress and completed sales. Records shall be maintained of all sales process reviews.

4.3 Sales Operations Continual Improvement

4.3.1 Preventive Actions

The sales operation shall define and implement on-going actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. When appropriate these actions shall include recommendations of changes in sales and marketing procedures or documents. The effectiveness of the corrective actions shall be evaluated. When identified QEHS issues have not been eliminated, the plan shall be reassessed and additional appropriate actions initiated.

4.3.2 Sales Operations Training

A program of training for all Sales Operations employees and independent realtors involved in meeting new homebuyer sales and marketing expectations shall be implemented. This training shall include identified opportunities for improvement that leads to continual improvement on department specific metrics and reducing recurring issues in the Sales Operation. This training shall also include both task specific skills and training in the operation of the company's QEHS Management System. Suggestions for and coordination of the training subjects from the other operational areas of the company may be utilized to meet some of the requirements of this section. Sales Operations staff will be trained on the use of approved documents and procedures for assuring a complete and accurate sales documentation process that meets the expectations of the new home buying customer. Sales personnel shall be trained on any different versions of the company's sales documents and when those different versions apply. Sales personnel shall be trained on applicable industry practices and safety regulations.

5.0 DESIGN OPERATIONS

5.1 Design Operations QEHS Policies And Procedures

5.1.1 Scope of the Design Operations

The Design operation shall define the scope of its Design operations.

5.1.2 Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the Design operation of the company. This sequence shall include all major planning, Design phases by trades, interactions with other departments in the company during design and QEHS assurance activities. This can be in list form or any other clear logical sequence. It is recommended that flowcharts are used where possible.

5.1.3 Codes and Regulations

Procedures shall be implemented to assure that all applicable codes, and governmental regulations are identified and complied with. The company shall have access to all applicable codes.

5.1.4 Company Standards

Company standards shall be documented to define the requirements for workmanship, including tolerance requirements, industry standards, design procedures, and material specifications. These company standards shall be included in scopes of work or other agreed upon document(s). When a conflict exists between local practice and other requirements (e.g., industry standards, manufacturer's instructions, etc.), there shall be a procedure for allowing exceptions while maintaining QEHS. All plans will be approved by an Engineer or equivalent for that city/state/region.

5.1.5 Manufacturer's Product Installation Instructions

The Design Operation shall develop, document, and implement procedures for obtaining and maintaining current copies of all installation/application instructions. Design operations shall ensure that all products / components are properly drawn, specified and detailed.

5.1.6 Trade Partner and Supplier Contract Documents and Scopes of Work

Procedures shall be implemented to prepare and review the subcontracts and design documents specific to the work of each support service firm or trade utilized by the Design Operation to assure that builder requirements and typical home buyer expectations will be met. Trade contracts, scopes of work, or other documents shall include mutually agreed upon job ready conditions for design and procedures to follow when these conditions are not met.

5.1.7 Scheduling

Schedules for organizing and completing the work to meet established time requirements shall be documented. Processes to monitor the plan specific work progress shall be established and shall have criteria under which deviations from the time requirements can occur. Procedures shall be established for communicating all schedules as well as any schedule changes to other operational areas, consultants, support service firms, trade partners, suppliers, and new home buyer customers.

5.1.8 Approval and Selection of Trade Partners, Materials, and Other Support Services

Procedures shall be established and implemented for review, approval, selection, and monitoring of:

5.1.8.1 Trade partners;
5.1.8.2 Materials and suppliers; and
5.1.8.3 Consultants and Support Service Firms.

There shall be a procedure for adding and removing suppliers, trade partners or support services firms from the builder's approved vendor list.

5.1.9 Control of Plans, Specifications, and Options

Procedures shall be established and implemented to assure that all plans, details, specifications, and options are updated when changes are made, and that no outdated or obsolete versions of any design document can inadvertently be used.

5.1.10 Job Completion Policy

Senior management shall establish a policy that states the conditions under which a new home can be closed. It shall include a process for how unfinished items or defects are to be completed or corrected after closing or other formal turnover.

5.2 Design Operations Inspections

5.2.1 General

Various inspections will be conducted by Design Operations to ensure Design activities comply with codes, regulations, scopes of work, manufacturer's instructions, and company standards. Design Operations will develop checklists and/or other documentation for recording the inspection results. The inspection criteria shall be consistent with the company standards and scopes of work. Items requiring corrections shall be recorded, corrected, and their status documented. The Design operation shall take steps to ensure any item requiring correction is completed and documented. A list of common design errors should be developed as a checklist to avoid recurring errors. The QEHS Management System shall document the inspection process, including who performs the inspection; what is inspected; when and where it is inspected; and the process for recording and storing inspection documentation. The personnel conducting inspections will be trained in the inspection and documentation process.

5.2.2 Job Ready Inspection

The Design Operations shall ensure that design work is ready via an inspection consistent with agreed upon job ready requirements including a program for the design, and agreed upon input from other operational areas of the company. Deviations from the job ready conditions shall be recorded on the job ready inspection record. Design work shall not commence until all job ready conditions are met.

5.2.3 In-Process Inspections

Activities and work done in the Design Operation shall have in-process inspections to assure that the builder's QEHS policy and procedures are being followed. These inspections shall be documented. The inspection criteria shall be consistent with the company standards and scopes of work.

5.2.4 Final Inspection

Each completed plan shall have a final inspection. Any non-conformance(s) to the builder's documented standards for completed work shall be recorded. Corrections shall be completed and documented.

5.2.5 Inspection Records

Records shall be maintained of all code compliance, engineer, company QEHS inspections, and the correction of noted non-conformances.

5.3 Design Operations Continual Improvement

5.3.1 Corrective and Preventive Actions

The Design operation shall define and implement on-going actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. The effectiveness of these actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated.

5.3.2 Design Operations Training

A program of ongoing training shall be implemented for all Design Operations employees involved in meeting QEHS requirements, and meeting new home buyer customer expectations. This training shall include identified opportunities for improvement that leads to continual improvement on department specific metrics and reducing recurring issues Design Operation. Training of design personnel shall include how to assure that job ready conditions exist for all phases of design work. This training shall include both task specific skills and training in the operation of the Design Operation's QEHS Management System and shall be documented.

5.3.3 Trade Partner QEHS Program Support

The Design Operations QEHS Management System shall support the QEHS programs of trade partners and other material and service providers. Communication shall be established between the Design QEHS representative of the company and the QEHS representatives of the trade partners to support the QEHS initiatives of each other. Feedback shall be periodically provided to the trade partner to enable the trade partner to improve the QEHS and safety of their work. Feedback shall be periodically solicited from the trade partner in order for the company to improve the QEHS and safety of the company's work.

5.3.4 Trade Partner and Consultant QEHS Management Oversight

All critical design activity performed by trade partners or consultants shall be supervised by a documented QEHS Management System.

The effective QEHS management activities to be ensured include code compliance, workmanship standards, compliance with manufacturer's instructions, documented inspections, corrective actions, preventive actions, and training.

6.0 PURCHASING OPERATIONS

6.1 Purchasing Operations QEHS Policies And Procedures

6.1.1 Scope of the Purchasing Operations

The Purchasing Operation shall define the scope of its Purchasing operations.

6.1.2 Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the Purchasing Operation of the company. This sequence shall include all major planning, Purchasing phases by trade, and QEHS assurance activities. This can be in list form or any other clear logical sequence. It is recommended that flowcharts are used where possible.

6.1.3 Codes and Regulations

Procedures shall be implemented to assure that all applicable codes, and governmental regulations are identified and complied with. The company shall have access to all applicable codes.

6.1.4 Company Standards

Company standards shall be documented to define the requirements for workmanship, including tolerance requirements, industry standards, purchasing procedures, and material specifications. These company standards shall be included in scopes of work and other agreed upon document(s).

6.1.5 Manufacturer's Product Installation Instructions

The Purchasing Operation shall develop, document, and implement procedures for obtaining and maintaining current copies of all installation/application instructions.

6.1.6 Trade Partner and Supplier Contract Documents and Scopes of Work

Procedures shall be implemented to prepare and review the subcontracts and purchasing documents specific to the work of each trade utilized to assure that builder requirements and typical home buyer expectations will be met. Trade contracts, scopes of work, or other documents shall include mutually agreed upon job ready conditions and procedures to follow when these conditions are not met. Trade contracts shall also include provisions requiring the trade partner to comply with all environmental and safety regulations and provide their accident prevention plan to the company. Trade partners shall be required to periodically report to builder management on non-compliance of job ready conditions at the builder's various communities.

6.1.7 Scheduling

Schedules for organizing and completing the purchasing activities to meet established time requirements shall be documented. Processes to monitor specific work progress shall be established and shall have criteria under which deviations from the time requirements can occur. Procedures shall be established for communicating all schedules as well as any schedule changes to other operational areas, trade partners, and suppliers,.

6.1.8 Approval and Selection of Trade Partners, Materials, and Other Support Services

Procedures shall be established and implemented for review, approval, selection, and monitoring of:

6.1.8.1 Trade partners;
6.1.8.2 Materials and suppliers; and
6.1.8.7 Other support services.

These procedures shall include a review of QEHS performance, warranty history, and their safety record. An approved vendor list shall be maintained of all suppliers, trade partners and support services. This list shall be reviewed at least annually.
There shall be a procedure for adding and removing suppliers, trade partners or support services firms from the builder's approved vendor list.

6.1.9 Control of Plans, Specifications, and Options

Procedures shall be established and implemented to assure that all plans, specifications, and options are updated when changes are made, and that no outdated or obsolete versions of any Purchasing document can inadvertently be used.

6.1.10 Job Completion Policy

Senior Management shall establish a job completion policy for key purchasing processes such as contract signing and renewal.

6.2 Purchasing Operations Inspections

6.2.1 General

Various inspections will be conducted by Purchasing Operations to ensure Purchasing activities comply with codes, regulations, scopes of work, manufacturer's instructions, and company standards. The frequency and detail of these inspections shall be sufficient to ensure compliance. Purchasing Operations will develop checklists and/or other documentation for recording the inspection results. The inspection criteria shall be consistent with the company standards and scopes of work. Items requiring corrections shall be recorded, corrected, and their status documented. The personnel conducting inspections will be trained in the inspection and documentation process.

6.2.2 Job Ready Inspection

The Purchasing operations shall ensure the required meetings are scheduled, necessary contracts and agreements templates, and construction documentation are all in place prior to commencing purchasing activities.

6.2.3 In-Process Inspections

Activities done in the Purchasing Operation shall have in-process inspections to assure that the builder's QEHS policy and procedures are being followed. These inspections shall be documented. Items requiring correction shall be documented, corrected, and confirmed prior to continuing the activities. The inspection criteria shall be consistent with the company standards and scopes of work.

6.2.4 Final Inspection

Each completed activity done in the Purchasing Operation shall have a final inspection. Any non-conformance(s) to the builder's documented standards for completed work shall be recorded. Corrections shall be completed and documented.

6.2.5 Inspection Records

Records shall be maintained of all code compliance, third-party inspections, company QEHS inspections, and the correction of noted non-conformances.

6.3 Purchasing Operations Continual Improvement

6.3.1 Corrective and Preventive Actions

The Purchasing Operation shall define and implement on-going actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. The effectiveness of these actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated.

6.3.2 Purchasing Operations Training

A program of ongoing training shall be implemented for all Purchasing Operations employees involved in meeting QEHS requirements, and meeting new home buyer customer expectations. This training shall include identified opportunities for improvement that leads to continual improvement on department specific metrics and reducing recurring issues in the Purchasing Operation. Training of Estimating personnel shall include how to assure that job ready conditions exist for all phases of estimating work and how to maintain a safe workplace. This training shall include both task specific skills and training in the operation of the Purchasing Operation's QEHS Management System and shall be documented.

6.3.3 Trade Partner QEHS Assurance Program Support

The Purchasing Operations QEHS Management System shall support the QEHS, environmental and safety programs of trade partners and other material and service providers. Communication shall be established between the Purchasing QEHS representative of the company and the QEHS representatives of the trade partners to support the QEHS initiatives of each other. Feedback shall be periodically provided to the trade partner to enable the trade partner to improve the QEHS and safety of their work. Feedback shall be periodically solicited from the trade partner in order for the company to improve the QEHS and safety of the company's work.

7.0 ESTIMATING OPERATIONS

7.1 Estimating Operations QEHS Policies And Procedures

7.1.1 Scope of the Estimating Operations

The Estimating Operation shall define the scope of its Estimating operations.

7.1.2 Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the Estimating Operation of the company. This sequence shall include all major planning, estimating phases by trade, and QEHS assurance activities. This can be in list form or any other clear logical sequence. It is recommended that flowcharts are used where possible.

7.1.3 Codes and Regulations

Procedures shall be implemented to assure that all applicable codes, and governmental regulations are identified and complied with. The company shall have access to all applicable codes.

7.1.4 Company Standards

Company standards shall be documented to define the requirements for workmanship, including tolerance requirements, industry standards, estimating procedures, and material specifications. These company standards shall be included in scopes of work or other agreed upon document(s). When a conflict exists between local practice and other requirements (e.g., industry standards, manufacturer's instructions, etc.), there shall be a procedure for allowing exceptions while maintaining QEHS. There shall be a procedure to require that all equipment used in the estimating process requiring calibration is properly calibrated and maintained.

7.1.5 Manufacturer's Product Installation Instructions

The Estimating Operation shall develop, document, and implement procedures for obtaining and maintaining current copies of all installation/application instructions. Estimating Operations shall ensure that all parties responsible for installation have the appropriate materials / documentation / drawings etc. to enable proper installation of all products.

7.1.6 Trade Partner and Supplier Contract Documents and Scopes of Work

Procedures shall be implemented to prepare and review the subcontracts and estimating documents specific to the work of each trade utilized by the Estimating Operation to assure that builder requirements and typical home buyer expectations will be met. Trade contracts, scopes of work, or other documents shall include mutually agreed upon job ready conditions and procedures to follow when these conditions are not met. Trade contracts shall also include provisions requiring the trade partner to comply with all environmental and safety regulations and provide their accident prevention plan to the company. Trade partners shall be
required to periodically report to builder management on non-compliance of job ready conditions at the builder's various communities.

7.1.7 Scheduling

Schedules for organizing and completing the estimating work to meet established time requirements shall be documented. Processes to monitor specific work progress shall be established and shall have criteria under which deviations from the time requirements can occur. Procedures shall be established for communicating all schedules as well as any schedule changes to trade partners, suppliers, and new home buyer customers.

7.1.8 Approval and Selection of Trade Partners, Materials, and Other Support Services

Procedures shall be established and implemented for review, approval, selection, and monitoring of:

7.1.8.1 Trade partners;
7.1.8.2 Materials and suppliers; and
7.1.8.3 Other support services.

These procedures shall include a review of QEHS performance.
An approved vendor list shall be maintained of all suppliers, trade partners and support services. This list shall be reviewed at least annually.

There shall be a procedure for adding and removing suppliers, trade partners or support services firms from the builder's approved vendor list.

7.1.9 Control of Plans, Specifications, and Options

Procedures shall be established and implemented to assure that all plans, specifications, and options are updated when changes are made, and that no outdated or obsolete versions of any Estimating document can inadvertently be used.

7.1.10 Job Completion Policy

Senior management shall establish a job completion policy for key estimating processes prior to turnover to Construction Operations.

7.2 Estimating Operations Inspections

7.2.1 General

Various inspections will be conducted by Estimating Operations to ensure estimating activities comply with codes, regulations, scopes of work, manufacturer's instructions, and company standards. The frequency and detail of these inspections shall be sufficient to ensure compliance. Estimating Operations will develop checklists and/or other documentation for recording the inspection results. The inspection criteria shall be consistent with the company standards and scopes of work. Items requiring corrections shall be recorded, corrected, and their status documented. The Estimating Operation shall take steps to ensure any item requiring correction is completed and documented. The QEHS Management System shall document the inspection process, including who performs the inspection; what is inspected; when and where it is inspected; and the process for recording and storing inspection documentation. The personnel conducting inspections will be trained in the inspection and documentation process.

7.2.2 Job Ready Inspection

The Estimating Operations shall ensure that all work required is completed by any other department prior to beginning estimating activities.

7.2.3 In-Process Inspections

Activities done in the Estimating Operation shall have in-process inspections to assure that the builder's QEHS policy and procedures are being followed. These inspections shall be documented. Items requiring correction shall be documented, corrected, and confirmed prior to continuing the activities. The inspection criteria shall be consistent with the company standards and scopes of work.

7.2.4 Final Inspection

Each completed activity done in the Estimating Operation shall have a final inspection. Any non-conformance(s) to the builder's documented standards for completed work shall be recorded. Corrections shall be completed and documented.

7.2.5 Inspection Records

Records shall be maintained of all code compliance, third-party inspections, company QEHS inspections, and the correction of noted non-conformances.

7.3 Estimating Operations Continual Improvement

7.3.1 Corrective and Preventive Actions

The Estimating Operation shall define and implement on-going actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. The effectiveness of these actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated..

7.3.2 Estimating Operations Training

A program of ongoing training shall be implemented for all Estimating Operations employees involved in meeting QEHS requirements, and meeting new home buyer customer expectations. This training shall include identified opportunities for improvement that leads to continual improvement on department specific metrics and reducing recurring issues in the Estimating Operation. Training of Estimating personnel shall include how to assure that job ready conditions exist for all phases of estimating work and how to maintain a safe workplace. This training shall include both task specific skills and training in the operation of the Estimating Operation's QEHS Management System and shall be documented.

7.3.3 Trade Partner QEHS Program Support

The Estimating Operations QEHS Management System shall support the QEHS, environmental and safety programs of trade partners and other material and service providers. Communication shall be established between the Estimating representative of the company and the representatives of the trade partners to support the QEHS initiatives of each other. Feedback shall be periodically provided to the trade partner to enable the trade partner to improve the QEHS and safety of their work. Feedback shall

be periodically solicited from the trade partner in order for the company to improve the QEHS and safety of the company's work.

8.0 CONSTRUCTION OPERATIONS

8.1 Construction Operations QEHS Policies And Procedures

8.1.1 Scope of the Construction Operations

The Construction Operation shall define the scope of its construction operations.

8.1.2 Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the Construction Operation of the company. This sequence shall include all major planning, construction phases by trade, and QEHS assurance activities. This can be in list form or any other clear logical sequence. It is recommended that flowcharts are used where possible.

8.1.3 Codes and Regulations

Procedures shall be implemented to assure that all applicable codes, and governmental regulations are identified and complied with. The company shall have access to all applicable codes.

8.1.4 Company Standards

Company standards shall be documented to define the requirements for workmanship, including tolerance requirements, industry standards, construction procedures, and material specifications. These company standards shall be included in scopes of work or other agreed upon document(s). When a conflict exists between local practice and other requirements (e.g., industry standards, manufacturer's instructions, etc.), there shall be a procedure for allowing exceptions while maintaining QEHS. There shall be a procedure to require that all equipment used in the construction process requiring calibration is properly calibrated and maintained.

8.1.5 Manufacturer's Product Installation Instructions

The Construction Operation shall develop, document, and implement procedures for obtaining and maintaining current copies of all installation/application instructions. Construction Operations shall ensure that all products are properly installed.

8.1.6 Trade Partner and Supplier Contract Documents and Scopes of Work

Procedures shall be implemented to prepare and review the subcontracts and construction documents specific to the work of each trade utilized by the Construction Operation to assure that builder requirements and typical home buyer expectations will be met. Trade contracts, scopes of work, or other documents shall include mutually agreed upon job ready conditions and procedures to follow when these conditions are not met. Trade contracts shall also include provisions requiring the trade partner to comply with all environmental and safety regulations and provide their accident prevention plan to the company. Trade partners shall be required to periodically report to builder management on non-compliance of job ready conditions at the builder's various communities.

8.1.7 Scheduling

Schedules for organizing and completing the work to meet established time requirements shall be documented. Processes to monitor the house specific work progress shall be established and shall have criteria under which deviations from the time requirements can occur. Procedures shall be established for

communicating all schedules as well as any schedule changes to trade partners, suppliers, and new home buyer customers.

8.1.8 Approval and Selection of Trade Partners, Materials, and Other Support Services

Procedures shall be established and implemented for review, approval, selection, and monitoring of:

8.1.8.1 Trade partners;
8.1.8.2 Materials and suppliers; and
8.1.8.8 other support services.

These procedures shall include a review of QEHS performance, warranty history, and their safety record. An approved vendor list shall be maintained of all suppliers, trade partners and support services. This list shall be reviewed at least annually.

(This list shall identify trade partners that are NHQ certified, trade partners that are not NHQ certified but have formal QEHS Management Systems implemented audited and verified by the builder, and trades that require QEHS management activities to be conducted by the builder.)

There shall be a procedure for adding and removing suppliers, trade partners or support services firms from the builder's approved vendor list.

8.1.9 Control of Plans, Specifications, and Options

Procedures shall be established and implemented to assure that all plans, specifications, and options are updated when changes are made, and that no outdated or obsolete versions of any construction document can inadvertently be used.

8.1.10 Job Completion Policy

Senior management shall establish a policy that states the conditions under which a new home can be closed. It shall include a process for how unfinished items or defects are to be completed or corrected after closing or other formal turnover.

8.2 Construction Operations Inspections

8.2.1 General

Various inspections will be conducted by Construction Operations to ensure construction activities comply with codes, regulations, scopes of work, manufacturer's instructions, and company standards. Consistent with the builder's experience with each trade partner, the frequency and detail of these inspections shall be sufficient to ensure compliance. Construction operations will develop checklists and/or other documentation for recording the inspection results. The inspection criteria shall be consistent with the company standards and scopes of work. Items requiring corrections shall be recorded, corrected, and their status documented. The Construction Operation shall take steps to ensure any item requiring

correction is not covered up before the correction is completed and documented. The QEHS Management System shall document the inspection process, including who performs the inspection; what is inspected; when and where it is inspected; and the process for recording and storing inspection documentation. The personnel conducting inspections will be trained in the inspection and documentation process.

8.2.2 Job Ready Inspection

The Construction Operations shall ensure the worksite is prepared for the work of the next trade to begin via an inspection consistent with agreed upon job ready requirements. If a trade is required to begin work when the job ready conditions are not met, the Construction Operations will ensure that the proper procedure is followed. Deviations from the job ready conditions shall be recorded on the job ready inspection record.

8.2.3 In-Process Inspections

Activities and work done in the Construction Operation shall have in-process inspections to assure that the builder's QEHS policy and procedures are being followed. These inspections shall be documented. Items requiring correction shall be documented, corrected, and confirmed prior to the covering or concealment of any trade's completed work. The inspection criteria shall be consistent with the company standards and scopes of work.

> *(Note: If an NHQ Certified trade contractor provides the builder with a copy of their inspection reports, this will satisfy this requirement for work of that trade provided the builder maintains a copy of this inspection document and periodically verifies the accuracy of the trade contractor's inspection.)*

8.2.4 Final Inspection

Each completed house shall have a final inspection. Any non-conformance(s) to the builder's documented standards for completed work shall be recorded. Corrections shall be completed and documented.

8.2.5 Inspection Records

Records shall be maintained of all code compliance, third-party inspections, company QEHS inspections, and the correction of noted non-conformances.

8.3 Construction Operations Continual Improvement

8.3.1 Corrective and Preventive Actions

The Construction Operation shall define and implement on-going actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. The effectiveness of these actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated.

8.3.2 Construction Operations Training

A program of ongoing training shall be implemented for all Construction Operations employees involved in meeting QEHS requirements, and meeting new home buyer customer expectations. This training shall include identified opportunities for improvement that leads to continual improvement on department specific metrics and reducing recurring issues in the construction operation. Training of construction personnel shall include how to assure that job ready conditions exist for all phases of construction work and how to maintain a safe jobsite. This training shall include both task specific skills and training in the operation of the construction operation's QEHS Management System and shall be documented.

8.3.3 Trade Partner QEHS Assurance Program Support

The Construction Operations QEHS Management System shall support the QEHS, environmental and safety programs of trade partners and other material and service providers. Communication shall be established between the construction QEHS representative of the company and the QEHS representatives of the trade partners to support the QEHS initiatives of each other. Feedback shall be periodically provided to the trade partner to enable the trade partner to improve the QEHS and safety of their work. Feedback shall be periodically solicited from the trade partner in order for the company to improve the QEHS and safety of the company's work.

8.3.4 Trade Partner QEHS Management Oversight

All critical construction activity shall be supervised by a documented QEHS Management System. The builder shall define a list of critical trades that require formal QEHS Management System oversight. This list shall include at a minimum all trades involved with the building envelope; HVAC; plumbing; electrical; and any work that becomes concealed during the construction process. Trades that have a significant impact on customer satisfaction, as identified by the builder, shall also be considered critical trades.

The effective QEHS management activities to be ensured include code compliance, workmanship standards, compliance with manufacturer's instructions, documented inspections, corrective actions, preventive actions, and training.

> *(NOTE: for NHQ Certification purposes)*
> *The Construction Operation shall ensure QEHS management supervision of each critical trade by:*
> *a) Utilizing NHQ Certified trade partners, and/or*
> *b) Conducting and documenting periodic QEHS audits sufficient in scope and detail to verify the implementation and effectiveness of the trade partner's QEHS Management System per the NHQ requirements, and/or*
> *c) Internally providing all QEHS management activities comparable to the NHQ requirements.*
>
> *For small trade partners with three or fewer working crews and where the owner is daily involved with the work on the job site, the builder can meet this NHQ requirement by:*
> *1) Conducting and documenting (or accepting the trade's documentation) for appropriate in process and job complete inspections; and*

2) Documenting quarterly review meetings with the owner of the trade partner to discuss recurring issues, needed crew training, workmanship standards, and providing/receiving feedback. The documentation can be brief but should note date, participants, and topics discussed.

9.0 CUSTOMER RELATIONS WARRANTY AND SERVICE OPERATIONS

9.1 Customer Relations Warranty And Service Operations QEHS Policies And Procedures

9.1.1 Scope of the Customer Relations Warranty and Service Operations

The Warranty and Service Operation shall define the scope of its operations including whether employees or trade partners typically do warranty service work in existing homes, and what conditions must be met to affect "turnover" from Construction Operations to Warranty and Service Operations.

9.1.2 Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the Warranty and Service Operation of the company. This sequence shall include all major communications, service work in existing homes, managing and tracking service requests, and QEHS assurance activities.

9.1.3 Warranty Documents, Repair Procedures, and Installation Manuals

9.1.3.1 Warranty Policy

The company shall have a defined warranty policy that is provided to each home buyer customer.
At least annually all warranty documents including performance standards for all items and systems found in a new home shall be reviewed to assure expectations of the new home buyer customer are met.

9.1.3.2 Individual Trade's Performance Standards

Scopes of work or construction documents for trade partners providing warranty service shall define the warranty service performance requirements expected of the trade partner.

9.1.3.3 Procedures and Manuals

The Warranty and Service Operation will maintain access to current copies of repair procedures and installation manuals for any materials or equipment that requires repair or replacement.

9.1.4 Codes, Standards, Regulations, and Manufacturer's Instructions

Procedures shall be implemented to assure identification of and compliance with all applicable codes, industry standards, governmental regulations, and manufacturer's instructions.

9.1.5 Warranty and Service Operations Policies

The Warranty and Service Operations shall have a warranty request completion policy. Procedures shall be developed, documented, and implemented for communicating the company's warranty and service obligations, procedures, and the company's customer satisfaction commitment to the new home buyer.

9.1.6 Scheduling

Processes for scheduling and monitoring the warranty service work progress shall be established and shall have criteria under which deviations from the time requirements can occur. Procedures shall be established for communicating all schedules and any schedule changes to trade partners, suppliers, and new home buyer customers.

9.1.7 Selection and Approval of Trade Partners, Materials, and Other Support Services to Complete Warranty Service Work

Procedures shall be established and implemented for review, approval, selection, and monitoring of any trade partner or consultant not already approved by the company.

9.1.8 Version Control

Procedures shall be established and implemented to assure that the records for all new homes covered under the company's warranty documents clearly indicate which version of the company's warranty applies to each new home sold. When more than one version of the company's warranty exists, all warranty and service personnel shall understand the terms and coverage of the warranty as it relates to each specific home.

9.1.9 Confirmation of Completed Warranty and Service Work

There shall be a procedure that obtains the homeowner's confirmation that a warranty or service request has been completed. This procedure shall address when and under what conditions a warranty or service request can "remain open" until some reasonable confirmation that the warranty or service work is, in fact, satisfactory.

9.1.10 Protection of Work

There shall be procedures established to protect all affected areas of a completed home during the warranty or service work by individual trades or other warranty personnel. These procedures shall address the process for correcting any damage that occurs during the performance of this work and the process of authorizing any such correction.

9.2 Warranty And Service Operations Inspections

9.2.1 Confirmation of Needed Warranty or Service Work

There shall be procedures established and implemented to determine the scope of the actual work required for each warranty claim received in accordance with the company's Warranty and Service Operations Policy and who is responsible for the completion of this work.

9.2.2 Final Inspection

The completed warranty and service work shall have a final inspection. All non-conformances to the Warranty and Service Operation's policies and procedures shall be documented. Corrections shall be completed and documented in accordance with the Warranty and Service Operations Policy. Each trade partner shall be required to provide to the builder documented assurance that, their warranty work is complete and meets the builder's requirements.

9.2.3 Inspection Records

Records shall be maintained of all warranty and service inspections.

9.3 Warranty And Service Operations Continual Improvement

9.3.1 Corrective and Preventive Actions

The Warranty and Service Operation shall define and implement on-going actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis and development and implementation of an action plan. When appropriate these actions shall include recommendations of changes in materials, equipment, trade partners, or company performance standards. The effectiveness of the corrective actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate actions initiated.

9.3.2 Warranty Service Training

A program of ongoing training for all Warranty and Service Operations employees and trade partners involved in meeting new home buyer customer expectations shall be implemented. This training shall include identified opportunities for improvement that leads to continual improvement on department specific metrics and reducing recurring issues in the warranty and service operation. This training shall include both task specific skills and training in the operation of the company's QEHS Management System.

Warranty and service operations staff will be trained on required repair and installation procedures for equipment or products used in the warranty and service operation. Warranty and service personnel shall be trained on all current versions of the company's warranty in use and where and when those different versions apply. Warranty and service personnel shall be trained on industry performance standards, company performance standards, and work practices of the company's trade partners.

9.3.3 Trade Partner QEHS Assurance Program Support

Communication shall be established between the warranty QEHS representative of the company and the representatives of the trade partners to support the QEHS initiatives of each other. Where a trade partner QEHS Management System does not exist, the warranty and service QEHS representative will establish necessary procedures for assuring that the QEHS of any trade partner's warranty work meets customer expectations. Feedback shall be periodically provided to the trade partner to enable the trade partner to improve the QEHS of their warranty and service work. Feedback shall be periodically solicited from the trade partner in order for the warranty and service to improve the QEHS of the company's work.

10.0 ADDITIONAL FUNCTIONAL AREAS

At the discretion of the company, additional functional areas beyond those listed above may be included in the company's QEHS Management System. The QEHS Management System for each of the additional functional areas shall include meeting the requirements of the following:

10.1 Functional Area QEHS Policies And Procedures

The functional area will have a plan to understand and meet their customer's expectations. This plan shall also define the scope of the functional area activities and process flow. The plan shall include any internal or external standards that apply, any scheduling / timing, expectations / commitments, training and personnel qualifications, and document / version control.

10.2 QEHS Reviews

Appropriate review and approval points to verify compliance with policies and procedures of the functional area shall be established along with criteria for that review and / or approval. Documentation requirements for these reviews shall also be defined and implemented.

10.3 Continual Improvement

A process shall be defined and implemented for on-going actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. The effectiveness of these actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated.

About IBACOS

Since 1991, IBACOS has helped builders address issues in the field so they can deliver better homes today and has conducted forward-thinking research that leads the industry to great homes tomorrow. The goal is an industry that delivers high performance homes that are designed and built to new standards of quality. For more information, please visit www.ibacos.com.

About the Best Practices Research Alliance

The Best Practices Research Alliance is a research-based community of production homebuilders collaborating with building performance specialists, quality and business management experts, and product and material manufacturers. Its ultimate goal is to identify and share how to deliver high quality, zero energy homes as an everyday part of mainstream America. These homes produce as much energy as they consume, while offering higher levels of comfort, durability, safety, and earth friendliness. The Alliance was created and is operated by IBACOS. For more information, please visit www.theresearchalliance.org.

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Appendix E: Frequently Asked Questions Presentation

Frequently Asked Questions

Duncan Prahl, RA
IBACOS
October 26, 2010
Pittsburgh, PA

Frequently Asked Questions

- Provided to help builders translate QEHS and implement
- First cut at perceived “biggest Issues”
- Structured around Key Attributes
    1. Cultural and corporate alignment
    2. Clear intent for quality and performance
    3. Whole house integrated design and specification
    4. Measurement and verification of performance
    5. Better communication practices and systems
    6. Increased collaboration across internal and external teams
    7. Disciplined approach to quality control
    8. Continuous feedback and improvement

FAQ Layout

X.1. Title

<Title of FAQ>

Question

QEHS Section Reference

<References to the relevant sections in the draft "Quality Energy Health and Safety (QEHS) Management System Requirements">

Recommendations

<Recommendations for inclusion in an organization's QEHS Management System>

Commentary

<Commentary on the topic>

FAQ Discussion

- General
  - Right FAQ Topics in Right Key Attributes?
  - Is the structure of the FAQ's useful?
    - Is there additional information / sections that should be included?
- FAQ by FAQ
  - What challenges have you encountered in implementing each topic of the FAQ's in your business?
  - What do you feel are your best practices in these areas that we can include as real world examples?
- What other FAQ's are needed?

Appendix F: Frequently Asked Questions

Quality Management for High Performance Homes

Quality, Environmental, Health & Safety (QEHS) Management System: Frequently Asked Questions

Prepared by:
Duncan Prahl

In collaboration with:
Denis Leonard, Business Excellence Consulting

October 26, 2010

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| Home Quality + Performance |

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INTRODUCTION

Characteristics of Companies Implementing High Performance Homes

Builders generally use a "spec and purchase" business management system (BMS) when implementing energy efficiency. A BMS is the overall operational and organizational systems and strategies that a builder uses to set up and run its company. This type of BMS treats building performance as a simple technology swap (e.g. a tank water heater to a tankless water heater) and typically compartmentalizes energy efficiency within one or two groups in the organization (e.g. purchasing and construction). While certain tools, such as details, checklists, and scopes of work, can assist builders in managing the quality of the construction of higher performance homes, they do nothing to address the underlying operational strategies and issues related to change management that builders face when they make high performance homes a core part of their mission. To achieve the systems integration necessary for attaining 30%+ levels of energy efficiency (with respect to the 2009 International Energy Conservation Code), while capturing the cost tradeoffs, builders must use a "systems approach" BMS, rather than a "spec and purchase" BMS. The following attributes are inherent in a systems approach BMS; they are also generally seen in quality management systems (QMS), such as the NAHB Research Center's National Housing Quality Certification program.

A. Cultural and corporate alignment
B. Clear intent for quality and performance
C. Whole house integrated design and specification
D. Measurement and verification of building performance
E. Better communication practices and systems
F. Increased collaboration across internal and external teams
G. Disciplined approach to quality control
H. Continuous feedback and improvement

While there are market leaders who are successful at implementing quality management systems to profitably deliver low first-cost "code" housing, there are very few who have developed quality management systems associated with a holistic systems approach to delivering high performance homes. In an effort to help the industry more widely adopt the technical results from the Building America (BA) program, IBACOS is undertaking an ongoing research project to:

- Characterize the organizational and operational structure of a systems approach BMS and supporting QMS for a profitable company building high performance homes.
- Identify the barriers, level of effort, and costs associated with transformation from a "spec and purchase" to systems approach BMS and QMS, and provide template solutions to these issues for builders to adopt.

The following Frequently Asked Questions have been grouped under the 8 general quality management attributes listed above. They are intended to be a companion to the "Quality, Environmental, Health, and Safety Management System Requirements" draft document (IBACOS 2010) Each FAQ is structured as follows:

X.1. Title

<Title of FAQ>

QEHS Section Reference

<References to the relevant sections in the draft "Quality Energy Health and Safety (QEHS) Management System Requirements">

Recommendations

.<Recommendations for inclusion in an organization's QEHS Management System>

Commentary

<Commentary on the topic.>

Resources have been provided where appropriate, typically as web links. These were last accessed on October 18, 2010.

CULTURAL AND CORPORATE ALIGNMENT

A.1. Why High Performance is a Cultural Issue

Question: How much does a company need to internalize high performance home thinking to successfully implement a high performance home technical strategy?

QEHS Section Reference

1.2 Leadership

Senior management shall demonstrate leadership regarding the company's quality, environmental, health, and safety (QEHS) initiatives. Leadership is demonstrated by:

- Setting policy and performance expectations
- Communicating to the organization the importance of quality, safety, and the environment, as well as meeting customer expectations
- Providing resources
- Reviewing the effectiveness of the management system

A fundamental aim of leadership is the full integration of QEHS initiatives, which inherently includes a focus on integrating design approaches, problem solving, implementation, and measurement systems.

1.3 QEHS, Environmental, and Safety Statement

Senior management shall prepare a written statement(s) that describes the company's commitment to QEHS, the environment, and safety, as well as addresses customer's expectations. This statement should have a direct link to the company's vision and mission statement. The statement(s) will commit the entire organization to continually improving, achieving measurable business performance metrics, and having a safe workplace, and it shall be communicated to all stakeholders, customers, suppliers, trade partners, and employees.

Recommendations

Consider including language in leadership statements related to the company's vision, mission, and QEHS on its commitment to higher performing houses. Taking this step will help connect the commitment to high performing homes directly to the strategic plan and can help emphasize the delivery of higher performance homes as part of everyone's job in the organization.

Strategic Integration of Annual Review and Self-Assessment & SWOT Analysis

It is recommended to link the Annual Management Review (and its review of audits and organizational performance) to the annual strategic planning of the organization, so the results from internal reviews and the opportunities for improvement from them can be addressed in the evaluation of the Strengths,

Weaknesses, Opportunities, and Threats (SWOT). This work can be supported by conducting a gap analysis and self-assessment using the National Housing Quality (NHQ) Award Criteria and the IBACOS Green Blueprint. Including the annual review as part of the strategic planning meeting ensures that the focus is kept on high performing homes, makes full use of the QEHS, and provides key input for the strategic decision making process.

Commentary

The success of adopting a high performance home strategy in an organization starts and ends with the leadership team. The leadership of the company provides the vision, direction, strategy, and especially the culture of the organization. Leadership actions and behaviors create the culture and the disciplines required to design, market, build, and sell high performing homes. If the leadership team does not really believe in high performance and relegates it only to one area of the company, the results will not be as robust had the entire organization been involved.

Many builders consider the overall performance of a house to be a function of the individual parts and pieces that make up the end product. While in a strict sense this is true, a house is a complex set of interrelated systems with individual parts that rely on one another. This same concept holds true for a company building high performance homes. Sustained success is virtually impossible if only one part of the company is delegated to “do that high performance homes thing.”

A parallel concept would be to delegate the goal of improving customer satisfaction to one department. It has been demonstrated that the entire homebuying process influences customer satisfaction and every member of the organization must be involved. Unless delivering high performance homes becomes one of the key cultural goals of the organization, supervisors and trades will not be motivated or even inspired by their work, the sales team will not discuss the benefits of a high performance home with buyers, and customer care may feel the brunt of unmet expectations.

Leaders in a homebuilding company must address the many implications associated with making delivery of high performance homes a core strategy. The leadership team must understand the strategy, be vocal champions for it at all levels within the organization, and integrate this thinking into as many aspects of the organization as possible. Some points to consider:

- All departments must align behind the strategy; it cannot be seen as simply a purchasing and construction exercise.
- High performance homes can positively contribute to bottom line business results through improved customer satisfaction, reduced risk, and increased retained earnings.
- Land planning and lot orientation may be impacted to optimize performance or enable the future addition of renewable energy systems, such as photovoltaic (PV) panels.
- Design strategies may need to be modified to achieve the energy performance goals.

- Marketing and sales departments must be knowledgeable about the high performance strategy and be able to share the story. They do not need to be technical experts, but they must be able to provide customers with the basic features and benefits.
- Purchasing and construction departments must be able to execute the strategy, and support the trades in collaboratively achieving the energy performance goals.
- The different trades need to be well-integrated and coordinated, since all of the systems in the house are relying on one another to perform. Each trade must properly execute its scope of work in order for the house to perform properly.
- Customer care must reinforce the difference with high performance products to buyers through the maintenance and operation of the homes.
- One aspect of incentive pay could be developed around the successful execution of the energy performance strategy companywide.
- Community giveback events can be focused around energy efficiency or improving the performance of a building.

CLEAR INTENT FOR QUALITY AND PERFORMANCE

B.1. Internal Standards

Question: What kinds of standards should I evaluate when developing a high performance home strategy?

QEHS Section Reference

1.11 Performance Measures

The company shall establish performance measures and goals that are indicative of the effectiveness of the QEHS Management System. These shall be defined, documented, and quantified for each functional area covered by the company's QEHS Management System. Progress towards meeting these goals shall be documented and reported quarterly to the management of the various functional areas.

(The topic in section 5.1.4 is repeated in sections 3, 6, 7, 8 and 9 and adapted for those departments.)

5.1.4 Company Standards

Company standards shall be documented to define the requirements for workmanship, including tolerance requirements, industry standards, design procedures, and material specifications. These company standards shall be included in scopes of work or other agreed upon document(s). When a conflict exists between local practice and other requirements (e.g. industry standards, manufacturer's instructions), there shall be a procedure for allowing exceptions while maintaining the QEHS. All plans will be approved by an Engineer or equivalent for that city/state/region.

Recommendations

Standards for high performance homes can be found in the following locations:

- Builders Challenge: http://www1.eere.energy.gov/buildings/challenge/pdfs/bcqc_version_1_3_060408.pdf
- EEBA Criteria: http://www.eeba.org/bookstore/cat-Builders_Guides-4.aspx
- ENERGY STAR Homes: http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_2011_comments
- Environments for Living: http://www.environmentsforliving.com/index.jsp?action=bd_pgm_details
- International Green Construction Code: http://www.iccsafe.org/cs/igcc/pages/default.aspx
- ICC-700-2008 National Green Building Standard: http://www.nahbgreen.org/Guidelines/ansistandard.aspx
- LEED for Homes: http://www.usgbc.org/DisplayPage.aspx?CMSPageID=2135#2008
- Local and regional green building programs: http://www.pathnet.org/sp.asp?id=20978
- DSIRE website (Database of State Incentives for Renewables and Efficiency): http://www.dsireusa.org/

Commentary

As a building company moves to high performance housing, it is important to define exactly what that means. Doing so will improve internal communications and provide a common understanding; it will also enable every employee in the company to be able to communicate the message to customers, trades, and others on the outside. It may be useful to create an overarching theme (i.e. "we build healthy, safe, durable houses that are 30% or more energy efficient than code with guaranteed comfort for our customer"); however, this messaging must be substantiated by clearly defined metrics associated with the actual performance of the houses and used by all departments.

A good set of company standards will document the climate-related issues that are being addressed by the thermal enclosure and mechanical systems. These issues include:

- Rainfall and wind – water management
- Heating and cooling degree days
- Humidity profile
- Vapor control / enclosure drying strategy

The standards should also explicitly state interrelationships and strategies the builder is implementing related to the high level systems. For example, the standards should describe in a narrative format how heat air and moisture are to be controlled by the building enclosure, how the mechanical system are to be integrated, and overall minimum levels of performance for the overall house using the HERS Index. The standard can also document why the company has taken this approach. Reasons include past failures, calculated future risk avoidance, or a response to customer input (past issues or stated needs). This set of standards can be integrated in the checklists for the product design and purchasing functions to help enable a quick review of critical factors throughout the various stages in the design process (schematic, design development, and construction drawings). It can also be integrated as a part of the development of the scopes of work, step-by-steps, and other construction documentation.

Some performance criteria for standards could include:

- Structural
  - Industry rating systems (e.g. floors and wind/hurricanes)
    - http://www.ilevel.com/services/s_T-Pro-Rating-System.aspx
    - http://www.disastersafety.org/text.asp?id=fortified_living
- Acoustics
  - Noise separation in multifamily buildings
    - https://www03.cmhc-schl.gc.ca/catalog/productDetail.cfm?cat=18&itm=11&lang=en&fr=1286468715281

        - http://www.cmhc-schl.gc.ca/en/inpr/bude/himu/coedar/upload/Sound-Control-in-multi-family-wood-frame-buildings.pdf
    - Exterior noise to interior
        - http://www.nrc-cnrc.gc.ca/eng/projects/irc/aircraft-noise.html
- Water management
    - Window installation
        - North American Fenestration Standard/Specification (NAFS) for windows, doors, and skylights (AAMA/WDMA/CSA 101/I.S.2/A440-08)
        - Residential Air Infiltration Standard for Windows: AAMA/WDMA/CSA 101/I.S.2/A440
    - Weather-resistive barriers
        - International Residential Code Section R703
    - Below-grade water management
        - International Residential Code Section R405 and 406
    - Roofing
        - Asphalt Roofing Manufacturer's Association (ARMA) Asphalt Roofing Residential Manual: Design and Applications Methods for Residential Roofing
        - ARMA's Good Application Makes A Good Roof Better - A Simplified Guide: Three Tab Asphalt Shingles For Maximum Life & Weather Protection
        - http://www.asphaltroofing.org/resources_publications_arma.html
        - International Residential Code Section R903 Weather Protection
        - International Residential Code Section R905 Requirements for Roof Coverings
    - Flashings
        - International Residential Code section R703
- Energy performance
    - HERS Index
        - http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_HERS
    - Building air tightness
        - http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/94/940110.html
        - http://www.energyconservatory.com/download/bdmanual.pdf
    - HVAC system tightness
        - http://www.energyconservatory.com/download/bdmanual.pdf
- Ventilation
    - ASHRAE 6.2 Compliance & Strategy
        - http://www.techstreet.com/lists/ashrae_standards.tmpl
- Water vapor control strategy
    - Climate zone
    - Vapor control layer location in building assemblies
    - Vapor barrier class (I,II, and III)

        - http://www.buildingscience.com/documents/information-sheets/3-water-management-and-vapor-control/info-sheet-310-vapor-control-layer-recommendations
- General design strategies for system integration of thermal enclosure, structure, and mechanical systems
    - HVAC location
    - Types of structural systems used to facilitate HVAC integration
        - http://www.toolbase.org/Design-Construction-Guides/HVAC/forced-air-system

B.2. Cost of Documentation

Question: What is the cost-benefit of providing a higher level of documentation for high performance homes?

QEHS Section Reference

1.11 Performance Measures

The company shall establish performance measures and goals that indicate the effectiveness of the QEHS Management System. These shall be defined, documented, and quantified for each functional area covered by the company's QEHS Management System. Progress toward meeting these goals shall be documented and reported quarterly to the management of the various functional areas.

(The topic in section 5.1.1, 5.1.3, and 5.1.6 is repeated in sections 3, 6, 7, 8, and 9 and adapted for those departments.)

5.1.1 Scope of the Design Operations

The Design operation shall define the scope of its Design operations.

5.1.5 Manufacturer's Product Installation Instructions

The Design operation shall develop, document, and implement procedures for obtaining and maintaining current copies of all installation/application instructions. Design operations shall ensure that all products/components are properly drawn, specified, and detailed.

5.1.6 Trade Partner and Supplier Contract Documents and Scopes of Work (Similar to Sections 6, 7, and 8)

Procedures shall be implemented to prepare and review the subcontracts and Design documents specific to the work of each trade utilized by the Design operation to ensure that builder requirements and typical homebuyer expectations will be met. Trade contracts, scopes of work, or other documents shall include mutually agreed-upon job ready conditions and procedures to follow when these conditions are not met.

9.1.3.2 Individual Trade's Performance Standards

Scopes of work or construction documents for trades providing warranty service shall define the warranty service performance requirements expected of the trade.

Recommendations

When determining the appropriate level of documentation, look at the total lifecycle cost of the documentation, including the cost of rework and repairs for building failures due to inadequate documentation, as well as the associated costs in referral sales and goodwill from customer dissatisfaction.

Commentary

FAQ E.3 covers the rationale for having comprehensive documentation as a tool to successfully implement a high performance home strategy. But what is the cost-benefit of the documentation?

In high performance homes, all of the systems and their interactions should be intentional and designed to enable the optimal performance at the lowest risk. These decisions should be made through an Integrated Design Process (see FAQ C.1). Once made, it is imperative to communicate the decisions to the entire team. When the chain of participants is mapped from design to warranty, there can easily be over 500 individuals who will in some way be a part of building the home. This chain includes the builder's internal team, as well as the external teams of designers, engineers, architects, trades, suppliers, and manufacturers' representatives. Without clear and effective documentation, it is impossible to communicate well to all of the participants and expect a high performance home as a result.

The incremental cost to achieve high quality documentation will depend on the documentation currently used in the construction process. Documentation can also be built up over time. Evaluate the critical aspects of material selection and purchasing, as well as construction execution that share the most risk associated with the strategy. If you have never had a window leak but find that your HVAC system has 50% of the system fan flow leaking to the outdoors, then creating installation guidance for sealing duct leaks moves to the top of the list.

Develop comprehensive strategies for looking at the embedded cost of change as opportunities to roll out new systems or strategies. Construction drawings typically need to be revised and updated as new codes are implemented. This cost must be included in the base operating plan. At this point, making a change, such as transitioning from 2x4 wall framing to 2x6, can be relatively small, provided that the implications have been thought through before creating the actual documentation.

Effective documentation is critical to overall customer satisfaction and the success of the high performance design. For example, one builder in the mid Atlantic region was faced with a situation where the documentation fell short. The builder spent additional money to have a mechanical engineer design and size the space conditioning system of a large, executive-type home. The engineer specified the right equipment, duct sizes, and diffusers but did not effectively integrate the duct layout with the framing plan on the drawings. As a result, many of the critical issues within the layout were left to the trade in the field. The trade essentially made sure the ducts reached their intended locations, regardless of the number of additional bends and serpentine routes made to avoid framing interferences. As a result, when the home was complete and fully operational, the homeowners complained of inadequate cooling and heating delivery. The first round of field measurements found that airflow volumes at the supply diffusers and return grilles were extremely low and did not match the engineering flow rates. After extensive troubleshooting and repair efforts, it was concluded that the initial trade installed an excessive number of elbows, pinched down the sizing of branch ducts to squeeze them through tight spaces, and used unnecessary lengths of ductwork. The cost of the rework was very high because a new mechanical

contractor had to be hired to make all of the necessary repairs. The original trade took no blame for the situation due to the lack of explicit details on the drawings.

WHOLE HOUSE INTEGRATED DESIGN AND SPECIFICATION

C.1. Integrated Design Process

Question: How does the design of the house impact my ability to implement a high performance home strategy?

QEHS Section Reference

5.1 Design Operations QEHS Policies and Procedures

5.1.1 Scope of the Design Operations

The Design operation shall define the scope of its Design operations.

5.1.2 Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the Design operation of the company. This sequence shall include all major planning, Design phases by trades, and interactions with other departments in the company during design and QEHS assurance activities. This can be in list form or any other clear logical sequence. It is recommended that flowcharts are used where possible.

Recommendations

Recommended scope of the Design operations:

- Utilize an integrated design approach involving a team from marketing and sales, design and purchasing, home construction, customer care, and key trades. Review each plan with the team at the schematic design stage, design development stage, and prior to issuing the final construction drawings. Do so to gain feedback on potential defects and errors and to design a customer-oriented home built efficiently and effectively.
- Consider each interrelated component of the home for function, design/aesthetics, and cost with input from those team members closest to that component.
- Provide the construction department and trades with accurate plans and details.
- Provide the sales department with accurate plans for the homebuyer.
- Each time a new home plan is first built, make sure the team completes a walkthrough to gather detailed feedback on how to improve the plan and construction based on the experience.

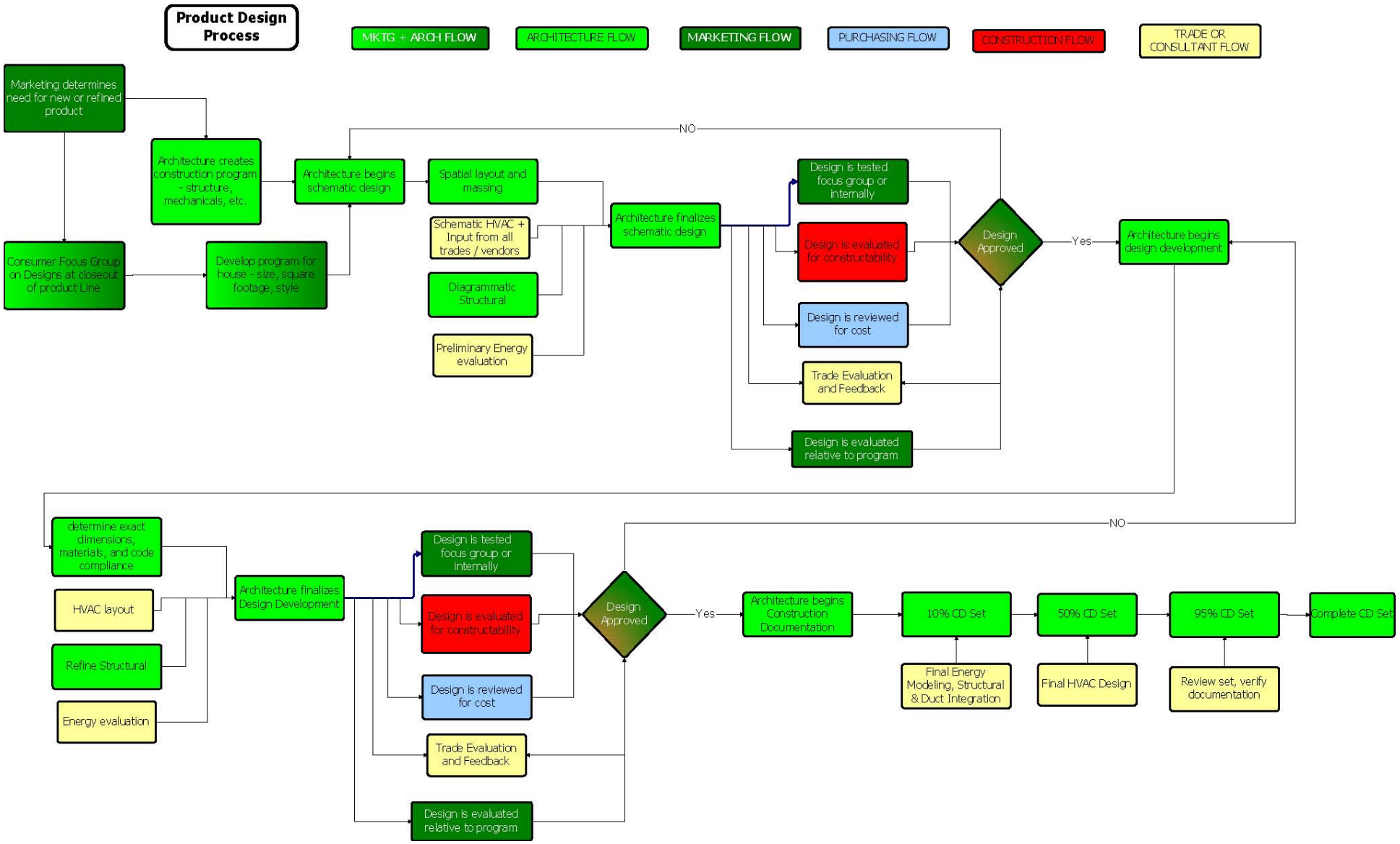
Commentary

Integrated Design Process (IDP) is a mechanism that builders can use to more successfully integrate all aspects of building performance with the entire team. By using an IDP, the builder can ensure the compatibility of the higher performance systems and design while capturing all cost-saving opportunities to offset the higher performance practices. A fully implemented IDP will make clear the interrelated

systems in the house, the tradeoffs that can take place, and help to rally the team toward the goal. In establishing an IDP, it is critical for builders to have a set of overall performance criteria or a specific performance metric for the team to achieve, such as meeting ENERGY STAR® requirements, participating in DOE's Builders Challenge, or using the EEBA Criteria or other criteria from the green building program of your choice. Meeting these requirements will be much easier when the entire team has a voice in the initial design. The team can agree on decisions that significantly impact performance (like number of windows, orientation, thermal enclosure options, mechanical system routing, and structure) that are balanced with aesthetic goals and cost constraints. The IDP gives the team the opportunity to understand and work through the interrelated components of the home, such as the floor space vs. mechanical system vs. thermal enclosure vs. size of the windows.

IDP is a forward-looking process and not the time to assign blame for things in the past. The focus must be on working collaboratively to achieve the project goals. Everyone at the table must be open, honest, and able to accept responsibility for their actions and develop proactive solutions.

Below is a flow chart of a generic integrated design process and all of the parties involved. For more information, see FAQ C.2.


Product Design Process
MKTG + ARCH FLOW
ARCHITECTURE FLOW
MARKETING FLOW
PURCHASING FLOW
CONSTRUCTION FLOW
TRADE OR CONSULTANT FLOW
Marketing determines need for new or refined product
Architecture creates construction program - structure, mechanicals, etc.
Architecture begins schematic design
Spatial layout and massing
Schematic HVAC + Input from all trades / vendors
Diagrammatic Structural
Preliminary Energy evaluation
Architecture finalizes schematic design
Design is tested focus group or internally
Design is evaluated for constructability
Design is reviewed for cost
Trade Evaluation and Feedback
Design is evaluated relative to program
Design Approved
NO
Yes
Architecture begins design development
Consumer Focus Group on Designs at closeout of product Line
Develop program for house - size, square footage, style
determine exact dimensions, materials, and code compliance
HVAC layout
Refine Structural
Energy evaluation
Architecture finalizes Design Development
Design is tested focus group or internally
Design is evaluated for constructability
Design is reviewed for cost
Trade Evaluation and Feedback
Design is evaluated relative to program
Design Approved
NO
Yes
Architecture begins Construction Documentation
10% CD Set
50% CD Set
95% CD Set
Complete CD Set
Final Energy Modeling, Structural & Duct Integration
Final HVAC Design
Review set, verify documentation

C.2. Team Roles for Integrated Design

Question: Who should be involved in the product design process when implementing a high performance home strategy?

QEHS Section Reference

5.1 Design Operations QEHS Policies and Procedures

5.1.1 Scope of the Design Operations

The Design operation shall define the scope of its Design operations.

5.1.2 Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the Design operation of the company. This sequence shall include all major planning, trades' Design phases, and interactions with other departments during design and QEHS assurance activities. The sequence can be in list form or any other clear, logical sequence. It is recommended that flowcharts are used where possible.

5.3.3 Trade Partner QEHS Program Support

The Design operations QEHS Management System shall support the QEHS, programs of trades and other materials and service providers. Communication shall be established between the Design QEHS representative of the company and the QEHS representatives of the trades to support the QEHS initiatives of each other. Feedback shall be periodically provided to the trade to enable the trade to improve the QEHS and safety of its work. Feedback shall be periodically solicited from the trade in order for the company to improve the QEHS and safety of its work.

Recommendations

Recommended scope of the Design operations:

- Use an integrated design approach involving a team from marketing, sales, design, purchasing, construction, customer relations and key trades. Review each plan with the team at schematic design and design development stages, as well as prior to issuing final construction drawings, to gain feedback on potential defects and errors and to design a customer-oriented home built efficiently and effectively.
- Provide the construction department and trades with accurate plans and details.
- Provide the sales department with accurate plans for the homebuyer.
- Each time a new home plan is first built, conduct a walkthrough of this "pilot"' home with the team to gather detailed feedback on how to improve the plan and construction based on their experiences.

Commentary

When implementing a high performance home strategy, design can play a powerful role in helping to achieve the company standard (see FAQ B.1) cost effectively. Key energy efficiency strategies like integrating the HVAC system with the structural system, bringing the HVAC system inside the conditioned space, and optimizing glass-to-floor area ratios are all within the realm of the design group. Unfortunately, this group rarely has the amount of information needed to make important decisions during the design phase, leading to marketable houses that frequently have sub-optimal solutions from the standpoint of energy efficiency or building performance. By bringing additional individuals to the table through an integrated design process (see FAQ C.1), the product can be developed to meet the overall high performance goals while still meeting all aesthetic and market criteria. Below are some of the additional parties to invite to the table during the design phase and what roles they might play.

HERS Rater

A rater can provide guiding parameters, so the design can hit specific energy targets, such as Builders Challenge, ENERGY STAR®, or local utility program targets. Items can include window-to-floor area ratios, insulation packages, window and mechanical equipment specification, and various design strategies (e.g. all ducts inside conditioned space). Many design teams feel that an energy analysis cannot be performed until it is "designed," but many rating tools can provide designers with guiding parameters to hit specific energy targets if they undertake a collaborative exchange of very early in the design process. With as little information as the intended floor area, aspect ratio of the house, number and height of stories, and the number of bedrooms, a rater can generate an energy model to evaluate the HERS Index and energy cost impacts of different window-to-floor area ratios, thermal enclosure elements, and different space conditioning system locations.

Customer Care

Builders should thoroughly examine and determine the root causes of historical failures and customer service issues. If these root causes are in the design of the building (e.g. roof intersections prone to leaks, room placement with difficult HVAC runs leading to comfort complaints), then they should be addressed during the design stage. If a design solution is not possible, then the team needs to make sure a robust technical solution is in place to eliminate the problem.

Voice of the Customer

Customer feedback from tools like surveys and focus groups (see FAQ E.6) should always inform the design team. This feedback should not just be on aesthetic issues but also on function and operational issues related to how customers actually live in their houses and what makes it easier or more difficult for them to enjoy the experience. Look at maintenance and other warranty call data that relates to difficulties occupants are experiencing with their home that do not pertain specifically to just defects. For instance, if a house has 10' ceilings, how practical is it for a homeowner to change the furnace filter in a ceiling-mounted grille?

Purchasing

The purchasing group receives direct feedback from trades on details that are difficult to execute or are high-priced features/strategies that may not add value for the customer. This group should be able to provide general costs for various strategies in the early stages of the design phase.

Trades

Trades can directly contribute to the design phase by providing input on constructability; costs; and new products, systems, and materials up for consideration. This information can be valuable in the earliest stages when the basic massing of a building is being decided, which inherently dictate the structural strategies and mechanical system layouts.

C.3. Design vs. Products: Understanding Product Performance with Respect to the Design

Question: What is the relationship between specific products and systems approaches when developing a high performance home strategy?

QEHS Section Reference

1.11 Performance Measures

The company shall establish performance measures and goals that are indicative of the effectiveness of the QEHS Management System. These shall be defined, documented, and quantified for each functional area covered by the company's QEHS Management System. Progress toward meeting these goals shall be documented and reported quarterly to the management of the various functional areas.

5.1.1 Scope of the Design Operations

The Design operation shall define the scope of its Design operations.

(The topic in section 5.1.4 and 5.1.8 is repeated in sections 3, 6, 7, 8 and 9 and adapted for those departments.)

5.1.4 Company Standards

Company standards shall be documented to define the requirements for workmanship, including tolerance requirements, industry standards, design procedures, and material specifications. These company standards shall be included in scopes of work or other agreed-upon document(s). When a conflict exists between local practice and other requirements (e.g. industry standards, manufacturer's instructions), there shall be a procedure for allowing exceptions while maintaining QEHS. All plans will be approved by an Engineer or equivalent for that city/state/region.

5.1.8 Approval and Selection of Trade Partners, Materials, and Other Support Services

Procedures shall be established and implemented for review, approval, selection, and monitoring of:

- 5.1.8.1 Trade Partners
- 5.1.8.2 Materials and Suppliers
- 5.1.8.3 Other Support Services

There shall be a procedure for adding and removing suppliers, trades, or support services firms from the builder's approved vendor list.

Recommendations

Develop a process where the specific properties of the materials and products being used are evaluated in the context of the overall system. Taking this step helps ensure that long-term risks are not introduced inadvertently.

Commentary

The development of a systems strategy to high performance homes must be evaluated at many scales - the whole house, the various systems and subsystems, and the products used.

Example: Cathedralized Attics as a System Strategy

Cathedralizing the attic is one strategy that brings the space conditioning system inside the conditioned space of the house. However, this seemingly simple decision requires examining and evaluating a host of product questions, as well as risks.

The first question to ask when considering a cathedralized attic is “How often does the roof leak due to installation failures?” Roofs frequently leak from installation failures and degradation to roofing materials over time. Roofing underlayment should be installed as a secondary drainage layer, but it is often mishandled. If the roof is a zero defect item, then the next question is “What is the longevity of the roofing material?” Is the longevity 25 years for the asphalt shingles or 100 years for concrete tile? The risks associated with cathedralizing a 100-year roof with no history of leaks are considerably lower than one with a 3% failure for a 25-year product.

With a 3% failure rate, the builder has a reasonable “early warning system.” With a conventionally insulated attic, the homeowner typically sees water staining the drywall ceiling under the roof system. If the builder switches to a cathedralized attic with closed-cell spray foam on the underside of the roof deck, leaks may not be identified for long periods of time, leading to repeated wetting of the roof sheathing, which can cause rot in the sheathing and possibly roof structure. The failure may not become apparent for five to ten years, and it is costly to repair. The question of liability also comes into play. While the roofer may be responsible for the actual leak, the fact that the builder chose spray foam (which prevented an early detection of the leak) would likely put more liability on the builder to make the repair.

This sequence of events does not mean closed-cell foam should not be used on the underside of the roof deck. It simply means that a builder must apply broader thinking when evaluating a system or product. In this case, if a 0% roof leak rate is achievable with a proven history, spray foam may be the best choice. Or other strategies may work equally well, depending on the climate and construction methods. Eliminating roof leaks should be the first order of business, so if it is impossible to achieve to a 0% failure rate, then evaluating other system strategies for bringing the space conditioning system inside the conditioned space may be more appropriate.

For more information specifically on unvented roof assemblies, see http://www.buildingscience.com/documents/reports/rr-0301-unvented-roof-summary-article.

MEASUREMENT AND VERIFICATION OF BUILDING PERFORMANCE

D.1. Performance Testing: Why Do It and What Does It Get You?

Question: When implementing a high performance home strategy, how can building performance testing and inspections be useful beyond just "getting the label"?

QEHS Section Reference

1.11 Performance Measures

The company shall establish performance measures and goals that are indicative of the effectiveness of the QEHS Management System. These shall be defined, documented, and quantified for each functional area covered by the company's QEHS Management System. Progress towards meeting these goals shall be documented and reported quarterly to the management of the various functional areas.

(The topic in section 7.1.3, 7.1.4, 7.1.5, and 7.3.1 is repeated in sections 3, 5, 6, 8, and 9 and should be adapted for those departments.)

7.1.3 Codes and Regulations

Procedures shall be implemented to ensure that all applicable codes and governmental regulations are identified and complied with. The company shall have access to all applicable codes.

7.1.4 Company Standards

Company standards shall be documented to define the requirements for workmanship, including tolerance requirements, industry standards, purchasing procedures, and material specifications. These company standards shall be included in scopes of work or other agreed-upon document(s).

7.1.5 Manufacturer's Product Installation Instructions

The purchasing operation shall develop, document, and implement procedures for obtaining and maintaining current copies of all installation/application instructions.

7.3.1 Corrective and Preventive Actions

The purchasing operation shall define and implement on-going actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. The effectiveness of these actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated. Structured Plan-Do-Check-Act methodologies are recommended for the corrective and preventive actions, as are creating defined charters for improvement teams.

8.2 Construction Operations Inspections

8.2.1 General

Various inspections will be conducted by construction operations to ensure construction activities comply with codes, regulations, scopes of work, manufacturer's instructions, and company standards. Consistent with the builder's experience with each trade, the frequency and detail of these inspections shall be sufficient to ensure compliance. Construction operations will develop checklists and/or other documentation for recording the inspection results. The inspection criteria shall be consistent with the company standards and scopes of work. Items requiring corrections shall be recorded, corrected, and their status documented. The construction operation shall take steps to ensure that any item requiring correction is not covered up before the correction is completed and documented. The QEHS Management System shall document who, what, when, where, and why/how inspections are to be recorded for the inspection processes. The personnel conducting inspections will be trained in the inspection and documentation process.

8.2.2 Job Ready Inspection

The construction operations shall ensure the jobsite is prepared for the work of the next trade to begin via an inspection consistent with agreed-upon job ready requirements. If a trade is required to begin work when the job ready conditions are not met, the construction operations will ensure that the proper procedure is followed. Deviations from the job ready conditions shall be recorded on the job ready inspection record.

8.2.3 In-Process Inspections

Activities and work done in the construction operation shall have in-process inspections to ensure that the builder's QEHS policy and procedures are being followed. These inspections shall be documented. Items requiring correction shall be documented, corrected, and confirmed prior to the covering or concealment of any trade's completed work. The inspection criteria shall be consistent with the company standards and scopes of work.

8.2.4 Final Inspection

Each completed house shall have a final inspection. Any non-conformance(s) to the builder's documented standards for completed work shall be recorded. Corrections shall be completed and documented.

Recommendations

Once internal standards have been set, it is critical to verify that they are being met. In the same way that financial metrics are not tracked on a pass/fail basis, building performance test results can provide a wealth of information to evaluate individual trade performance and overall company performance related to certain building performance goals. Performance test results can also help the management team identify opportunities for improvement, as well as when an advance in building performance standards may be possible.

Commentary

Many builders rely on their HERS rater to provide them with energy efficiency certification (e.g. ENERGY STAR®, Environments for Living, and green certifications); however, very few builders actually breakdown, report, and analyze the data that is collected for certifications. A typical HERS rating or performance path includes insulation and other thermal enclosure component inspections, building airtightness measurements, HVAC distribution system air tightness testing, and HVAC system commissioning. Some programs include other building performance and durability verifications, such as the proper installation of water management features and ventilation system performance. In many cases, this information is provided to the builder in a pass/fail format. But this data is incredibly rich, and if analyzed, can yield trends and opportunities for improvement, as well as provide the organization with the means to determine when to pursue the next level of performance.

In addition, this data can be used for root cause analysis when there are longer-term warranty requests. Many of these inspections or performance tests provide information not only on the energy efficiency of a house but also on the long-term durability and comfort issues. HVAC systems with airflows that barely pass may lead to occupant discomfort more readily than those that pass the criteria by a wide margin. Houses that required rework to pass may have a higher likelihood of long-term customer complaints. This information can help identify needs for training and enhancing trade skills or transferring best practices from one trade to another within a particular area (e.g. HVAC installation).

Some of these performance measurements can be leading indicators of other issues surrounding customer satisfaction, such as:

- Comfort
    - Air tightness and duct performance impact customer comfort (comfort and utility bills)
    - Insulation quality and levels impact customer satisfaction (comfort and utility bills)
    - HVAC basic measurements confirm airflow and system performance (comfort and utility bills)
- Building durability (long-term repair risk)
    - Verifying air tightness provides information on the movement of warm moist air through the building enclosure, which can cause mold, rot, or decay
    - Water intrusion testing verifies window/door installation (e.g. ASTM E110)
- Indoor air quality
    - Fresh air ventilation airflows

D.2. How Much Testing and Why?

Question: When implementing a high performance home strategy, how much performance testing should be undertaken and why?

QEHS Section Reference

1.11 Performance Measures

The company shall establish performance measures and goals that are indicative of the effectiveness of the QEHS Management System. These shall be defined, documented, and quantified for each functional area covered by the company's QEHS Management System. Progress toward meeting these goals shall be documented and reported quarterly to the management of the various functional areas.

(The topic in sections 7.1.3, 7.1.4, 7.1.5 and 7.3.1 is repeated in sections 3, 5, 6, 8, and 9 and should be adapted for those departments.)

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Procedures shall be implemented to ensure that all applicable codes and governmental regulations are identified and complied with. The company shall have access to all applicable codes.

7.1.4 Company Standards

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7.1.5 Manufacturer's Product Installation Instructions

The purchasing operation shall develop, document, and implement procedures for obtaining and maintaining current copies of all installation/application instructions.

7.3.1 Corrective and Preventive Actions

The purchasing operation shall define and implement on-going actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. The effectiveness of these actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated. Structured Plan-Do-Check-Act methodologies are recommended for the corrective and preventive actions, as are creating defined charters for improvement teams.

8.2 Construction Operations Inspections

8.2.1 General

Various inspections will be conducted by construction operations to ensure construction activities comply with codes, regulations, scopes of work, manufacturer's instructions, and company standards. Consistent with the builder's experience with each trade, the frequency and detail of these inspections shall be

sufficient to ensure compliance. Construction operations will develop checklists and/or other documentation for recording the inspection results. The inspection criteria shall be consistent with the company standards and scopes of work. Items requiring corrections shall be recorded, corrected, and their status documented. The construction operation shall take steps to ensure that any item requiring correction is not covered up before the correction is completed and documented. The QEHS Management System shall document the inspection process, including who performs the inspection; what is inspected; when and where it is inspected; and the process for recording and storing inspection documentation. The personnel conducting inspections will be trained in the inspection and documentation process.

8.2.2 Job Ready Inspection

The construction operations shall ensure the jobsite is prepared for the work of the next trade to begin via an inspection consistent with agreed-upon job ready requirements. If a trade is required to begin work when the job ready conditions are not met, the construction operations will ensure that the proper procedure is followed. Deviations from the job ready conditions shall be recorded on the job ready inspection record.

8.2.3 In-Process Inspections

Activities and work done in the construction operation shall have in-process inspections to ensure that the builder's QEHS policy and procedures are being followed. These inspections shall be documented. Items requiring correction shall be documented, corrected, and confirmed prior to the covering or concealment of any trade's completed work. The inspection criteria shall be consistent with the company standards and scopes of work.

8.2.4 Final Inspection

Each completed house shall have a final inspection. Any non-conformance(s) to the builder's documented standards for completed work shall be recorded. Corrections shall be completed and documented.

Recommendations

"You can expect what you inspect" – Dr. W. Edwards Deming

For higher performance homes, everything needs to work right and work together in order to perform properly and meet the customer's expectations. There are two schools of thought regarding performance testing. One school of thought is to test 100% of houses built to verify that every house has met the internal standards set by the builder (see FAQ B.1) or certification program requirements. Another is to undertake a sampling protocol after a certain number of 100% inspections, usually one house in seven (~15%) for a production builder. Third-party quality control (QC) provides can offer a valuable service by helping to ensure that performance goals for houses are met, but the construction operations must not rely solely on these programs. They should be regarded as serving a supportive role alongside regular and ongoing internal QA/QC protocols.

Commentary

While 100% performance testing is a cost of building homes, it is also a valuable data set and potential way to reduce risk and protect against litigation. Below is a discussion of the pros and cons of 100% testing in relation to random sampling.

100% Testing: Pros

- The builder is assured that every house meets internal standards and certification program requirements and can promote that fact to the customer.
- If the customer ever questions the performance of the house (e.g. high utility bills or a comfort complaint), the builder has the data to substantiate claims that the house meets the standards.
- If multiple trades use any single scope of work, it is easier to identify variations between the companies and design and implement actions plans to correct any issues.
- In certain cases, the testing can be integrated as part of the trade's scope of work as an inspection "test out" documented on the job complete checklist (e.g. duct tightness).
- Builders and trades may find that having internal HERS raters conduct testing is a cost effective way to achieve 100% inspections. While 15%of homes may need a third party rating for certain certification programs, internalizing HERS ratings (or at least the testing) can give immediate feedback on construction issues.
- This type of testing provides a complete data set of house performance attributes, enabling builders to analyze between trades, communities, site supervisor, crew leader, and model type, etc.

100% Testing: Cons

- The testing may add to the costs on the construction budget (however, this con needs to be weighed in light of potential liability for random sampling in the event of a customer complaint on a house that was not tested).
- The testing may add time to the schedule.

Sampling after a period of 100% Testing: Pros

- Sampling reduces the cost of testing (however, this pro needs to be weighed in light of potential liability for random sampling in the event of a customer complaint on a house that was not tested).
- If only one trade is performing the work, there may be less of a need to verify the installed performance (provided that the trade has a reasonable quality control and assurance program.

Sampling after a period of 100% Testing: Cons

- Sampling may not detect variations from crew-to-crew or among multiple trades following the same scope of work, risking undetected, intermittent non-compliance.
- The builder may have harder time explaining to customers why their house was not specifically tested.

It is important to recognize that all testing is not simply to “get the label.” It can also verify other performance attributes of the house, such as water intrusion or comfort. Testing may be localized (e.g. one or two windows for water intrusion) or conducted frequently when working on process improvement (e.g. 100% testing when trying to get air leakage numbers down). Over time, the number of inspections may decrease as the results grow more consistent; however, decreasing the amount of testing should correspond with the consistency of the workforce. Once new people come onboard (e.g. new trade, new trade crew, new trade crew lead, or new site supervisor), the amount of testing may need to occur more frequently to verify that new workers are trained properly and performing the work according to company standards.

D.3. Types of Testing

Question: What types of tests can be done on a home, and what do they mean?

QEHS Section Reference

1.11 Performance Measures

The company shall establish performance measures and goals that are indicative of the effectiveness of the QEHS Management System. These shall be defined, documented, and quantified for each functional area covered by the company's QEHS Management System. Progress toward meeting these goals shall be documented and reported quarterly to the management of the various functional areas.

(The topic in sections 7.1.3, 7.1.4, 7.1.5, and 7.3.1 is repeated in sections 3, 5, 6, 8, and 9 and should be adapted for those departments.)

7.1.3 Codes and Regulations

Procedures shall be implemented to ensure that all applicable codes and governmental regulations are identified and complied with. The company shall have access to all applicable codes.

7.1.4 Company Standards

Company standards shall be documented to define the requirements for workmanship, including tolerance requirements, industry standards, purchasing procedures, and material specifications. These company standards shall be included in scopes of work or other agreed-upon document(s).

7.1.5 Manufacturer's Product Installation Instructions

The purchasing operation shall develop, document, and implement procedures for obtaining and maintaining current copies of all installation/application instructions.

7.3.1 Corrective and Preventive Actions

The purchasing operation shall define and implement on-going actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. The effectiveness of these actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated. Structured Plan-Do-Check-Act methodologies are recommended for the corrective and preventive actions, as are creating defined charters for improvement teams.

8.2 Construction Operations Inspections

8.2.1 General

Various inspections will be conducted by construction operations to ensure construction activities comply with codes, regulations, scopes of work, manufacturer's instructions, and company standards. Consistent with the builder's experience with each trade, the frequency and detail of these inspections shall be sufficient to ensure compliance. Construction operations will develop checklists and/or other

documentation for recording the inspection results. The inspection criteria shall be consistent with the company standards and scopes of work. Items requiring corrections shall be recorded, corrected, and their status documented. The construction operation shall take steps to ensure that any item requiring correction is not covered up before the correction is completed and documented. The QEHS Management System shall document the inspection process, including who performs the inspection; what is inspected; when and where it is inspected; and the process for recording and storing inspection documentation. The personnel conducting inspections will be trained in the inspection and documentation process.

8.2.2 Job Ready Inspection

The construction operations shall ensure the jobsite is prepared for the work of the next trade to begin via an inspection consistent with agreed-upon job ready requirements. If a trade is required to begin work when the job ready conditions are not met, the construction operations will ensure that the proper procedure is followed. Deviations from the job ready conditions shall be recorded on the job ready inspection record.

8.2.3 In-Process Inspections

Activities and work done in the construction operation shall have in-process inspections to ensure that the builder's QEHS policy and procedures are being followed. These inspections shall be documented. Items requiring correction shall be documented, corrected, and confirmed prior to the covering or concealment of any trade's completed work. The inspection criteria shall be consistent with the company standards and scopes of work.

8.2.4 Final Inspection

Each completed house shall have a final inspection. Any non-conformance(s) to the builder's documented standards for completed work shall be recorded. Corrections shall be completed and documented.

Recommendations

Document the tests that are needed to verify the high performance home strategy being established. Use the results from these tests to analyze trends and identify opportunities for improvement.

Commentary

Below is a list of common performance tests and what they mean.

Test	What it means
HVAC blower running, static pressure between air handler cabinet and filter	Test only when using the supply side fresh air intake located between the filter and the air handler. It allows an estimate of the outside air flow through the outside air duct. http://www.buildingscience.com/documents/reports/rr-0413-the-snapshot-a-quick-description
HVAC blower running, supply	It allows for a comparison between the design and as-built static

and return plenum static pressures	pressure. Can help verify if duct installation is close to what was designed.
Ventilation system airflows	It allows for a comparison between the design and as-built ventilation airflows.
Baseline house stack pressure (with blower door installed and covered)	It determines the pressure difference between the inside of the house and the outside of the house at the moment of testing (this is a baseline measurement for dominant duct leakage and house tightness).
Dominant duct leakage (with blower door installed and HVAC fan operating)	It shows if the duct leakage to the outside predominantly on the supply side, the return side, or relatively balanced. This test does not provide the magnitude of the leakage, only a likelihood of where it is.
Master Bedroom Door Closure Effect (HVAC fan operating, door closed to master bedroom)	It tests the change in pressure from the baseline due to the master door being closed. It gives a relative indication of how much HVAC induced air leakage (exfiltration or infiltration) is occurring from the master bedroom area.
All Doors to Isolated Rooms Closed Effect (HVAC fan operating, door closed to all bedrooms and other rooms with doors)	It tests the change in pressure from the baseline due to all of the doors being closed. It gives a relative indication of how much HVAC induced air leakage (exfiltration or infiltration) is occurring from all closed, isolated rooms.
Pressure with respect to main space in each room with a door that can be isolated from the main space (HVAC fan operating)	It measures the relative supply and return airflow for each room. The pressure difference between the room and main body of the house should not be more than 3 pascals.
Blower door test (cfm 50)	This test is a direct measure of a house's air tightness. It is typically converted to ACH50 (air changes per house at 50 pascals, or cfm50/sq. ft. of shell area). See http://www.buildingenergysolutions.com/pdfs/bdtest.pdf.
HVAC system tightness (total leakage)	It measures the total amount of air leaking from the HVAC system (equipment and ducts) at 25 pascals. The test gives an indication of how much air is actually getting delivered to the intended locations as opposed to unintended locations (e.g. interstitial cavities, outside the conditioned space).
HVAC system air leakage to outside	It measures how much of the air leakage in an HVAC system is going outside, as opposed to staying within the conditioned space.
Room airflows (supply and return)	It allows a comparison between the design airflows and as-built conditions. This test can help to predict or diagnose comfort complaints (too hot or too cold rooms).

HVAC Oversizing (runtime method)	It compares the runtime of equipment to the inside / outside temperature difference to establish if the HVAC equipment is oversized
Water intrusion testing (ASTME110)	It allows for an evaluation of the effectiveness of a window or door installation with respect to water intrusion. The test involves spraying water at a specific rate on the exterior of the building assembly while depressurizing the enclosure to a specific test pressure with a blower door or calibrated fan to simulate a wind-driven rain event.
Worst case scenario	It tests the house while all of the fan and air handling systems are running to determine the potential for depressurization and backdrafting of combustion appliances. This test is unnecessary if only sealed combustion appliances are installed within the conditioned space.
Exhaust fan flow	This test ensures that exhaust fan ducts are installed correctly and working properly.

D.4. Compensation Metrics and Building Performance

Question: Is there a way to use data collected from the high performance homes built to tie into compensation incentives for employees?

QEHS Section Reference

1.11 Performance Measures

The company shall establish performance measures and goals that are indicative of the effectiveness of the QEHS Management System. These shall be defined, documented, and quantified for each functional area covered by the company's QEHS Management System. Progress toward meeting these goals shall be documented and reported quarterly to the management of the various functional areas.

Recommendations

Make the measured results of the houses part of companywide or individually-based incentive compensation (bonuses) to help instill high performance as a core part of the company's mission, vision, and values.

Commentary

Historically, a site supervisor's performance has been linked to measures that relate to the number of houses under construction (or closed), cycle time, and customer satisfaction. While these measures drive efficiency and focus on the customer, they may work at odds with achieving higher performance homes, especially when a company is embarking on the implementation of ENERGY STAR® or similar programs.

Another method companies use is to link bonus pay purely to customer satisfaction, sometimes providing incentives to all employees based on achieving certain scores. While building high performance homes can naturally boost these scores, they are also a direct measure of the quality, durability, and energy efficiency of a house, elements that are linked to customer satisfaction. It may be beneficial to include key indicators that are routinely measured to validate energy performance as a component of the individual or companywide compensation incentive program.

D.5. Having the Right Measures to Evaluate your High Performance Strategy

Question: What metrics should be used during various phases of implementation of high performance homes in a building company?

QEHS Section Reference

1.11 Performance Measures

The company shall establish performance measures and goals that are indicative of the effectiveness of the QEHS Management System. These shall be defined, documented, and quantified for each functional area covered by the company's QEHS Management System. Progress toward meeting these goals shall be documented and reported quarterly to the management of the various functional areas.

(The topic in section 8.2.1, 8.2.2, 8.2.3, and 8.2.4 regarding continual improvement (preventive actions and training) are repeated in sections 3, 4, 5, 6, 7, and 9 and adapted for those departments)

8.2.1 General

Various inspections will be conducted by construction operations to ensure construction activities comply with codes, regulations, scopes of work, manufacturer's instructions, and company standards. Consistent with the builder's experience with each trade, the frequency and detail of these inspections shall be sufficient to ensure compliance. Construction operations will develop checklists and/or other documentation for recording the inspection results. The inspection criteria shall be consistent with the company standards and scopes of work. Items requiring corrections shall be recorded, corrected, and their status documented. The construction operation shall take steps to ensure that any item requiring correction is not covered up before the correction is completed and documented. The QEHS Management System shall document the inspection process, including who performs the inspection; what is inspected; when and where it is inspected; and the process for recording and storing inspection documentation. The personnel conducting inspections will be trained in the inspection and documentation process.

8.2.2 Job Ready Inspection

The construction operations shall ensure the jobsite is prepared for the work of the next trade to begin via an inspection consistent with agreed-upon job ready requirements. If a trade is required to begin work when the job ready conditions are not met, the construction operations will ensure that the proper procedure is followed. Deviations from the job ready conditions shall be recorded on the job ready inspection record.

8.2.3 In-Process Inspections

Activities and work done in the construction operation shall have in-process inspections to ensure that the builder's QEHS policy and procedures are being followed. These inspections shall be documented. Items requiring correction shall be documented, corrected, and confirmed prior to the covering or concealment

of any trade's completed work. The inspection criteria shall be consistent with the company standards and scopes of work.

(Note: If an NHQ certified trade provides the builder with a copy of its inspection reports, this will satisfy this requirement for work of that trade, provided the builder maintains a copy of this inspection document and periodically verifies the accuracy of the trade's inspection.)

8.2.4 Final Inspection

Each completed house shall have a final inspection. Any non-conformance(s) to the builder's documented standards for completed work shall be recorded. Corrections shall be completed and documented.

Recommendations

Metrics are typically used to gauge the general financial and operational health of a company. General metrics (such as those recommended by the Shinn group) help builders evaluate if things are "on track" and can alert management if action needs to be taken.

When implementing a high performance strategy, it can be helpful to collect and analyze various key metrics related to achieving the strategy. Different metrics are used at different times and are can be grouped by the phase of integration within the organization: adoption, sustained implementation, and improvement.

Commentary

The Shinn Group recommends the following minimum metrics for an operational and financial dashboard for a company.

Accounting / Financial Metrics

INCOME STATEMENT	Calculation
Cost of sales	Cost of sales / sales
Gross profit	Gross profit / sales
Indirect construction	Cost Indirect cost / sales
Financing expenses	Financing / sales
Sales & marketing expenses	Sales & marketing / sales
General & administrative exp.	General & administrative / sales
Total operating expenses	Operating expenses / sales
Owner's compensation	Owner's compensation / sales
Net profit	Net profit / sales
BALANCE SHEET	
Current ratio	Current assets / current liab.
Debt to equity	Total liabilities / owner's equity
Receivable days	365 / (Sales / avg. accounts rec.)
Payable days	365 / (Purchases / avg. accts payable)

Sales	Traffic at communities Conversion of traffic to sales Sales contract cancellations Sales per community Sales per plan type
Inventory	Raw land Finished lots Unsold under construction Unsold completed houses
Production Operations	(Track deviations from accepted or target rather than actual) Cycle time (average lost days from schedule) Cost (percentage of actual to budget) Supervisor efficiency (houses per supervisor)
Warranty	Average aging of outstanding items Group requests by “type”
Customer Satisfaction	Willingness to refer

When it comes to home performance, there are a number of possible metrics to track, all of which can be used for different purposes. These metrics can be broken down by phase of implementation in the high performance strategy: adoption, sustained implementation, and improvement, which are described below.

- Adoption: This phase is the initial transition to a comprehensive, systems approach (e.g. Builders Challenge, ENERGY STAR® version 3, Environments for Living). This period may last from three months to a year, depending on the volume of production, sophistication of trades, level of internal and external team training provided, feedback mechanisms, resources and materials available to support the transition, and company culture.
- Sustained Implementation: This phase is the time period that follows adoption where the desired strategy is being executed consistently.
- Improvement: This phase is where opportunities for improvement are identified and teams are formed to capitalize on these opportunities and develop a plan to implement solutions. This plan is the basis for the activities to take place in the adoption phase.

Different departments may be in different phases at the same time. For example, the company as a whole may be at the sustained implementation level of executing a high performance home strategy with existing plan types that have not been developed using an integrated design process. At the same time, the design group may be in the adoption phase as they create and refine a new set of plans using the integrated design process for the first time. Simultaneously, the sales staff may be in the improvement phase, working on the next generation of strategies to market and sell the high performance features of the builder’s product.

The following is a list of possible metrics that can be used in the adoption, sustained implementation, and improvement phases, and their importance.

Adoption Phase

Metric	Importance
HERS Index	Aggregate numeric indicator of whole house energy efficiency; allows quick understanding of how close product is getting to energy efficiency goal
Building Air Tightness	Specific measure of a key attribute that impacts comfort and durability in a home; an attribute that is "invisible".
HAVC System Tightness	A specific measure of how much air is escaping from the HVAC system that was intended for delivery to a specific space.
Percentage Re-Inspect to Pass Thermal Enclosure Checklists	This checklist verifies that insulation systems have been installed properly and other thermal enclosure components are being installed as required by ENERGY STAR; if re-inspection is needed to pass this checklist, it is an indication that trades and site supervisors are not fully versed in the proper installation methods and strategies needed to build a higher performance enclosure.
Percentage Re-Inspect to Pass Rater HVAC Checklists	This checklist verifies that the HVAC system has been installed properly by the HVAC trade and that key aspects were verified by the HRES Rater; if the rater needs to re-inspect to pass this checklist, it is an indication that HVAC trade and site supervisors are not fully versed in the proper installation methods and strategies needed to design and install a high performance HVAC system.
Percentage Re-Inspect to Pass Rater Water Management Checklists	This checklist verifies that the water management system has been installed properly as verified by the HERS Rater; if the rater needs to re-inspect to pass this checklist, it is an indication that trades and site supervisors are not fully versed in the proper installation methods and strategies needed to achieve acceptable water management strategies for higher performance houses.
Costs by Department	Implementing a high performance home strategy involves all aspects of the building company's people, departments, outside trades, and suppliers; ultimately, the decision to move to higher performance homes should provide financial benefits to the company. Some costs may increase, but others should decrease. Cost increases should be expected for construction documentation, construction, and inspections. Cost decreases should be expected with the first-year warranty, long-term defect repair, customer satisfaction, and positive referrals. Setting up cost tracking systems early (if they do not already exist as part of the operational dashboard) can help evaluate the effectiveness of adopting a high performance approach and provide ongoing data for making operational decisions.
Cycle Time	During the adoption phase, cycle time will likely deviate, as new systems and techniques are being learned and consistently applied. Additional inspection by the HERS Rater may also add time to the schedule. This data can be used in the following two phases to look for improvement opportunities.

Sustained Implementation Phase

Metric	Importance
HERS Index	Aggregate numeric indicator of whole house energy efficiency; allows quick understanding of how close product is getting to energy efficiency goal.
Building Air Tightness	Specific measure of a key attribute that impacts comfort and durability in a home; an attribute that is "invisible".
HAVC System Tightness	A specific measure of how much air is escaping from the HVAC system that was intended for delivery to a specific space.
Warranty Items by High Performance Strategy Area	Warranty items related to water intrusion and comfort should be reduced. Tracking these items will verify that the high performance strategy is working and may lead to price renegotiations with key trades if their warranty work has decreased significantly. These measures may also be correlated to customer satisfaction scores.
Thermal Enclosure Checklist Failure Items	Track the specific items that fail at the first inspection by the HERS Rater. These items are an indicator of improvement opportunities to undertake in the improvement phase. Once in sustained implementation, these failures will likely be the result of a change in trades or new crews who are unfamiliar with the specific construction methods needed to achieve the high performance strategy.
Rater HVAC Checklists Failure Items	Track the specific items that fail at the first inspection by the HERS Rater. These items are an indicator of improvement opportunities to undertake in the improvement phase. Once in sustained implementation, these failures will likely be the result of a change in trades or new crews who are unfamiliar with the specific construction methods needed to achieve the high performance strategy.
Rater HVAC Checklists Failure Items	Track the specific items that fail at the first inspection by the HERS Rater. These items are an indicator of improvement opportunities to undertake in the improvement phase. Once in sustained implementation, these failures will likely be the result of a change in trades or new crews who are unfamiliar with the specific construction methods needed to achieve the high performance strategy.
Costs by Department	Evaluate the metrics that were tracked from adoption, and evaluate them for opportunities for improvement. Are there system tradeoffs that should be more aggressively pursued? Are the cost reductions in areas being achieved? The full impact of some issues may take several years to become apparent (e.g. the elimination of historical systemic water management failures that may only appear 3–5 years after closing).
Cycle Time	Use the days deviating from the schedule to see if systemic issues are arising with specific high performance systems implementation. These areas could be the focus for additional training or discussing staffing with trades.

Metrics for the Improvement Phase

At a very high level, the following general metrics can be used as part of an improvement phase.

Metric	Importance
HERS Index	Aggregate numeric indicator of whole house energy efficiency; allows quick understanding of how close product is getting to energy efficiency goal.
Building Air Tightness	Specific measure of a key attribute that impacts comfort and durability in a home; an attribute that is “invisible”.
HAVC System Tightness	A specific measure of how much air is escaping from the HVAC system that was intended for delivery to a specific space.
Costs by Department	Use costs as benchmarks for improvements. Based on the specific improvement measures, the costs implications should be understood, both to form a historical standpoint and to set targets for the improvement activity. It may be that costs in one area may need to rise in order to achieve a net overall reduction in costs across several areas.
Cycle Time	Evaluate any changes in the system strategies with trades to see the impact on cycle time. Changes may require re-evaluating sequencing or staff level s on crews to meet cycle time targets.

A discussion of using metrics for the improvement phase can be found in FAQ H.1 and H.2.

BETTER COMMUNICATION PRACTICES AND SYSTEMS

E.1. Company Meetings

Question: How can the high performance home strategy be integrated in regular meetings held by the company?

QEHS Section Reference

1.9 Corporate Communications

Procedures shall be implemented to ensure that communication exists between all areas of the company and the trade partners of the company. This includes identification of and communication to other functional areas to address recurring non-conformances in QEHS. There shall be procedures implemented to communicate with new home buying customers and to manage their expectations.

2.3 Annual Management Review

At least annually, the QEHS management committee shall review the operation and effectiveness of its respective systems with the senior management of the company. This annual review shall include a summary of the internal and external audits of the activities of each functional area of the company, performance measures, customer feedback, trade and supplier feedback, complaints, and recommendations from the QEHS department representatives. The annual review shall also include ensuring compliance with these requirements, setting new annual goals, and addressing needed changes to the management system. Records shall be maintained for each review. The records shall be in sufficient detail to disclose the participants, significant issues, conclusions, recommendations, and planned changes. The aim is to ensure that the QEHS Management System is working to the satisfaction of the leadership and management of the organization. The annual review is an opportunity to make significant changes to the QEHS Management System and make sure it is functioning effectively and efficiently.

8.3.3 Trade Partner QEHS Assurance Program Support

The construction operations QEHS Management System shall support the QEHS, environmental, and safety programs of trades and other material and service providers. Communication shall be established between the construction QEHS representative of the company and the QEHS representatives of the trades to support the QEHS initiatives of each other. Feedback shall be periodically provided to the trade to enable the trade to improve the QEHS and safety of its work. Feedback shall be periodically solicited from the trade in order for the company to improve the QEHS and safety of the company's work.

1. Training will be provided to all trades on basic quality principles, tools, and techniques.
2. The builder will conduct each month regular meetings with the trades to discuss QEHS, schedules, and opportunities for improvement (OFIs).

3. The builder will develop a Trade Council to improve communication with the trade base and ensure that the builder focuses on how to improve the daily life of the trade. This will therefore allow the builder to focus on OFIs that it needs to implement in its own business and practices.

Recommendations

Continual communication is a key factor in the successful execution of any strategy within an organization. Regular meetings can help to both chart the progress toward the strategic objective and identify barriers and opportunities for improvement. It is important to include key metrics that relate to the execution of the high performance home strategy (see FAQ D.5) in the meetings as appropriate. Do not duplicate work or efforts.

Commentary

Effective meetings are a crucial part of a well-functioning communication process in an organization. Common types of meetings where the high performance home strategy can be integrated include the following.

Annual leadership strategic planning
This meeting can include a review of the past building performance strategy, the goal targets for future improvements, and the contribution to other success metrics in the company.

Annual or quarterly all-company meetings
These meetings provide an opportunity for the leadership team to communicate the high performance strategy, the successes and challenges in implementation, and the impact it is having within the company. Taking this step reinforces the strategy as a key cultural foundation for the company.

Semi- annual trade partner meetings
These meetings provide an opportunity to review trend data on the implementation of the high performance strategy, identify opportunities for improvement in a blame-free environment (see FAQ F.2), review completed improvement team activities, and communicate new directions in the high performance home strategy. If possible, having the trades own the meeting by forming a Trade Council (see FAQ E.5) can help create a more collaborative environment as opposed to the builder “calling in the trades.”

Regular meetings with key trades
Based on production volume, it may be advantageous to met on a regular basis with key groups of trades (e.g. site prep to foundation, framing to rough mechanicals, insulation to paint, finishes to house completion) to help build relationships, identify opportunities for improvement, and create solutions. The successes and challenges associated with the implementation of the high performance home strategy can be a part of the agenda of these meetings and form a key part of the company’s quality standards (see FAQ B.1).

Weekly departmental and management team meetings
The company goals and key metrics for high performance homes (see FAQ D.5) should be reviewed to help reinforce the strategy within the company culture (see FAQ A.1) and to communicate interdepartmental changes and procedures as they relate to the strategy. These meetings should not be a

laundry list of updates; rather, they should focus on relevant actions for achieving key strategic objectives for the company.

General meeting best practices

Weekly meetings communicate fast, ongoing changes. Department meetings can be conducted on a weekly basis to keep track of key metrics so changes are as proactive as possible and reactive approaches are as fast as possible. These meetings are perhaps in danger of growing boring or routine, but they should actually be high pressure. With just a week to prepare and achieve assigned work, attendees should be very focused. These meetings are the closest to daily operational activities and the key way for departments to implement strategy and tactics and to see an impact.

Monthly meetings are conducted for those issues that need close, ongoing observation or have a short timeframe for implementation of solutions. Monthly meetings are used for improvement teams to ensure that work continues with a sense of purpose and to keep the cycle of sharing information, establishing deadlines, and achieving work on track. Meetings with trade groups can also be conducted on a monthly cycle, perhaps having two to three trade groups meeting on the same agreed day the first week of each month, with other groups meeting during the other weeks. As a result, the entire trade base will have met each month, one key method for quickly communicating, training, and rolling out changes in materials, specifications, scopes of work, and installation methods. For example, during the first month, the builder alerts trades about changes and asks for input; during the second month, the builder shares the specifications and new scopes of work; the third month is used to conduct training and the fourth month to implement changes. During each month, the trade representative communicates the information and specifications to their company, coordinates training, and prepares for the launch date. In this manner, any changes can be communicated, scheduled, trained, and implemented in a quarter.

An example of a bi-annual meeting could be a Trade Council. These meetings are held on a regular basis but are not needed every week or month. They are held to ensure that past goals and assignments have been achieved and to elicit the next goals from the group. A bi-annual basis provides a long enough period of time to gather and analyze trend data to evaluate the success of the previous work of the team. Like the annual meeting, the bi-annual is a critical event, since the parties will not be together again for another six months; so, it is vital that the meeting be well-organized, attended, coordinated, and facilitated. It is also vital that those attending be well-prepared, coming to the meeting with the proper information and decisions made in order for the meeting to be effective.

Annual meetings are used for significant events like strategic planning that may take an entire day (or up to three days) to conduct and in many cases are held offsite to make sure there are no distractions. These meetings need strong agendas built around a very focused goal for the event. The day (or days) is broken up into distinctly defined segments to compile a self-assessment of the organization and its environment, creating a list of Strengths, Weaknesses, Opportunities, and Threats (SWOT). The list can then be used to identify how the strengths and opportunities can be best taken advantage of and how the weaknesses and threats can be minimized and leveraged.

The Annual Strategic Planning Meeting takes the most advantage of staging various levels of meetings to gather information beforehand. It also takes advantage of the opportunity to communicate the results, ensuring that the strategic plan is accurate, understood, deployed, and implemented effectively at every level of the organization. Therefore, its information is shared at department meetings and specific team meetings formed perhaps specifically to address an aspect of the strategic plan.

E.2. Scopes of Work

Question: How much information should be in a scope of work to communicate a high performance home strategy?

QEHS Section Reference

(The topic in Section 5.16 regarding trade partners, supplier contract documents and Scopes of Work is repeated in sections 3, 6, 7, 8 and 9 and adapted for those departments)

5.1.6 Trade Partner and Supplier Contract Documents and Scopes of Work

Procedures shall be implemented to prepare and review the subcontracts and Design documents specific to the work of each trade utilized by the Design operation to ensure that builder requirements and typical homebuyer expectations will be met. Trade contracts, scopes of work, or other documents shall include mutually agreed-upon job ready conditions and procedures to follow when these conditions are not met.

9.1.3.2 Individual Trade's Performance Standards

Scopes of work or construction documents for trades providing warranty service shall define the warranty service performance requirements expected of the trades.

Recommendations

Having detailed scopes of work for implementing the high performance home strategy is critical. Scopes of work create clarity as to who is doing what work, how the work is performed, conditions for starting and completing work, and means and methods of construction. Resources for scopes of work for high performance homes can be found here:

- IBACOS High Performance Scopes of Work: http://www.ibacos.com/resources/publication (to be used alongside Linda Haas Davenport's "Scope of Work Program")
- NAHB Research Center Scopes of Work: http://www.toolbase.org/ToolbaseResources/level3.aspx?BucketID=5&CategoryID=62
- BuildIQ Toolbelt: http://toolbelt.buildiq.com/
- Atlanta Homebuilders Association Trade Partnering Guide

Commentary

Scopes of work are a vital component of the homebuilding process. They are an integral connection between construction drawings, details, material specifications, and trade contracts. The scopes of work communicate accurate and agreed-upon methods of construction, performance standards for work, and warranty responsibilities, and they can be used as a basis for documenting improvement activities.

The scopes of work should not be developed by the builder in isolation. A cross-functional team representing design and purchasing, home construction, and customer care should work closely with suppliers and trades to create scopes of work that communicate the key information needed to price the

work and execute it in the field in the agreed-upon manner. Working collaboratively ensures that the trades and suppliers (as experts in their areas) have an opportunity to incorporate the most up-to-date best practices to achieve the builder's performance standards (see FAQ B.1). Working together in this manner also makes sure the trades and the builder agree on the exact work requirements, training needs, process issues, acceptable materials, and installation sequencing and methods. It also identifies the working relationships between the various trade groups and between each individual trade and the builder. By using this approach, multiple departments and trade groups have a vested interest in each scope of work.

This level of detail and buy-in is critical to implementing a high performance strategy, because each component and sub-system must perform its intended function to enable the entire house to perform as designed. A failure by one trade to properly execute the work can result in the failure of another trade. For instance, if the insulation and air sealing trades fail, the house may not provide the occupant's desired level of comfort, which may be perceived as a problem with the HVAC system.

Scopes of work need to be used onsite as key reference documents kept by the trades and builder's staff in trucks and site offices. The scopes of work should be used as regular onsite verification tools and meeting reference materials. If the central source of information is the scopes of work, miscommunications and misunderstandings can be avoided. These documents communicate and enforce a single method of construction in order to ensure consistency from house-to-house and community-to-community, as well as across multiple trades performing similar work. Scopes of work are common basis of understanding that both the builder and trade have agreed-upon, helping to avoid conflicts onsite. They are living documents that should be updated as better methods, processes, and materials are discovered. This improvement can take place through regular trade meetings or Trade Councils (see FAQ E.1 and E.5).

Scopes of work also provide legal protection. Contracts, drawings, specifications, and scopes of work all provide solid evidence of the builder designing and proposing to build a quality home. For a builder, this evidence is critical when a homeowner brings a problem to the forefront that was caused by a trade not completing the work correctly.

E.3. Construction Documentation for High Performance Homes

Question: How much construction documentation should be created when implementing a high performance home strategy?

QEHS Section Reference

(The topic in Section 5.1.1, 5.1.3 and 5.1.6 is repeated in sections 3, 6, 7, 8 and 9 and adapted for those departments.)

5.1.1 Scope of the Design Operations

The Design operation shall define the scope of its Design operations.

5.1.5 Manufacturer's Product Installation Instructions

The Design operation shall develop, document, and implement procedures for obtaining and maintaining current copies of all installation/application instructions. Design operations shall ensure that all products/components are properly drawn, specified, and detailed.

5.1.6 Trade Partner and Supplier Contract Documents and Scopes of Work

Procedures shall be implemented to prepare and review the subcontracts and Design documents specific to the work of each trade utilized by the Design operation to ensure that builder requirements and typical homebuyer expectations will be met. Trade contracts, scopes of work, or other documents shall include mutually agreed-upon job ready conditions and procedures to follow when these conditions are not met.

9.1.3.2 Individual Trade's Performance Standards

Scopes of work or construction documents for trades providing warranty service shall define the warranty service performance requirements expected of the trade.

Recommendations

Examples of documentation for high performance homes can be found in the following locations.

Construction documents:

- http://www.buildingscience.com/documents/primers/bsc-building-america-greensburg-plan-1-drawings/view?searchterm=greensburg
- http://www1.eere.energy.gov/buildings/challenge/pdfs/bcqc_version_1_3_060408.pdf
- http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/builders_challenge_quality_criteria.pdf

Scopes of work and pre and post-installation checklists:

- IBACOS High Performance Scopes of Work: http://www.ibacos.com/resources/publication (to be used alongside Linda Haas Davenport's "Scope of Work Program")

- NAHB Research Center Scopes of Work: http://www.toolbase.org/ToolbaseResources/level3.aspx?BucketID=5&CategoryID=62
- BuildIQ Toolbelt: http://toolbelt.buildiq.com/

Installation step-by-steps:

- BuildIQ Toolbelt: http://toolbelt.buildiq.com/, http://toolbelt.buildiq.com/media/16795/dpstandardwindowsbs.pdf

Commissioning checklists:

- BuildIQ Toolbelt: http://toolbelt.buildiq.com/, http://toolbelt.buildiq.com/media/16789/dpentrydoorchk.pdf
- http://www.buildingscience.com/documents/information-sheets/reports/rr-0413b-snapshot-form/view?topic=/doctypes/researchreport
- http://www.buildingscience.com/documents/reports/rr-0413-the-snapshot-a-quick-description
- http://www.energystar.gov/ia/partners/bldrs_lenders_raters/downloads/InspectionChecklists.pdf

Commentary

To effectively build high performance homes, it is critical to document the full intent of the design and methodologies to construct the home. Traditionally, the primary purpose of construction drawings and scopes of work was to obtain permits, secure pricing for trades, and provide a set of “guardrails on the road” of how to build the house. Trades were relied on for their expertise in executing their particular area of the work, and the builder provided the general framework and schedule to get the house completed.

This methodology works for code construction, but as the builder progresses toward a full systems integrated strategy for implementing high performance homes, the road must become narrower, the guardrails higher, and the map much more clearly defined. Everything in a high performance house is about attention to detail. To increase energy efficiency, the thermal enclosure must be well airsealed with higher levels of properly installed insulation. With lower energy flows through the enclosure, water management becomes critical—flashing, drainage planes, roofing, and site drainage—all elements must be correct to prevent the intrusion of bulk water. In addition to bulk water management, materials must be selected properly to control vapor diffusion and enable the building assemblies to dry. HVAC systems must be correctly designed, installed, and commissioned to ensure energy savings and occupant comfort. All of these steps require a higher level of documentation than is traditionally provided in the industry today. Plans must have accurate details. Complex assemblies must be clearly drawn (in isometric, if necessary) to eliminate “field decisions” whenever possible. The plans and scopes of work must be free of conflicting details and specifications.

A list of the minimum documentation to consider developing includes:

- Construction drawings
- Scopes of work

- Material specifications
- Installation step-by-steps
- Pre and post-installation checklists (Job ready, job complete)
- Commissioning checklists

This documentation is used in all aspects of the design, construction, and servicing of the house.

- Design and purchasing: Comprehensive documentation aids in understanding potential conflicts prior to construction and helps to communicate the high performance strategy embodied in the Builder's Standard to all parties in the integrated design process (see FAQ C.1). Documentation is critical in getting accurate pricing and setting expectations for the work.
- Home construction: This documentation is used in the field for day-to-day evaluations of the work, as a training tool for new employees (builder or trade), as a quality assurance mechanism, and as a means to capture recurring construction issues (see FAQ G.1).
- Customer care: This documentation describes what was actually built and can assist in evaluating customer warranty issues. In addition, some of this documentation may be useful in the builder's homeowner manual. Some aspects of these documents may even be included in the customer manual, particularly in the manufacturer's maintenance instructions and warranty information.

E.4. Step-by-Steps

Question: How can various specific means and methods of construction be communicated effectively when executing a high performance home strategy?

QEHS Section Reference

(The topic in Section 5.1.1, 5.1.3 and 5.1.6 is repeated in sections 3, 6, 7, 8 and 9 and adapted for those departments.)

5.1.1 Scope of Design and Operations

The Design operation shall define the scope of its Design operations.

5.1.5 Manufacturer's Product Installation Instructions

The Design operation shall develop, document, and implement procedures for obtaining and maintaining current copies of all installation/application instructions. Design operations shall ensure that all products/components are properly drawn, specified, and detailed.

5.1.6 Trade Partner and Supplier Contract Documents and Scopes of Work

Procedures shall be implemented to prepare and review the subcontracts and Design documents specific to the work of each trade utilized by the Design operation to ensure that builder requirements and typical homebuyer expectations will be met. Trade contracts, scopes of work, or other documents shall include mutually agreed-upon job ready conditions and procedures to follow when these conditions are not met.

9.1.3.2 Individual Trade's Performance Standards

Scopes of work or construction documents for trades providing warranty service shall define the warranty service performance requirements expected of the trade.

Recommendations

Use step-by-step instructions to convey the building process to all members of the internal and external team. Examples of step-by-steps can be found here:

- BuildIQ Toolbelt: http://toolbelt.buildiq.com/, http://toolbelt.buildiq.com/media/16795/dpstandardwindowsbs.pdf, http://toolbelt.buildiq.com/media/16822/sogmonopenetrsbs.pdf, http://toolbelt.buildiq.com/media/16759/shpcustomshowerpansbs.pdf, http://toolbelt.buildiq.com/media/16893/dwallinstallationsbs.pdf, http://toolbelt.buildiq.com/media/39213/stcapplic3coatsbs.pdf
- http://www.dow.com/PublishedLiterature/dh_0415/0901b80380415783.pdf?filepath=styrofoam/pdfs/noreg/179-07303.pdf&fromPage=GetDoc
- http://www2.dupont.com/Tyvek_Weatherization/en_US/assets/downloads/01IntFlangeWindowAFTER.pdf

Commentary

Step-by-steps are visual and sequential guides to the work process. They are becoming a commonplace tool to convey specific information about how to properly put work in place. These documents can come from a variety of sources—manufacturers, consultants, trades, design team, or a combination of all of these. Ideally, step-by-steps are created in a collaborative environment with special emphasis on involving the trades. A program is likelier to succeed if all parties who use the documents have input and agree on the specifics. Manufacturers' instructions and associated standards should also be reflected in the documents; however, builders may find slight variations that comply with the intent of these standards but provide for lower risk and greater ease of installation. These modifications should be vetted by the team and approved by the manufacturer to establish material compatibilities, expected performance, and warranty applicability. The documents can begin and end with a "work ready" checklist. Formalizing the hand-off between trades will help ensure that the following trade does not cover up incomplete or insufficient work.

Step-by-steps are intuitive documentation for constructing a house; however, they can be used in virtually every stage of the process and can help drive consistency and accountability in all departments. For example:

- Design and purchasing: The design team cannot create designs that violate the intent or ability of those in the field to execute the step-by-steps. This encourages designers to acknowledge how the building is assembled and can inherently imbed the performance standards in the design. The purchasing team has a clear set of actions and methods expected of the trades when bidding projects and can use them as a basis for discussing opportunities for improvement.
- Construction: Step-by-step documents clearly convey the builder's expectations of the trade to execute the work in the field and can serve as the basis for pre and post-construction checklists. The step-by-step documents can serve as a training tool for new workers and site supervisors.
- Customer care: Step-by-steps document how materials and products were installed and by who when evaluating customer warranty claims.
- Step-by-steps serve as a guide for facilitating process improvement across all departments.
- Step-by-steps serve as a common language and tool to use when evaluating and documenting process improvement to speed construction or avoid failures.

E.5. Trade Councils

Question: What kind of mechanisms can be used to get trade partners to fully participate in executing a high performance home strategy?

QEHS Section Reference

(The topic in section 5.3.3 regarding trade partners is repeated in sections 6, 7, 8, and 9 and adapted for those departments.)

5.3.3 Trade Partner QEHS Program Support

The Design operations QEHS Management System shall support the QEHS, programs of trade partners, and other material and service providers. Communication shall be established between the Design QEHS representative of the company and the QEHS representatives of the trades to support the QEHS initiatives of each other. Feedback shall be periodically provided to the trade to enable the trade to improve the QEHS and safety of the work. Feedback shall be periodically solicited from the trade in order for the company to improve the QEHS and safety of the company's work.

Recommendations

A Trade Council can be a critical way to support the implementation strategy for building high performance homes. It can develop a forum for two-way communication not simply with the builder but between trades and can be a key way to help drive quality improvement efforts throughout the trade base. By creating a team approach to the homebuilding process, there is less of an opportunity to point fingers or lay blame. A blame-free workplace (see FAQ F.2) is one aspect of operational excellence, and a Trade Council can help foster constructive dialogue and interactive problem solving among the different parties; the builder does not have to play referee.

Commentary

In order to consistently build higher performing houses, everyone involved—including both the internal team (see FAQ A.1, F.1, and C.1) and the external team (FAQs C.1, H.2, and F.3)—must work together as a team. Generally, the builder is responsible for the larger tasks of land acquisition, marketing and sales, design, construction project management, and customer care. The trades are the ones who actually construct the house, so if a key strategy is to improve the house's performance, then their involvement is integral to the project. This point is important to understand, since many of the systems that are critical to a house's performance (e.g. the thermal enclosure) are touched by multiple trades. All parties must be aligned with a common goal and respect the work of others.

One method to begin collaborative dialogue between trades is through the formation of a Trade Council. This method brings together the leaders or representatives from key trades to improve their working relationships, and more importantly, to focus on the builder improving issues that the trades have in common.

Trade Councils can operate and meet in different ways. Council members may meet monthly as an executive committee, quarterly for all-member quality site walks, and biannually or annually for a formal business meeting with senior builder management. The bi-annual and annual meetings tend to be large events that last a full day and involve large numbers of trade representatives and builder team members. These larger events are a time to gather input on the trades' attitudes, conduct training, present changes for the upcoming year, and work together to address key strategic issues. The quarterly meetings tend to distribute the work over the course of a year or are used to conduct quality site walks. Each meeting addresses a particular area of focus.

Trade Councils are primarily about working together to reduce problems, frustrations, and impediments to efficiently and effectively conducting their work and achieving the performance standards set by the builder. This work can be from trade-to-trade or result in recommendations for how the builder can better facilitate the process at any stage of interaction with its trades. Ideally, the builder shares the strategic plan with its trades, enabling them to appropriately plan their business on an annual and quarterly basis. The meetings are led, facilitated, and organized by the trades, which shows a huge amount of respect and provides more control of their relationship with the builder. The councils are not recognition events or social parties but working sessions to improve business relationships and operational and strategic efforts during the homebuilding process.

Trade Councils have firm agendas and stay on schedule to ensure the best use of time. It is essential to start with only a few topics and make sure they are achieved, which will help demonstrate the council's value and secure its success and continuation. A typical structure for a council includes a Chair and Vice-Chair with future Chairs earmarked so that each trade has a chance to lead and participate over time. A set of bylaws can also help to define the relationships and organizational structure of the council.

Resources:

- http://www.tpcva.com/news/tpc-article-in-professional.html
- http://jarasek.com/PDFs/HomeBuilderTradeCouncils.pdf

E.6. Focus Groups

Question: How can focus groups help the team develop a high performance home strategy?

QEHS Section Reference

1.10 Customer Feedback

The company shall establish and implement procedures to evaluate customer satisfaction with the company's work. This assessment shall be conducted at least annually and shall identify overall satisfaction, as well as satisfaction with the functional areas of the company that come in contact with the new customer. This will include move- in and one-year customer satisfaction scores. These customer satisfaction scores will be shared with all builder employees. The results of this assessment shall be considered in analyzing the effectiveness of the QEHS Management System and initiating changes to the system. These procedures shall be documented and records kept of the customer feedback.

Recommendations

Third-party customer surveys are a good way to gather quantitative information about the homebuyer's experience and perception of the process for purchasing a home. Focus groups could be included in the implementation of a high performance home strategy, helping the builder gain more qualitative information regarding key local and regional demographic attitudes of high performing homes.

Commentary

There is danger assuming what the customer thinks. While customer satisfaction surveys and warranty data provide significant insight into customers' views and needs, they often do not provide enough detail. When developing a high performance home strategy, it can be valuable to use focus groups to gather details on specific areas. Past buyers, prospective buyers, and non-buyers can help to formulate marketing messaging and product positioning and to identify the key benefits for various demographic groups and customer profiles. While high performance homes can generally be said to be energy efficient, safe, healthy, durable, and comfortable, each of these attributes will likely have different meanings and value to different buyers. Using focus groups can help uncover these values.

Focus groups can also be useful when evaluating different system strategies and understanding the range of reactions sales agents may encounter with buyers. Consider this example—a new house series is being developed where the duct system is brought inside the conditioned space, requiring a mechanical room in the house and architectural soffits in a market where this is not standard practice. Here, a focus group can generate feedback prior to building models that may impact the floor plan layout or architectural treatment of the soffits.

INCREASED COLLABORATION ACROSS INTERNAL AND EXTERNAL TEAMS

F.1. Traditional Silos in Building Companies

Question: Will the internal and external team members associated with the organization be required to act differently when implementing a high performance home strategy?

QEHS Section Reference

1.2 Leadership

Senior management shall demonstrate leadership regarding the company's quality, environmental, health, and safety (QEHS) initiatives. Leadership is demonstrated by:

- Setting policy and performance expectations
- Communicating to the organization the importance of quality, safety, and the environment, as well as meeting customer expectations
- Providing resources
- Reviewing the effectiveness of the management system

A fundamental aim of leadership is the full integration of QEHS initiatives, which inherently includes a focus on integrating design approaches, problem solving, implementation, and measurement systems.

1.9 Corporate Communications

Procedures shall be implemented to assure communication exists between all areas of the company and the trades of the company. This includes identification of and communication to other functional areas to address recurring non-conformances in QEHS. There shall be procedures implemented to communicate with new home buying customers and to manage their expectations.

1.12 Company Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the overall company and their relationships to each other. Each sequence shall include all major planning, work, and QEHS assurance activities. Flowcharts are recommended where possible to assist with articulating the sequence.

2.1 QEHS Management Committee

A QEHS management committee shall be established and at a minimum shall consist of the QEHS Manager/Coordinator, a representative for each functional area, and a senior management representative. This committee shall meet periodically to review the regular operation of the QEHS

Management System, review the results of any internal audits, and discuss opportunities for improvement. Minutes of the committee meetings shall be documented.

2.2 Internal Audits

The company shall conduct internal audits at periodic intervals to assess effectiveness of the QEHS Management System. The company QEHS management committee, or similar group, shall provide the oversight of planning, conducting, and reporting results of internal audits of the departments covered under the QEHS Management System to assure that the policies and procedures are being met. The auditor shall be trained and independent of the functional area being audited. Results of these audits shall be documented. Deficiencies in the operation of the QEHS Management System will be identified and actions to correct any nonconformance shall be taken in a timely manner and further documented. Frequency and scope of internal audits shall be sufficient to ensure the effectiveness of the QEHS Management System but shall be conducted at least twice each year.

2.3 Annual Management Review

At least annually, the QEHS management committee shall review the operation and effectiveness of its respective systems with the senior management of the company. This annual review shall include a summary of the internal and external audits of the activities of each functional area of the company, performance measures, customer feedback, trade and supplier feedback, complaints, and recommendations from the QEHS department representatives. The annual review shall also include ensuring compliance with these requirements, setting new annual goals, and addressing needed changes to the management system. Records shall be maintained for each review. The records shall be in sufficient detail to disclose the participants, significant issues, conclusions, recommendations, and planned changes. The aim is to ensure that the QEHS Management System is working to the satisfaction of the leadership and management of the organization. The annual review is an opportunity to make significant changes to the QEHS Management System and make sure it is functioning effectively and efficiently.

(The topic in sections 5.1.1 and 5.1.2 is repeated in sections 3, 6, 7, 8 and 9 and adapted for those departments)

5.1.1 Scope of the Design Operations

The Design operation shall define the scope of its Design operations.

5.1.2 Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the Design operation of the company. This sequence shall include all major planning, Design phases by trades, and interactions with other departments during design and QEHS assurance activities. This information can be in list form or any other clear logical sequence. It is recommended that flowcharts are used where possible.

Recommendations

When developing the scope of operations and key processes, create interdepartmental dependencies and relationships that provide feedback and input. Each department must support the others in executing the company's high performance home strategy. Organizational "silos" can significantly restrict the flow of information that is the basis of this support.

Commentary

When identifying your core processes to implement a high performance home strategy, it is important to break down departmental and functional silos to help ensure an integrated approach. Breaking down the silos means that marketing and sales, design and purchasing, construction, and customer care must all be involved in a multi-disciplinary project team for the development, design, construction, sale, and occupancy of high performance homes. Operationally, your business is an interconnected set of processes and not a series of isolated blocks of activity with the minimum amount of overlap to "get the job done."

Using a matrix or spider diagram concept of creating and visualizing such teams can be more effective than the traditional hierarchical organizational chart approach. Operational processes should involve input from a variety of sources within the company. Getting this level of input can help make sure the appropriate level of documentation is created to enable site supervisors and trades to succeed in the field, ensure that the houses are designed to incorporate buildable solutions that will achieve the company's high performance home standards and meet customer needs, reduce long-term warranty items and associated risk, and increase customer satisfaction.

Examples of areas where organizational silos can create challenges with implementing a high performance home strategy include:

- Design creates a product that does not facilitate cost effective implementation of the company's performance goals
- Implementing high performance as simply a group of individual measures to be purchased and applied to the house like a coat of paint or a granite countertop, as opposed to a set of interrelated systems with inherent synergies and tradeoff opportunities
- Understanding customer satisfaction and warranty issues that high performance strategies may solve
- Inconsistent messages to customers from different departments regarding the company's high performance home product and strategy

Deconstructing silos can be addressed by focusing on leadership (FAQ A.1), corporate communications (FAQs B.1, E.1-E.6), improvement processes (QEHS Sections 5.3, 6.3, 7.3, 8.3 and 9.3), and especially through conducting audits and strategic reviews.

F.2. Blame-Free Workplaces

Question: What sort of organizational culture and employee mindset can lead to successful implementation of a high performance home strategy?

QEHS Section Reference

(The topic in section 3.3 regarding continual improvement (preventive actions and training) are repeated in sections 5, 6, 7, 8, and 9 and adapted for those departments)

3.3 Land Development Training Continual Improvement

3.3.1 Preventive Actions

The land development operation shall define and implement ongoing actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. When appropriate, these actions shall include recommendations of changes in land development procedures or documents. The effectiveness of the corrective actions shall be evaluated. When identified QEHS issues have not been eliminated, the plan shall be reassessed and additional appropriate actions initiated. Structured Plan-Do-Check-Act methodologies are recommended for the corrective and preventive actions, as are creating defined charters for improvement teams.

3.3.2 Land Development Operations Training

A program of training for all employees involved in land development shall be implemented. This training shall include identified opportunities for improvement that leads to continual improvement on department-specific metrics and reducing recurring issues in the land development operation. This training shall also include both task-specific skills and training in the operation of the company's QEHS Management System. Suggestions for and coordination of the training subjects from the construction operation and the warranty and service operation may be utilized to meet some of the requirements of this section. Land development personnel will be trained on the use of approved documents and procedures for ensuring that a complete and accurate land development documentation process meets the expectations of the customer. Land development personnel shall be trained on any different versions of the company's land development documents and when those different versions apply. Land development personnel shall be trained on applicable industry practices and safety regulations.

Recommendations

Create a company culture where providing input on how to improve work and pointing out issues are regular events that are recognized and rewarded. Doing so can significantly speed implementation and reduce the costs of a high performance home strategy. Leadership should endorse strategies like Plan-Do-Check-Act (PDCA) or Define, Measure, Analyze, Improve, and Control (DMAIC) to help provide the team with a structured or step-by-step approach to making improvements. Providing such tools during training events are important part of starting an improvement program and keeping it sustained and fresh.

Commentary

All too often in the homebuilding industry, the parties involved take an “Us vs. Them” approach. This approach shows up internally when leadership sets up goals that place two departments at odds with each other or when the builder pits trades against each other to garner the lowest price without regard for the long-term well being of the trade’s business or ability to perform quality work. When implementing a high performance homes strategy, this mentality can be disastrous. To truly succeed, an organization must strive to drive fear from the workplace. This task involves creating collaborative relationships internally and externally, as well as fostering a sense of innovation and support. When individuals fear retribution for seeking to make improvements to processes, systems, or strategies that may or may not succeed, then there will be little, if any, innovation.

To achieve the highest level of home performance at the lowest cost, it is necessary to create a company culture that encourages internal and external team members to freely identify improvements in any area, where nothing is treated as a “sacred cow.” Leadership should support creating teams to evaluate improvements and their associated risks, take deliberate steps to implement the improvement, and honestly evaluate its success or failure. If any individual or group believes they will be made into a scapegoat if success is not immediate and dramatic, then there will be little incentive to participate.

Using quality improvement teams to address problems and create solutions will only work if “blame” is not assigned. If the teams feel supported and safe, then they will be more open to trying new processes, suggesting new methods, testing them out, and being comfortable with change. This also means people will be more open and honest about current processes that do not work or on checklists and audits about the number and type of error or defects they are finding or even creating. Honesty means issues can be highlighted and improvements made.

Individuals, departments, and trades must be encouraged to identify opportunities, evaluate and modify processes, and allowed to succeed or fail while managing risks. The result may harness the entire mental capacity of the organization. While high performance homes costs more to build that code-minimum construction, it is critical to develop a mindset it every employee and trade to discover opportunities to drive out waste while maintaining consistent delivery or even improving results at lower costs.

F.3. Non Traditional Trade Partners

Question: Who should be considered "trades" when implementing high performance homebuilding strategies?

QEHS Section Reference

(The topic in sections 5.1.1, 5.1.3, and 5.1.6 is repeated in sections 3, 6, 7, 8, and 9 and adapted for those departments.)

5.1.1 Scope of the Design Operations

The Design operation shall define the scope of its Design operations.

5.1.2 Process Flow

The company shall define and document a sequence or sequences of activities (process flow) for the Design operation of the company. This sequence shall include all major planning, Design phases by trades, and interactions with other departments in the company during design and QEHS assurance activities. This can be in list form or any other clear logical sequence. It is recommended that flowcharts are used where possible.

5.1.4 Company Standards

Company standards shall be documented to define the requirements for workmanship, including tolerance requirements, industry standards, design procedures, and material specifications. These company standards shall be included in scopes of work or other agreed-upon document(s). When a conflict exists between local practice and other requirements (e.g. industry standards, manufacturer's instructions), there shall be a procedure for allowing exceptions while maintaining QEHS. All plans will be approved by an Engineer or equivalent for that city/state/region.

5.1.6 Trade Partner and Supplier Contract Documents and Scopes of Work

Procedures shall be implemented to prepare and review the subcontracts and design documents specific to the work of each trade utilized by the Design operation to ensure that builder requirements and typical home buyer expectations will be met. Trade contracts, scopes of work, or other documents shall include mutually agreed-upon job ready conditions and procedures to follow when these conditions are not met.

8.2 Construction Operations Inspections

8.2.1 General

Various inspections will be conducted by construction operations to ensure construction activities comply with codes, regulations, scopes of work, manufacturer's instructions, and company standards. Consistent with the builder's experience with each trade, the frequency and detail of these inspections shall be sufficient to ensure compliance. Construction operations will develop checklists and/or other documentation for recording the inspection results. The inspection criteria shall be consistent with the company standards and scopes of work. Items requiring corrections shall be recorded, corrected, and

their status documented. The construction operation shall take steps to ensure that any item requiring correction is not covered up before the correction is completed and documented. The QEHS Management System shall document the inspection process, including who performs the inspection; what is inspected; when and where it is inspected; and the process for recording and storing inspection documentation. The personnel conducting inspections will be trained in the inspection and documentation process.

8.2.2 Job Ready Inspection

The construction operations shall ensure the jobsite is prepared for the work of the next trade to begin via an inspection consistent with agreed-upon job ready requirements. If a trade is required to begin work when the job ready conditions are not met, the construction operations will ensure that the proper procedure is followed. Deviations from the job ready conditions shall be recorded on the job ready inspection record.

8.2.3 In-Process Inspections

Activities and work done in the construction operation shall have in-process inspections to ensure that the builder's QEHS policy and procedures are being followed. These inspections shall be documented. Items requiring correction shall be documented, corrected, and confirmed prior to the covering or concealment of any trade's completed work. The inspection criteria shall be consistent with the company standards and scopes of work.

8.2.4 Final Inspection

Each completed house shall have a final inspection. Any non-conformance(s) to the builder's documented standards for completed work shall be recorded. Corrections shall be completed and documented.

8.3 Construction Operations Continual Improvement

8.3.1 Corrective and Preventive Actions

The construction operation shall define and implement ongoing actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. The effectiveness of these actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated. Structured Plan-Do-Check-Act methodologies are recommended for the corrective and preventive actions, as are creating defined charters for improvement teams.

8.3.2 Construction Operations Training

A program of ongoing training shall be implemented for all construction operations employees involved in meeting QEHS requirements, and meeting new homebuyer customer expectations. This training shall include identified opportunities for improvement that lead to continual improvement on department-specific metrics and reducing recurring issues in the construction operation. Training of construction personnel shall include how to ensure that job ready conditions exist for all phases of construction work and how to maintain a safe jobsite. This training shall include both task-specific skills and training in the operation of the construction operation's QEHS Management System and shall be documented.

Recommendations

Consider including other members of the extended team to participate in regular meetings and provide data as you implement and continually improve high performance home solution sets. External designers and architects can be involved in conducting root-cause analysis, developing action plans, documenting corrective activities, and developing training tools (see FAQ E.3). Designers should be informed of internal actions to prevent recurring problems that can be eliminated at the design phase. HERS Raters have a wealth of information related to a building's tested performance and may be able to assist with documenting recurring building performance issues, transferring best practices from other builders, and providing ongoing data on key building performance metrics. A proactive dialogue with local building officials can provide them with insight into key building science-based strategies being considered for implementation. This type of dialogue can garner their feedback and reveal any concerns to address prior to construction. Taking this step can also proactively stop building officials from issuing stop work orders because they are unfamiliar with certain constructions practices. In addition, creating an environment of accountability and self-inspection by trades performing the work dramatically reduces the likelihood of failing third-party inspections. However, in order for this to be effective, trades must have a very clear understanding of what is being inspected, what the pass/fail criteria are, and how their work impacts and interacts with others.

Commentary

Designers, architects, HERS Raters, and building officials are integral players in how well the end product performs and meets the builder's internal standards and performance targets. But they are not typically considered part of the "trade base." These players can provide valuable insight and data on the successes and challenges of implementing various high performance home strategies, as well as facilitate streamlined inspections and verification processes.

One aspect of profitable building is even flow production and the ability to consistently meet predefined schedules for trades. The intent is to eliminate dry runs, rework, and delays due to incomplete items at key inspection points. Consider some of the inspections and their implications for a typical high performance house.

Construction Stage or Performance Verification	Trades Impacted	Inspector	Possible Delays
Foundation: Below-grade water management	Excavator/Foundation	Building official, site supervisor, trades	Rework to achieve proper drainage, capillary breaks; possible building official concerns regarding full vapor retarder under slab and grade beams

Construction Stage or Performance Verification	Trades Impacted	Inspector	Possible Delays
Above-grade water management	Drainage plane / siding installer, window and door installer, roofer	Third-party, building official, site supervisor, trades	Rework to address improperly installed drainage plane and flashing materials
Thermal bypass checklist	Framer, insulator, air sealing trade	HERS Rater, building official, site supervisor, trades	Rework of thermal bypass checklist items, stop work order to resolve building official's concerns regarding insulation / vapor control strategies
Insulation and other thermal enclosure component inspection	Insulator, window and door supplier/installer, framer	HERS Rater, building official, trades	Rework or stop work order to achieve appropriate grade certification for insulation installation (RESNET Grade 1, 2, or 3), or correct window/door specifications to achieve overall energy performance targets
Building air tightness	Insulator, air sealing trade, drywall installer, painter	HERS Rater, trades	Rework to meet maximum air leakage targets to comply with builder standards
Duct tightness and HVAC system performance	HVAC	HERS Rater, trades	Rework of installation to meet overall performance targets (e.g. duct tightness, system airflow, refrigerant charge, and temperature rise)

In addition, the design team has a critical role in the implementation of an overall high performance home strategy. Architects and designers are constantly blamed for an "ivory tower" mentality, creating designs that take significant gymnastics to achieve in the field and may embody significant flaws (e.g. windows placed in close proximity to bulk water drainage locations or building configurations with virtually

inaccessible spaces that cannot be easily and effectively insulated). One goal of an integrated design process (see FAQ C.1) is to deliberately engage the design team with the trades who are building the house, and give them an opportunity to evaluate the design as it progresses for constructability and opportunities for value engineering. Similarly, involve the HERS Rater early in the design phase to help ensure that the project will meet energy performance targets and to guide the design team on modifications (e.g. window areas or truss designs) that will enhance the energy performance and more cost effectively meet the overall energy performance targets. HERS Raters can also be a valuable resource to help train trades and “connect the dots” for them on the interrelated nature of the work in the house needed to achieve higher performance levels.

DISCIPLINED APPROACH TO QUALITY CONTROL

G.1. Checklists: Friend or Foe

Question: What purpose can checklists play in the implementation of a high performance home strategy?

QEHS Section Reference

(The topic in sections 8.2.2, 8.2.3, 8.2.4, and 8.2.5 regarding job ready, in-process, and final inspection processes are repeated in sections 3, 5, 6, 7, and 9 and adapted for those departments.)

8.2.2 Job Ready Inspection

The Construction Operations shall ensure the worksite is prepared for the work of the next trade to begin via an inspection consistent with agreed upon job ready requirements. If a trade is required to begin work when the job ready conditions are not met, the Construction Operations will ensure that the proper procedure is followed. Deviations from the job ready conditions shall be recorded on the job ready inspection record.

8.2.3 In-Process Inspections

Activities and work done in the Construction Operation shall have in-process inspections to assure that the builder's QEHS policy and procedures are being followed. These inspections shall be documented. Items requiring correction shall be documented, corrected, and confirmed prior to the covering or concealment of any trade's completed work. The inspection criteria shall be consistent with the company standards and scopes of work.

(Note: If an NHQ Certified trade contractor provides the builder with a copy of their inspection reports, this will satisfy this requirement for work of that trade provided the builder maintains a copy of this inspection document and periodically verifies the accuracy of the trade contractor's inspection.)

8.2.4 Final Inspection

Each completed house shall have a final inspection. Any non-conformance(s) to the builder's documented standards for completed work shall be recorded. Corrections shall be completed and documented.

8.2.5 Inspection Records

Records shall be maintained of all code compliance, third-party inspections, company QEHS inspections, and the correction of noted non-conformances.

Recommendations

Ensure that checklists address the most important issues for each functional area. Develop them by collaborating with all of the parties who are part of the work so the documents are user friendly and beneficial. Checklists should not be exhaustive pages with items to check off; rather, they should only

include items that are critical to the success of the work and recurring defect issues, as well as be representative of recent changes in the process. Sources for model high performance home checklists include:

- IBACOS High performance Scopes of Work: http://www.ibacos.com/resources/report (used in conjunction with the "Scope of Work Program" by Linda Haas Davenport)
- NAHB Research Center Scopes of Work: http://www.toolbase.org/ToolbaseResources/level3.aspx?BucketID=5&CategoryID=62
- Building Science Corporation's "SNAPSHOT" form http://www.buildingscience.com/documents/reports/rr-0413b-snapshot-form

Commentary

Checklists—who likes them? But when implementing a high performance home strategy, checklists can have a huge impact, ensuring work is done right the first time and preventing rework, which can save costs. In a high performance house there will be many changes to the products, materials, systems, and methods of construction that all need to be implemented correctly. Failure to do so can result in long-term defects and not meeting customer expectations. Checklists can quickly reinforce a scope of work, documenting specific responsibilities. Some areas where checklists can be helpful include:

- Critical aspects of a water management strategy
- Key components of the thermal enclosure and space conditioning strategy
- Performance test results (house tightness, duct system tightness, and heating and cooling system commissioning measurements)

Make sure the checklists are focused rather than pages of issues that are unessential. Do not assign one person to create the checklists in isolation from those who will use them. Having internal teams and trades participate in creating the checklists is also critical for achieving buy-in. Test them out and change them where needed. Checklists can also provide hard data for analysis and identify areas for improvement. If the data from the checklists are not reviewed and used with the team as a feedback mechanism, then the team will likely stop using them or check off all the right boxes simply to get the list done. Have the teams be honest on the checklist, noting where there are problems. It is important to emphasize that the information is not intended to assign blame but to identify recurring issues, which should then be addressed by finding the root cause and eliminating it. This process could include implementing training programs if the methodology is sound, developing new processes, using different materials, or creating ways of working.

Checklists should cover the job ready, in-progress, and job complete stages. They should be user friendly and comprehensive. A useful checklist will help reduce errors, rework, and defects. Keeping checklists provides a wonderful record of the work and proof that it was done correctly. Tracking the decrease in the amount of time spent on rework and warranty calls can show the impact on the bottom line and cause

buy-in and success. Ultimately, checklists are about reducing callbacks and warranty work and saving money.

Audits can support the effective use of checklists and inspections. Audits are a review of organizational performance and can help focus on what to improve. They are an opportunity to take a fresh, honest look at how processes are performing and identify what is going well and what needs to be changed. Leadership must seriously review and prioritize audits and the resulting data and put action plans in place in consultation with the team. It is helpful to try and identify risk costs or opportunity costs associated with the data. How much do water leaks cost the company? How much savings could be accrued by reducing HVAC callbacks from three per house to three per 100 houses? What value does this have in long term customer satisfaction and willingness to refer rates? Be prepared to receive some bad news while analyzing the data, but take a “glass half full” approach, since bad news reveals an opportunity to develop a way to improve. Audits give insights on how an organization is functioning in its key processes at various departmental levels, as well as in cross-department functions.

CONTINUOUS FEEDBACK AND IMPROVEMENT

H.1. Monitoring HERS Scores and Key Building Performance Metrics

Question: How can the data collected on building performance be used in continual improvement processes and to develop the next generation of high performance strategy?

QEHS Section Reference

1.11 Performance Measures

The company shall establish performance measures and goals that indicate the effectiveness of the QEHS Management System. These shall be defined, documented, and quantified for each functional area covered by the company's QEHS Management System. Progress toward meeting these goals shall be documented and reported quarterly to the management of the various functional areas.

8.3.1 Corrective and Preventive Actions

The construction operation shall define and implement ongoing actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. The effectiveness of these actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated. Structured Plan-Do-Check-Act (PDCA) methodologies are recommended for their corrective and preventive actions, as are creating defined charters for improvement teams.

Recommendations

Combine systems integration strategies with results of performance tests and the HERS Index to continually evaluate the high performance strategy. Look for opportunities to achieve the same level of performance at a lower cost or to make improvements at the same cost.

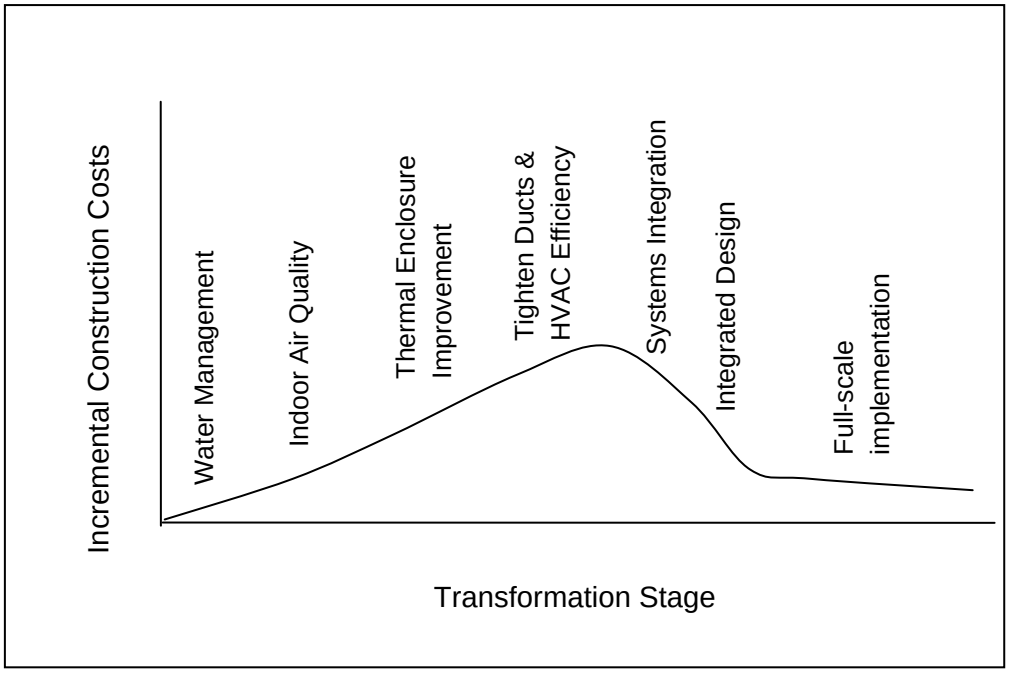
Commentary

FAQ D.5 delves deeper into the rationale behind using building performance metrics as key performance indicators in the adoption, sustained implementation, and improvement phases from an implementation standpoint. When undertaking improvement activities, gather, analyze, and use more specific data from the adoption and sustained implementation phases.

For example, an opportunity may be to evaluate achieving lower HERS scores while keeping current construction costs level. This effort could involve redesigning the framing and insulation systems to enable better energy performance, increasing the air tightness by using different sheathing materials, improving air sealing strategies, and looking for ways to simplify the mechanical system to reduce materials and the tonnage due to the thermal enclosure improvements. There may be costs involved in redesigning, creating new documentation, repurchasing, training, and rollout. Data from a variety of the

areas will be needed to make reasonable judgments and decisions. These costs could be mitigated by integrating this process into a new community rollout and new series of house plans (or into a mandated code change cycle). What is important here is to identify those metrics that impact the decision, use historical data to inform the decision making process, monitor them to see if the desired results are achieved, and if not, why. This process is commonly referred to as the Plan-Do-Check-Act cycle.

One set of metrics that could easily be overlooked are the individual building systems used to achieve the high performance strategy. These add up to the overall HERS Index; however, they are a result of many decisions. Periodically reevaluating them with the design team, HERS Rater, and trades may yield new ways to achieve the overall company standards. Similarly, there may be a five-year vision for the ultimate system strategy to provide the highest value to the customer at the lowest cost but to get there may take a number of iterative strategies. How to sequence these strategies is important to map out with the internal and external teams, gauge progress, and identify opportunities for transitions. The following is a schematic transformation curve a company should follow to implement high performance homes.



The first four steps can be done fairly prescriptively; however, the systems integration and integrated design stages are where the rubber meets the road. The following items are the broad categories that go into a HERS rating.

Component	Energy Impact
Insulation	Amount (R values), quality of installation
Windows	U value (conductive losses), SHGC (solar gain)

Building Air Tightness / Mechanical Ventilation	Heat loss / gain through infiltration / mechanical ventilation
Heating and Cooling System Performance	Equipment efficiency, distribution system conductive and air leakage losses to outside the conditioned space
Domestic Hot water	Equipment efficiency, water consumption
Lighting, Appliances, and Miscellaneous Electric Loads	Device efficiency, contribution to internal loads

These items can be individually and iteratively manipulated and a matrix developed with the resulting HERS Index providing a “price per point” for each incremental upgrade. This work will typically yield the highest incremental cost, as it simply looks at the first four stages in the transformation curve and does not inherently value systems integration. It also does not account of other attributes of various components and systems.

For example, evaluate advanced framing with 2x6 studs at 24” on center (o.c.) instead of 2x4 studs at 16” o.c. Numerous studies have shown that that a 2x6 wall uses less labor and material to build; however, the increased amount of insulation to fill the cavity may add to the cost. In addition, applying stucco over open frame construction may require reasonably stiff foam board and a one-coat application (as opposed to double metal lath with a traditional three-coat stucco application).

From an energy and building performance standpoint, the 2x6 wall is a superior system. But if only one component–going from 3 ½” cavity fill insulation to 5 ½” cavity fill insulation—is evaluated and all other parts of the system are held the same (e.g. no advanced framing, same exterior cladding system), then the cost increase will not justify the energy savings. However, if the whole system is evaluated, it may be cost competitive.

H.2. Engaging Trades in Continuous Improvement for Higher Performance Homes

Question: How can trades be used to continually improve a high performance home strategy?

QEHS Section Reference

7.3.7 Trade QEHS Assurance Program Support

The purchasing operations QEHS Management System shall support the QEHS, environmental and safety programs of trades, and other material and service providers. Communication shall be established between the purchasing QEHS representative of the company and the QEHS representatives of the trades to support the QEHS initiatives of each other. Feedback shall be periodically provided to the trade to enable the trade to improve the QEHS and safety of its work. Feedback shall be periodically solicited from the trade in order for the company to improve the QEHS and safety of the company's work.

8.3.1 Corrective and Preventive Actions

The construction operation shall define and implement ongoing actions to eliminate recurring QEHS issues. These documented actions shall include identification, prioritization, root-cause analysis, and development and implementation of an action plan. The effectiveness of these actions shall be evaluated. When identified issues have not been eliminated, the plan shall be reassessed and appropriate alternate actions initiated. Structured Plan-Do-Check-Act methodologies are recommended for the corrective and preventive actions, as are creating defined charters for improvement teams.

8.3.3 Trade Partner QEHS Assurance Program Support

The construction operations QEHS Management System shall support the QEHS, environmental and safety programs of trades, and other material and service providers. Communication shall be established between the construction QEHS representative of the company and the QEHS representatives of the trades to support the QEHS initiatives of each other. Feedback shall be periodically provided to the trade to enable the trade to improve the QEHS and safety of its work. Feedback shall be periodically solicited from the trade in order for the company to improve the QEHS and safety of the company's work.

- Training will be provided to all trades on basic quality principles, tools, and techniques.
- The builder will conduct regular monthly meetings with the trades to discuss QEHS, schedules, and opportunities for improvement (OFI).
- The builder will develop a Trade Council to improve communications with the trade base, ensuring that the builder can focus on how to make the “daily life of the trade better.” This effort will focus on OFIs that the builder needs to implement in its own business and practices.

Recommendations

Developing trades to become an integral part of the decision making process helps to grow the trust and interconnectedness that is needed for high performance homes. Instead of being viewed as a disposable

commodity, trades can help develop and achieve a high performance home strategy. Providing training, developing a Trade Council (see FAQ E.5), making trades part of an integrated design process (see FAQ C.1), and enlisting true two-way dialogue can help bring valuable experience and new ideas to the table.

Commentary

When looking for ways to improve the high performance strategy, do not overlook the opportunity to engage the trades who complete the bulk of the work associated with homebuilding. Using the company standards (see FAQ B.1) and the scopes of work (see FAQ E.2) as a starting point, request suggestions on how work activities, schedules, work handoffs from trade-to-trade, and/or sequencing can be improved to meet the desired performance result while driving waste (and frustration) out of the process. Using a Trade Council can be a perfect mechanism that provides a regularly structured forum for individual or group innovation. Look for opportunities to expand their input, such as getting involved in the integrated design process (FAQ C.1) or analysis of checklist data (FAQ G.1).

Trades should also regularly enlist in bringing new products, systems, and strategies to the table. Work with trades so they fully understand the role that high performance homes play in the overall the mission of the organization; foster an environment that continually evaluates (in a structured way) alternatives that meet the overall goals of the company and the intent of the company standards.

About IBACOS

Since 1991, IBACOS has helped builders address issues in the field so they can deliver better homes today and has conducted forward-thinking research that leads the industry to great homes tomorrow. The goal is an industry that delivers high performance homes that are designed and built to new standards of quality. For more information, please visit www.ibacos.com.

About the Best Practices Research Alliance

The Best Practices Research Alliance is a research-based community of production homebuilders collaborating with building performance specialists, quality and business management experts, and product and material manufacturers. Its ultimate goal is to identify and share how to deliver high quality, zero energy homes as an everyday part of mainstream America. These homes produce as much energy as they consume, while offering higher levels of comfort, durability, safety, and earth friendliness. The Alliance was created and is operated by IBACOS. For more information, please visit www.theresearchalliance.org.

Contact

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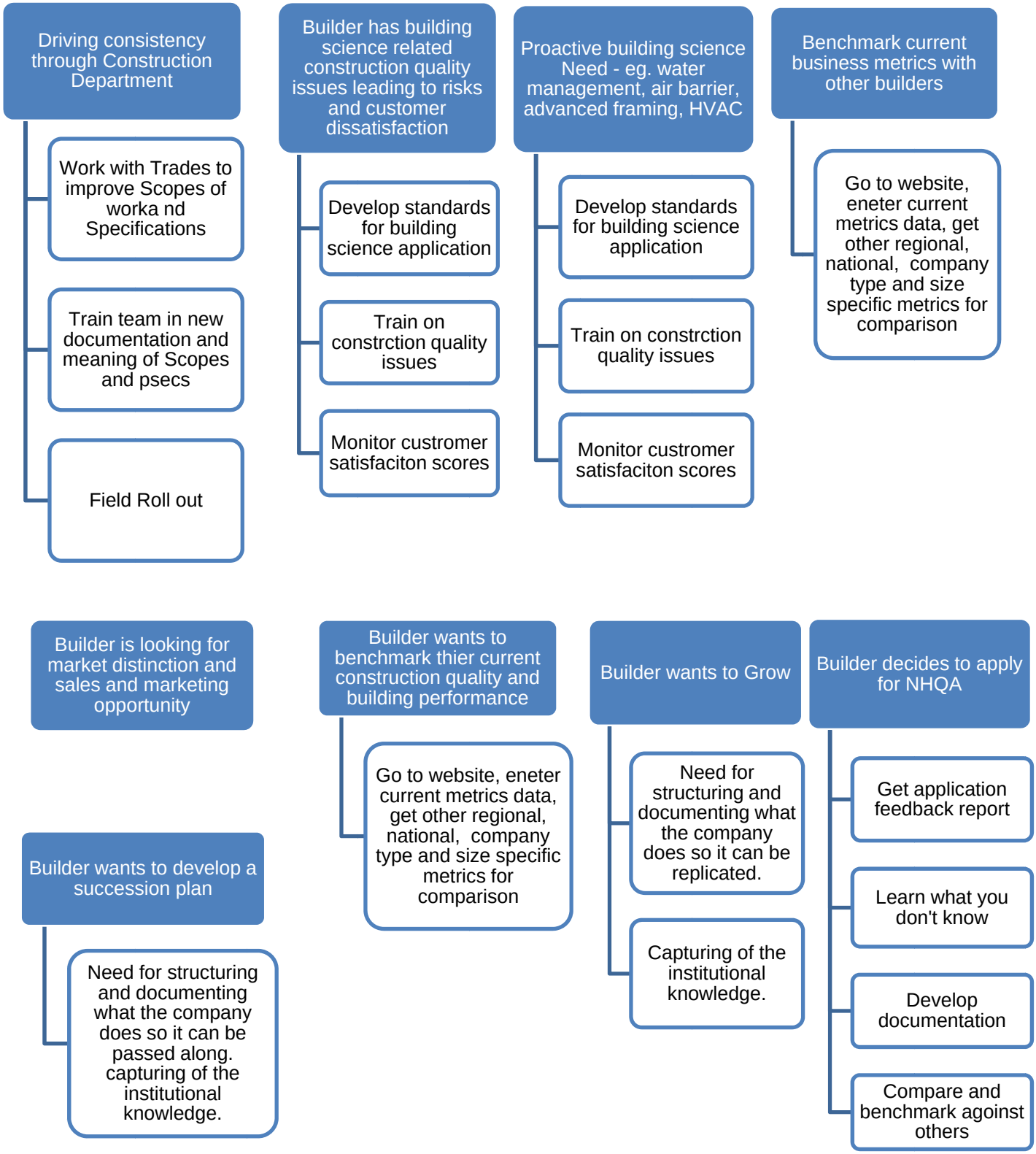
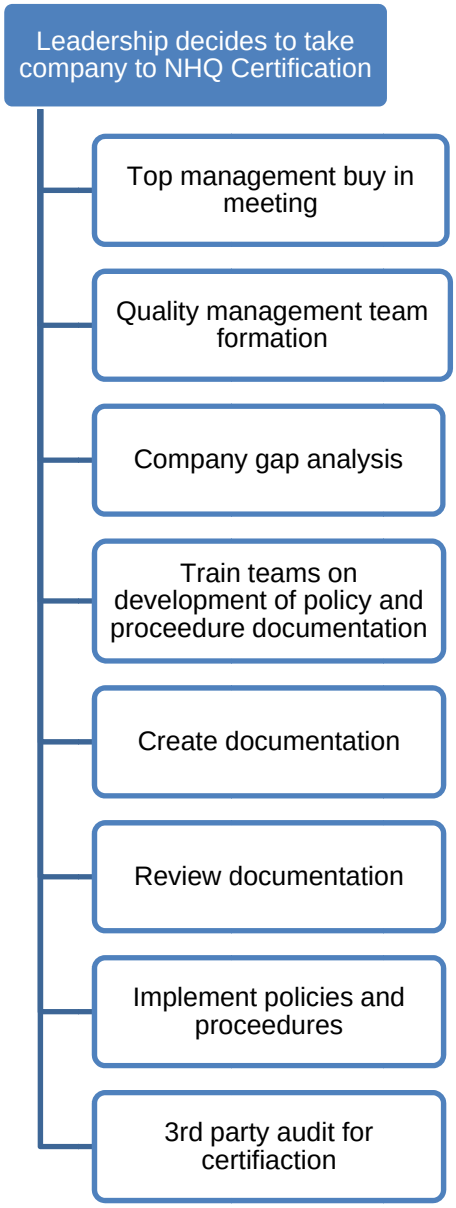
Appendix G: Points of Entry Diagrams

Points of Entry



Points of Entry



Appendix H: Business Metrics Presentation

Business Metrics

Denis Leonard, PhD
Business Excellence Consulting

October 26, 2010

Pittsburgh, PA

Business Metrics - FAQ D.5 and beyond...

- Business / Operational / Financial Metrics (Shinn)
- Change Management Building Performance Metrics (FAQ D.5)

- Without actual Business Benefits, why bother doing any of this High Performance Home stuff?

Business Metrics Discussion

- Measuring performance of Business Results
- Measuring performance of Product/Home & impact
- How many track these metrics (financial and home performance)?
- How many compare to best in industry benchmarks?
- Which of these are key for a corporate dashboard?

Additional Metrics ?

- Actual Referral Rate
- Employee satisfaction
- Trade / supplier satisfaction
- Defects
- Construction schedule cycle times

Risk

Cost of Quality?

‘Waste’

Call-Backs
Warranty
Insurance
Legal
Lost Time/ Productivity
Trades Impact
Customer Satisfaction
Referrals
Sales Price
Brand Value
Lost Opportunity
Etc….

Quality Experts Consulted

- Caldeira
- Criterium
- IBACOS
- QualityBuilt
- TrueNorth

Range 3-10% Sales.
Min. $10,000/ House

Cost of Quality

2011 Homes: 1,000

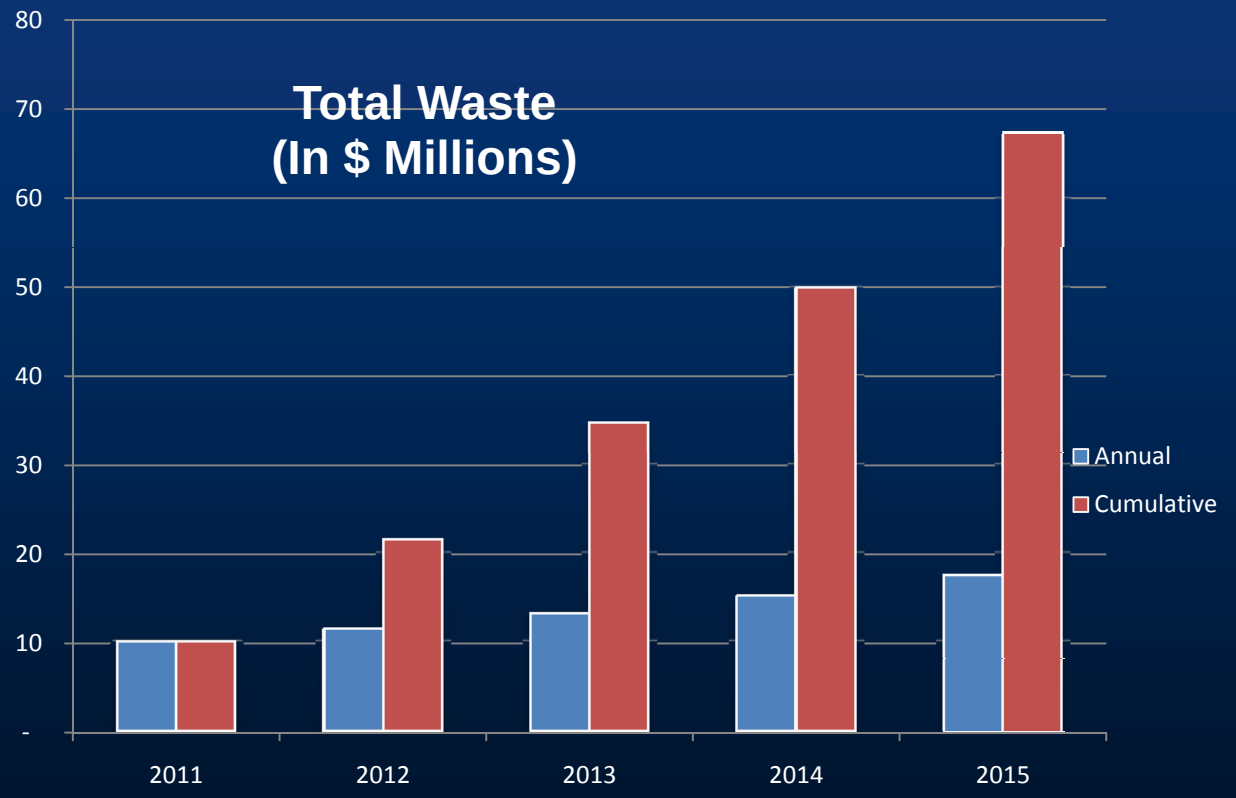
Annual Growth: 15%

Waste/Home: $10,000

Target Reduction: 50%

5-Years:
6,700 Homes
$33 Million Savings

Builder: 5-Year Assumptions



Significant Boost to Their Bottom Line

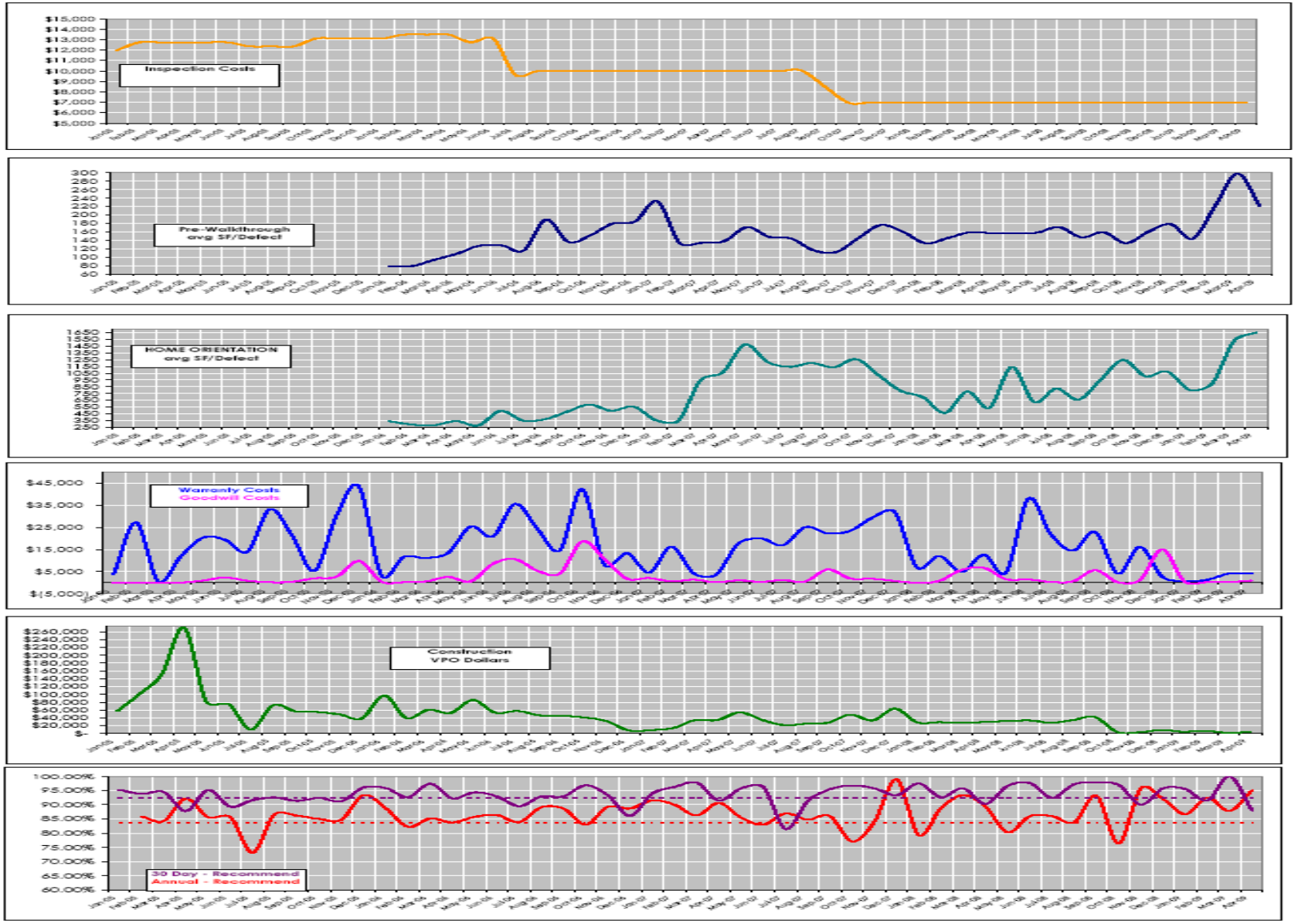
IBACOS | Home Quality + Performance |

Best Practices Research Alliance

Expert Meeting, October 26, 2010

Veridan Homes Stacked Metrics Charts

2005 thru 2009



Business Metrics Discussion

- How to tie Operational/Financial impact to Building Performance?
  - Leading and lagging indicators
  - Change driven by
    - Customer demand
    - Code and regulatory requirements
  - Cost and risk avoidance
    - Warranty and legal
  - Process improvement to achieve the above via change management and creating effective and efficient management

Business Metrics Discussion

- Creating apples to apples directly comparable sets of data, establishing common metrics or agreed conversions
- Benchmarking interest?

Appendix I: Transformation Pathways Case Studies Presentation

Transformation Pathways Case Studies

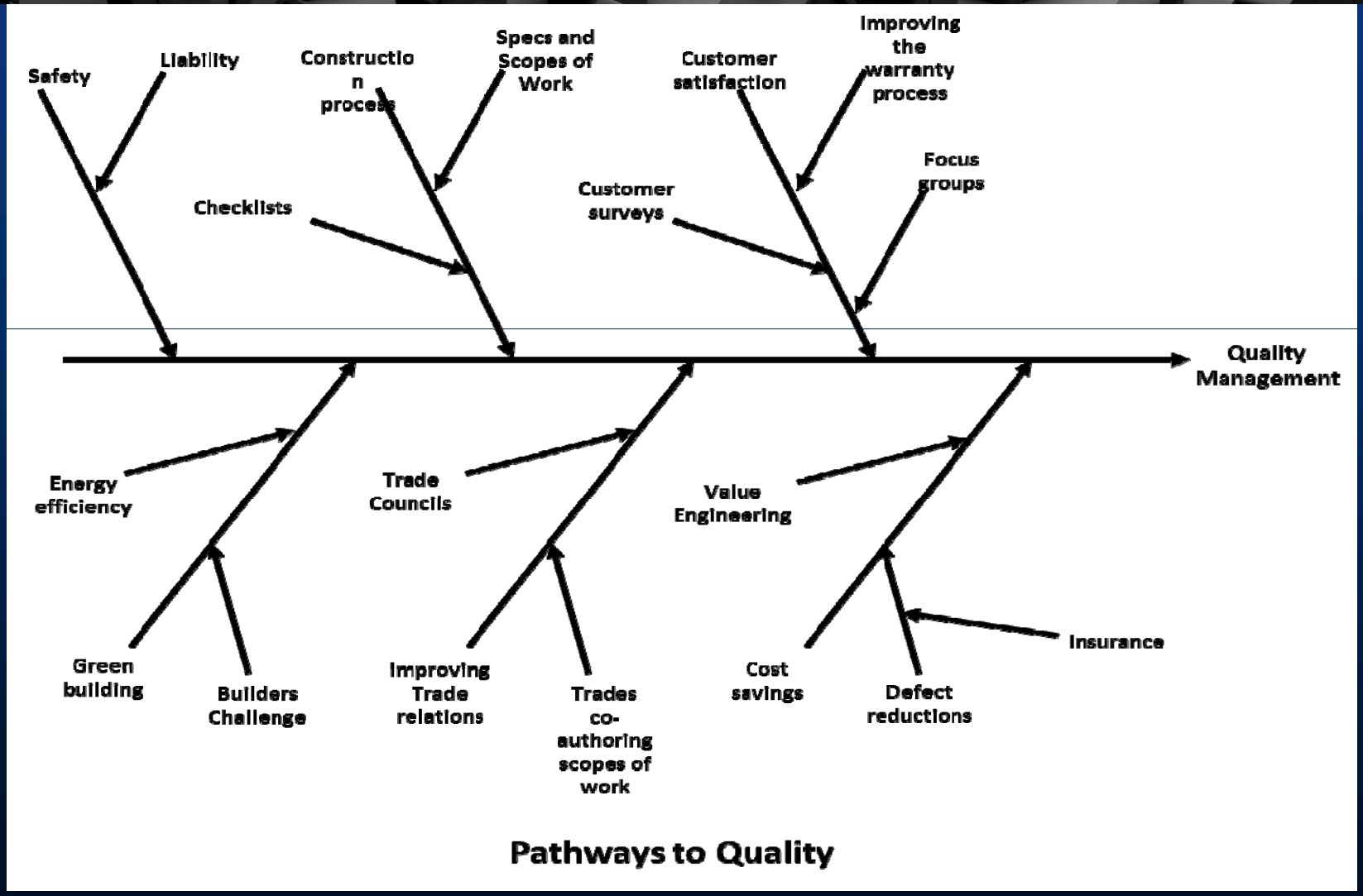
Duncan Prahl, RA
IBACOS

October 26, 2010
Pittsburgh, PA

Pathways – Case studies

- Two developed
- Using “Business Case” as models
- Still needs expansion
  - Include more discussion of work outlined in Flow Charts
  - Provide business metrics along the way – What is realistic and defensible?
  - Provide more quality management change actions directly tied to the QEHS?
  - Similar “Pathways to Quality Management”?
  - Timeline on Flowchart – How long would these take to implement?

5 . Pathways to Quality

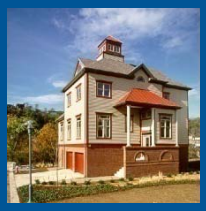


Pathways to Quality

Pathways Discussion

- Is the structure of the Pathways useful?
  - Are the current state situations plausible?
  - What other current state situations should be documented?
  - Surgical "change" strategy for the different consumer segments?
- Suggested solution sets reasonable, actionable, and practical?
- Provide more quality management change actions directly tied to the QEHS?
- Similar “Pathways to Quality Management”?
- Are the references to the FAQ’s reasonable?
- Holy Grail: case studies that clearly show improved business results from implementing the "high performance" home

Appendix J: Transformation Pathways Case Studies



IBACOS®
Home Quality + Performance

Quality Management for High Performance Homes

Casamedia Homes Case Study:

Moving from code construction to a High Performance Home using a Systems Approach strategy

Prepared by:
Duncan Prahl

In collaboration with:
Denis Leonard, Business Excellence Consulting

October 26, 2010

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Casamedia Homes Case Study

Current State of Business

Casamedia Homes is a production homebuilder that started operations in 1991 when three executives from a number of other builders decided to strike out on their own and formed a three way partnership. Casamedia currently builds homes in the 1,500 to 2,500 sq. ft. range, in a south-west metro area on lots developed by others. Hank Casedon is President, and continues to see opportunities serving the current market, however he considers that expanding to other territories or increasing the size of the company at this point is risky and wants to secure the business. Brian Amaldov is the VP of Operations, covering design, purchasing, estimating, and construction, and customer care. Casper Diamonte is VP of sales and marketing. Hank oversees lot acquisition, finance and human resources. Casamedia Homes had net margins of slightly over 6% in the best years, however with the recession they have lost money for the last three years. After looking for financing for the past 2 years, the partners gained access to private equity investors in 2010. Casamedia's operational model is to have all construction work performed by trade partners, many of whom have been with the company since the company was formed.

Casamedia's core business and mission is to provide affordable no frill homes is to deliver code standard homes to buyers at a rock bottom price by limiting the number of house plans and options available. There has been no focus on going green or energy efficient, rather the aim is. At the height of the market, there were approximately 9,000 housing starts in Casamedia's metropolitan area, and in the current market it is estimated that there are around 2,000 starts per year. Last year Casamedia closed 150 houses and is currently on track to close approximately 80 homes this year. This is down from 360 homes at the height of the market. The recession has forced layoffs, and Casamedia is currently operating with all their "A" players, most of who have been with the company for at least ten years. The three partners brought with them a number of business management strategies from their past experience with other builders and their educational backgrounds. Hank has an MBA he earned on evenings and weekends at a local community college while he worked full time with several large production builders. Casper has worked for Fortune 500 companies in marketing and direct sales, and Brian has a degree in Construction Management. The team used the experience they had gained at other companies to develop fairly comprehensive procedures and processes as a way to manage consistency of delivery and to quickly on-board new staff for the Casamedia. The focus was primarily in the construction area and has relied on inspection forms.

Casamedia has a well defined mission, vision and strategic plan, although with housing starts at less than 50% of the recent past, the management team is adjusting their strategy on a regular basis. They had been successful with a price competitive strategy, and were fortunate not to get caught with a large land exposure as the market collapsed. They have recently been buying lots at a deep discount, and have put significant pressure on trades and suppliers for price reductions in an effort to maintain their ability to compete as a low cost provider. In the 2000's they developed an even flow production schedule, in close

cooperation with their trade partners, however with the reduction in volume they have not been as successful at maintaining that flow of work for their trades. Each lot has site specific house plan generated by the internal drafting department. Brian meets regularly with all key trades to go over production schedules, quality items, and opportunities for cost reductions. In order to lean operations, Casamedia's site supervisors have had to increase the number of jobsites and homes, so they are rarely able to walk every house every day, and sometimes may only be able to drive by to verify a trade is on site. Brian has negotiated with his trade partners to complete job ready and job complete checklists which are primarily used as a mechanism for payment. They significantly increased the length of their job ready and job complete checklists but this has not resulted in reduced callbacks after closing. There is a heavy reliance on the team "knowing what to do," however with internal trade turnover a large part of the inspection process falls to the local building official.

Over the history of the company Casamedia has had their share of mildly dissatisfied customers, primarily after closing. A great deal of time is spent after closing on warranty calls, in an effort to prevent escalation to class actions and lawsuits. Casamedia included their minimum performance standards in their sale documentation and homeowner manuals, however they find customers rarely read this information. Casamedia has had several major failures, including one large scale problem related to a stucco application failure which lead to water leaks and mold in some areas. This problem impacted approximately 300 houses. The repairs came to roughly $9 million, which was covered in part by the builder, partly by the trades, and partly by insurance. As a result, Casamedia now has a stucco quality installation procedure, and water management strategy from roofs, walls, and windows to foundation drainage. Casamedia has also been regularly hit with storm water fines, and has been in the news over the years, generally prompted by a particularly disgruntled homeowner. Customer satisfaction scores at one month after closing are generally in the mid 80% range, with 11 month scores dropping by 10 – 15%.

Some other information on Casamedia homes include:
People

- 35 full time employees
    - 3 partners constitute the leadership team
    - 2 managers under Brian, one for preconstruction activities, and one for field operations
- Departments
    - Sales/ Marketing
    - Product Design & Drafting / Purchasing/ Estimating
    - Construction / Field Production / Warranty
    - Accounting / HR / Customer Satisfaction Survey (1 month and 11 month)
- Outsourced services
    - New product architectural and structural services – design only
    - Model Home merchandising
- Market
    - Buyers:
    - Primarily First Time Buyers

- Competition
  - 3 other production low priced builders
- Communities
  - Currently building in 3 separate communities,
  - One model home in each of those communities, with one selection center in the garage of one of the centrally located model homes.

One condition of the new equity is for Casamedia to develop a corporate responsibility policy and begin to participate in local utility energy efficiency programs. None of the partners have previous experience, however with current energy code changes being implemented on a local basis and the possibility of national energy and climate legislation, they see an opportunity. At a recent strategic retreat, they evaluated their strengths, Weaknesses, Opportunities, and Threats, and concluded that a rebranded series of homes, still targeted a first time buyers, but with an energy package 30% better than the 2009 IECC could let them stabilize production for at least the next five to seven years, and give themselves a unique market position in the first time buyer market.

After some research, the partners concluded that developing a new product line with slightly downsized houses that used space more efficiently and a whole house approach to energy efficiency with aggressive systems optimization and tradeoffs, they could probably be competitive in the market, and meet their new investors requirements. They also planned to work with their local utility to access incentives for a whole house approach and guaranteed utility bill program. Casper believes that this will provide Casamedia with the ability to create an entirely new marketing platform, and differentiate from their low price competitors. Brian has read that when properly executed, a whole house approach can actually lower warranty costs but is concerned about the upfront costs.

How should the partners proceed?

Proposed Course of Action

Key Quality Management Issues to Address

Casamedia has several key cultural and operational solutions in place that can help them make this transition these include:

- Leadership alignment on mission, vision and strategy, and agreement to aggressively pursue energy efficiency using a systems approach and leveraging tradeoffs to keep costs under control
- Regular contact with trades and the operational efficiency of even flow, however the recent pursuit of price reductions has left many trades somewhat skeptical of Casamedia's commitment to their businesses.
- The use of checklists, while at current not necessarily effective, can reinforce new work methods and training provided as the company transitions to a high performance home product line.

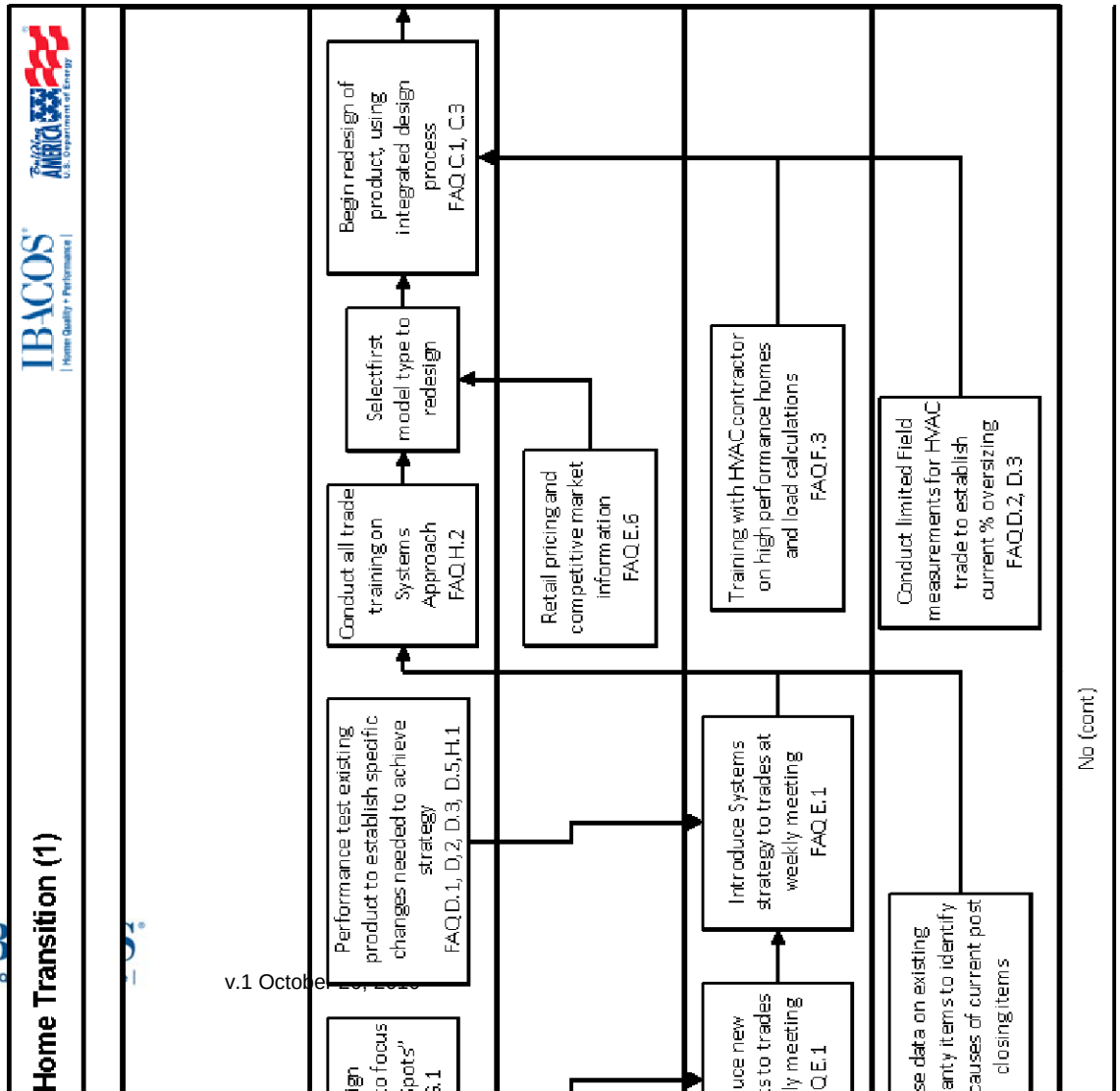
In consultation with a Home Energy Rater, and their utilities technical specialist, they decide to refine an existing product line of 6 houses, rationalizing them on a 2'-0" module to minimize waste, with 2'-0" 2"x6" advanced framing, a one coat stucco system over exterior foam, all HVAC inside the conditioned space of the house downsized and centralized mechanical system designs, high efficiency windows, airtight construction, and controlled mechanical ventilation.

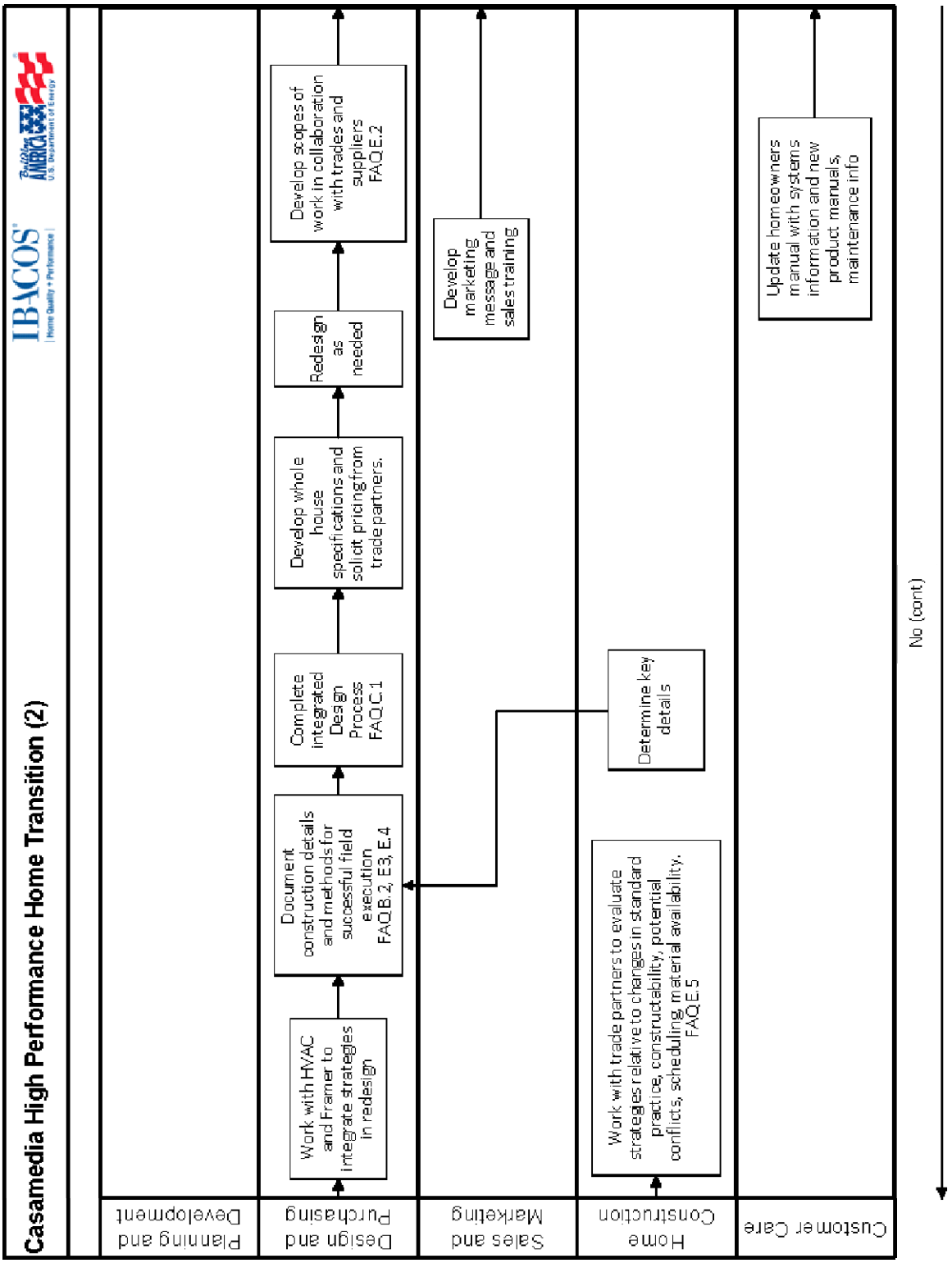
The challenges Casamedia faces include:

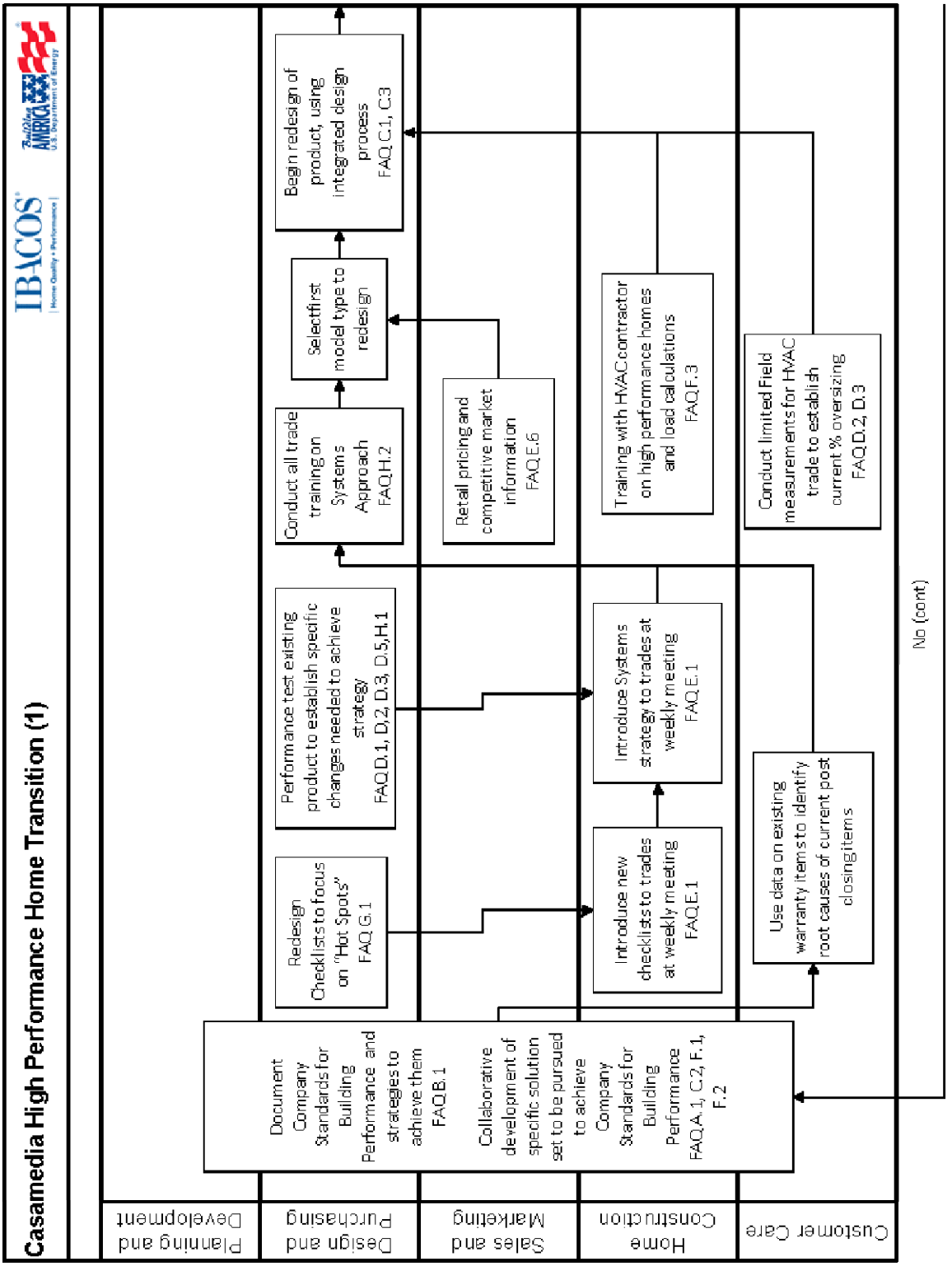
- Skepticism from the trade partners that the builder will take enough responsibility for making sure everyone else is doing the right job that will enable them to do theirs right.
- Reluctance from the HVAC contractor to significantly downsize the equipment for fear of even more callbacks than he already has.
- Getting building official approval for the new way of building
- Implementing an advanced framing strategy.

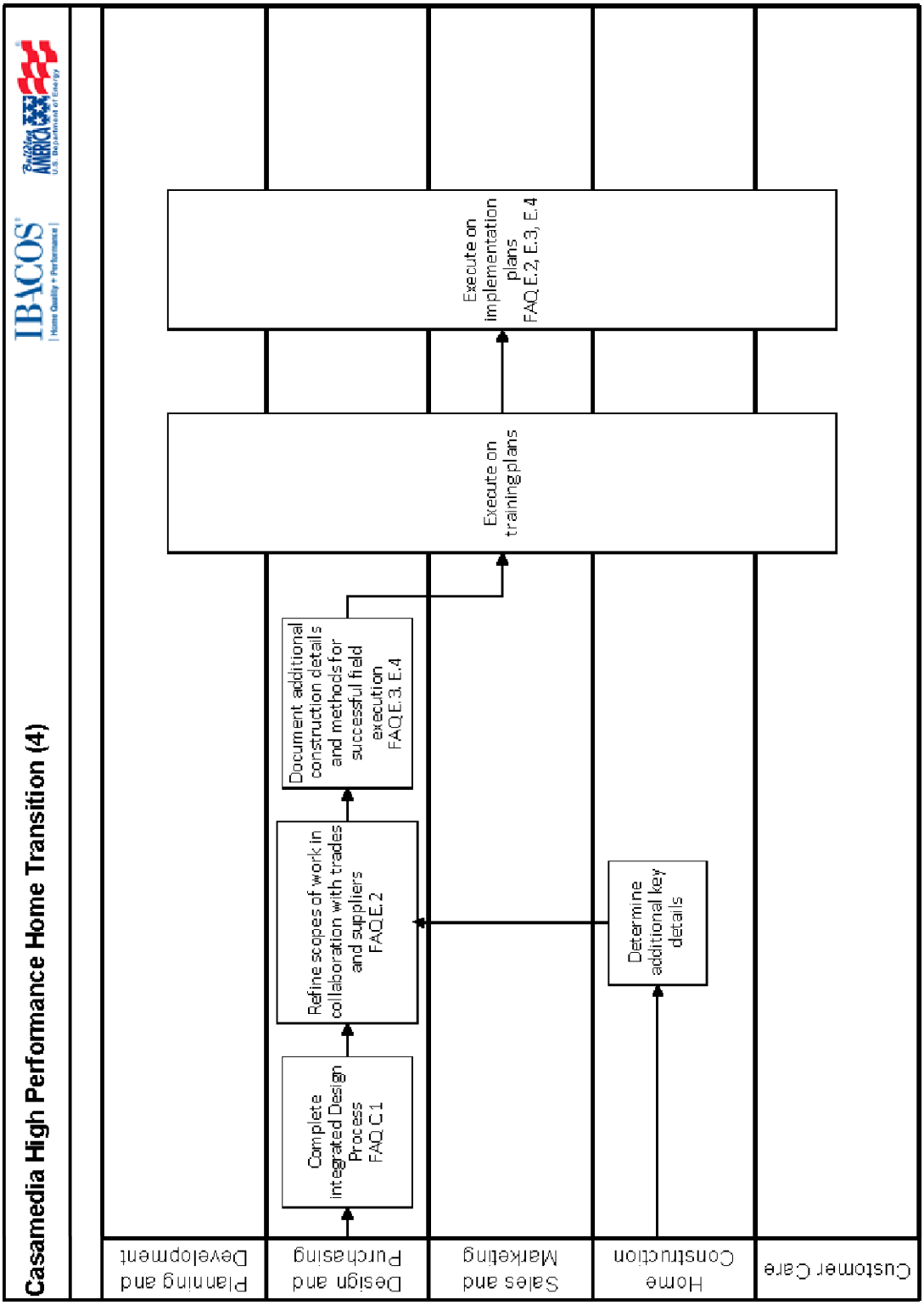
The following flow chart provides a suggested pathway to higher performance homes using a systems approach

Flow Charts




Casamedia High Performance Home Transition (2)
IBACOS
Home Quality + Performance
Planning and Development
Design and Purchasing
Sales and Marketing
Home Construction
Customer Care
Work with HVAC and Framer to integrate strategies in redesign
Document construction details and methods for successful field execution FAQ B.2, E3, E.4
Complete integrated Design Process FAQ C.1
Develop whole house specifications and solicit pricing from trade partners.
Redesign as needed
Develop scopes of work in collaboration with trades and suppliers FAQ E.2
Develop marketing message and sales training
Work with trade partners to evaluate strategies relative to changes in standard practice, constructability, potential conflicts, scheduling, material availability. FAQ E.5
Determine key details
Update homeowners manual with systems information and new product manuals, maintenance info
No (cont)


Casamedia High Performance Home Transition (1)
IBACOS
Planning and Development
Design and Purchasing
Sales and Marketing
Home Construction
Customer Care
Document Company Standards for Building Performance and strategies to achieve them FAQ B.1
Collaborative development of specific solution set to be pursued to achieve Company Standards for Building Performance FAQ A.1, C.2, F.1, F.2
Redesign Checklists to focus on "Hot Spots" FAQ G.1
Performance test existing product to establish specific changes needed to achieve strategy FAQ D.1, D.2, D.3, D.5, H.1
Conduct all trade training on Systems Approach FAQ H.2
Select first model type to redesign
Begin redesign of product, using integrated design process FAQ C.1, C.3
Retail pricing and competitive market information FAQ E.6
Introduce new checklists to trades at weekly meeting FAQ E.1
Introduce Systems strategy to trades at weekly meeting FAQ E.1
Training with HVAC contractor on high performance homes and load calculations FAQ F.3
Use data on existing warranty items to identify root causes of current post closing items
Conduct limited Field measurements for HVAC trade to establish current % oversizing FAQ D.2, D.3
No (cont)


Casamedia High Performance Home Transition (4)
IBACOS
Home Quality + Performance
Planning and Development
Design and Purchasing
Sales and Marketing
Home Construction
Customer Care
Complete integrated Design Process FAQ C.1
Refine scopes of work in collaboration with trades and suppliers FAQ E.2
Document additional construction details and methods for successful field execution FAQ E.3, E.4
Execute on training plans
Execute on implementation plans FAQ E.2, E.3, E.4
Determine additional key details

About IBACOS

Since 1991, IBACOS has helped builders address issues in the field so they can deliver better homes today and has conducted forward-thinking research that leads the industry to great homes tomorrow. The goal is an industry that delivers high performance homes that are designed and built to new standards of quality. For more information, please visit www.ibacos.com.

About the Best Practices Research Alliance

The Best Practices Research Alliance is a research-based community of production homebuilders collaborating with building performance specialists, quality and business management experts, and product and material manufacturers. Its ultimate goal is to identify and share how to deliver high quality, zero energy homes as an everyday part of mainstream America. These homes produce as much energy as they consume, while offering higher levels of comfort, durability, safety, and earth friendliness. The Alliance was created and is operated by IBACOS. For more information, please visit www.theresearchalliance.org.

Contact

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Appendix 1.B: K. Hovnanian Homes Southern California Gap Analysis

IBACOS®
| Home Quality + Performance |

K. Hovnanian Homes Southern California's High Performance Blueprint

Delivering High Performance Homes

Prepared by: Graham Davis and Duncan Prahl

March 10, 2010

KHovnanian® Homes™

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Background

IBACOS has been studying the homebuilding industry for close to 20 years and has developed a standardized methodology for characterizing the major functions within a building company, large or small. Each company typically does things a little differently, and also labels major phases and work activities by different names. However, we generally find that there are more similarities than differences, from one company to another. We believe that when a builder wants to implement a significant change in their business – for example, go Green – it is critical to create a holistic picture and plan of what is about to be undertaken in order to transform the company or division from its current state to tomorrow's sustainable, competitive position in the marketplace.

The first step in this process is to identify key goals and document current and future strategic initiatives and processes that can provide an overall framework for moving towards the consistent delivery of High Performance (HP) homes. The creation of this "High Performance Blueprint" is important to facilitate development of executive vision, foster inter-department understanding and communications, and drive towards successful implementation and continuous improvement in the field.

K. Hovnanian Homes Southern California's High Performance Blueprint

Such a transformative journey was started by K. Hovnanian on December, 9th, 2009 when IBACOS facilitated a half-day, kick-off event in Ontario, CA, at K. Hovnanian's Ontario Group and Southern California Division headquarters. The overall objectives of this first session were to:

- Meet all key players on the K. Hovnanian Ontario Group and Southern California Division (K. Hovnanian So Cal) management team
- Document "Where K. Hovnanian So Cal Homes wants to be in three years—by mid-2011"
- Document "What K. Hovnanian So Cal Homes does today"
- Document "What K. Hovnanian So Cal processes and activities need to change to achieve the goals identified"
- Plan next steps in the planning, design, development, and construction of a Building America (50% beyond the BA Benchmark) prototype home that also surpasses Title 24 (2009) by 30%, ENERGY STAR® and complies with the new mandatory California Green Building Code which will go into effect August 1, 2010.

The following individuals from K. Hovnanian So Cal, K. Hovnanian Corporate, and IBACOS were in attendance at the Strategic Planning session:

- K. Hovnanian So Cal: Shane Maloney - Director of Construction and Operations, Allen Donnelly - VP of Purchasing, Wally Miller - Area President, Paul Hepler - Production Manager, Debora Wilder - Documentation & QA of Policies and Procedures, Daniel McPherson - Quality Assurance Manager, Ruth

Stickley - Director of Purchasing, Mike Rothnie - Home Owner Service Manager, Kari Roland - Director of Marketing, Cheryl Contreras - Sales & Marketing (Ontario Group), Angela Wilson - VP of Planning

- K. Hovnanian Corporate: Dean Potter - Corp VP of Quality & Home Production Processes
- IBACOS: Brad Oberg, Duncan Prahl, Graham Davis

Status and Next Steps

K. Hovnanian So Cal must still do the following:

- Evaluate and prioritize these processes and activities based on their value to K. Hovnanian and their business/stakeholders.
- Prioritize the top opportunities/projects to pursue and brainstorm work activities for each one.
- Identify "tools" that are needed in order to achieve the high performance strategy.

IBACOS and K. Hovnanian So Cal have a agreed on a specification package that meets the Building America 50% goal, achieve over 30% savings with respect to Title 24, and align with K. Hovnanian So Cal's ENERGY STAR offering and future green building codes. The rollout of the plan is underway and construction is currently set to begin between May 15th and June 1st of 2010.

Company Background and Market Position

Founded in 1959, Hovnanian Enterprises, Inc., designs, constructs and markets a variety of for-sale housing in 18 states. K. Hovnanian ranks among the largest homebuilding companies in the U.S., with total revenues of $1.6 billion on 5,362 home deliveries in fiscal 2009. The Company's homes are marketed and sold under the trade names K. Hovnanian® Homes® (K. Hovnanian), Matzel & Mumford, Brighton Homes, Parkwood Builders, Town & Country Homes, Oster Homes and CraftBuilt Homes. K. Hovnanian builds for buyers ranging from first-time purchasers to luxury buyers, and has successfully developed active adult communities as well.

K. Hovnanian's strategy is to achieve powers of scale and market concentration by establishing a large presence in each of its markets. K. Hovnanian leverages its market position by providing mortgage and title services to homebuyers. K. Hovnanian has also been a leader in implementing streamlined processes and technology solutions for home sales and construction, leading to improved operational efficiencies.

The Southern California Division is part of K. Hovnanian's Ontario Group (Southern CA, Northern CA, and Phoenix, AZ markets) and serves buyers north of Los Angeles and south to San Diego. In 2010, most of the construction is focused around the Inland Empire, with projects in San Diego and Palm Springs in the final phases of activity. K. Hovnanian So Cal built approximately 543 houses in 2009, down from 1300 in 2008 due to significant weakness in the California housing market. Their homes are built primarily on land they develop themselves. The division currently has about 56 employees. As the division moves forward, they intend to focus

on the acquisition of finished lots rather than developing land themselves. The division is broken down into the following departments: Land Planning, Development, Marketing, Purchasing, Sales & Closings, Land Acquisition, Home Owner Services, Construction, Accounting, and Executive. The primary competition in the area includes: KB Homes, Lennar, Pulte/Centex Homes, DR Horton, Ryland and Richmond America. IBACOS became involved with the Ontario Group in 2008 when evaluating HVAC design and installations in Northern CA, It was decided in 2009 to embark upon a Building America project with K. Hovnanian So Cal, working to achieve 50% whole house energy savings with respect to the Building America Benchmark.

K. Hovnanian has been exploring high performance approaches in various parts of the country, notably in Maryland, Delaware, and New Jersey. K. Hovnanian So Cal has been participating in the ENERGY STAR Homes program since October of 2009. Their standard practice included performance testing for house tightness and HVAC system tightness, and a Quality Insulation Inspection, all performed by a third party HERS rater. California implemented a new set of Title 24 energy standards for new construction effective January 1, 2010, and it is anticipated that a mandatory Green Building Code is to go in effect in August of 2010. K. Hovnanian. So Cal is looking to stay ahead of these minimum regulations with cost effective high performance home strategies that can be successfully explained and add value for potential buyers. Energy efficiency is seen as a key differentiator, and can be related back to value to the buyer through reduced energy bills. In addition, CA utilities have incentive programs in place from 2010 – 2012 that can offset some of the incremental costs associated with achieving a minimum of 15% savings above Title 24, (Tier 1) and 30% and higher (Tier 2). Preliminary analysis indicates that if K. Hovnanian achieves the 50% Building America whole house savings target, they will be above 30% with respect to CA title 24, and would therefore be eligible for Tier 2 incentives.

Goals

To start the Strategic Planning session, the team was asked to identify the primary goals for the project. The following items were identified to be achieved through the Building America prototype house development experience. These goals were broken down into two categories, one for the Ontario Group / Southern California Division, and one for Corporate.

Ontario Group / Southern California Division

- Assure alignment exist between California Title-24 and the High Performance (HP) strategy.
- Gather data on what HP and "green" means to the potential buyer. What is the level of its importance in their buying decision?
- Move divisions from "playing catch up" to leading the market in HP housing. All divisions must have a "one step ahead" mentality.
- Gain a full understanding of all the impacts of local, regional and national programs, i.e. - Tier 1 & 2, tax credits, ENERGY STAR today and 2011/2012, and the California Green Building Standards.

- Develop a trade training program and new system evaluations (i.e. stucco over insulation, ducts in conditioned space).
- Learn to make the most of incentive benefits:
    - Utility rebates
    - Federal tax credits
    - ENERGY STAR for consumer recognition
- Gain an understanding of trade interaction towards new systems and convey to the trades the level of responsibility K. Hovnanian is taking to control all performance related systems in the house (thermal enclosure, HVAC, building tightness).
- Develop energy related inspection items for integration into the "Hyphen" program solution.
- Learn to drive cultural change in trade partner behavior towards "first time" quality and HP construction practices.
- Continue the integration of the HP story into home marketing.
- The evaluation of construction drawings and scopes of work to better communicate HP strategies and specific execution criteria.
- A "number one" priority is to develop cost effective analysis data on the transition to HP home building.

Corporate

It was noted that while many of the above goals can benefit the company on a national level, the following are goals specifically aimed at meeting corporate objectives:

- Perform excellent project documentation to allow the transfer of knowledge to other divisions and groups.
- This prototype effort is to be another building block in the national strategy to demonstrate that HP home construction is a reasonable target for production.
- Finding least cost solutions while achieving HP objectives. (Value engineered solutions).
- Document thorough cost comparisons for other divisions/groups to evaluate.
- Learn new product evaluation methods at purchasing.
- Enable corporate transfer of HP strategies.

Operational Activities

The chart below shows our view of the major phases of a 'generic' homebuilding company's operations, along with the key work activities for each phase. Builders typically name each major phase slightly differently, so we have selected names that should be understood and applicable to a broad cross section of builders. We also do not assume that every builder undertakes the same set of activities within each phase, or in the order shown. Rather, we see this map as a working tool that can be adapted specifically for any homebuilding company. The following pages provide an overview of each major phase of the process, the work activities in each, our view of some Best Practices for achieving high performance homes, and specific activities identified by K. Hovnanian So Cal. There is also a section for "tools" that are needed to execute each activity. Tools could include, but are not limited to, instructions, surveys, scopes of work, drawings, details, training programs, or checklists.

Planning & Development	Product Design & Purchasing	Marketing & Home Sales	Home Construction	Customer Care
Company Analysis	Market/ Consumer Research	Market/ Consumer Research	Permits	Customer Relations/ Communications
Market Evaluation	Initial Design	Marketing Plan/ Positioning	Scheduling	Service Requests/ Resolution
Vision/ Program Definition	Value Engineering	Promotional Campaign	Contractor Relations	Customer Satisfaction Surveys
Land Acquisition, Development & Construction	Budgeting/ Development	Options & Upgrades	Home Construction	1st Year Warranty
Governmental Approvals	Final Design	Model Homes	Inspections	On-going Warranty
Financial Pro-Forma	Specification	Sales Team Development	Customer Communications	
Team/ Resource Coordination	Scopes of Work	Realtor Program/ Relations	Closing/ Home Handover	
	Bidding/ Contracts	Sales/ Design Center		
		Customer Sales/ Financing		
		Customer Education/ Communications		

Planning & Development

This stage is where high level strategic activities take place within an organization. These include developing strategy / mission / vision, determining market position and location of projects, evaluating competition, evaluating organizational operations, determining overall value proposition to the buyer, land acquisition and development (if applicable) and human resources.

	Planning & Development				
	1	2	3	4	5
	Company Analysis	**Market/ Consumer Research**	**Company Vision/ Program Definition**	**Land Planning/ Acquisition/ Development**	**Governmental Approvals**
High Performance Best Practices	• Assess current business situation • Benchmark company against industry • Investigate home performance certification programs • Test current homes' performance	• Evaluate market / Conduct regional study • Analyze competition • Survey customer values • Analyze current product offering • Assess trade capabilities	• Define short and long-term vision for company • Define goals, company culture, markets and customers served. • Describe how high performance fits in with vision, goals, etc. • Set energy efficiency/ high performance/ green strategies and criteria ("performance criteria")	• Define/ Plan for solar orientation • Use performance criteria as a part of competitive advantage for land acquisition	• Position high performance housing as an aspect of the approvals process
K. Hovnanian So Cal Specific Activities	• Determine if first prototype will be sold unbranded, simply as a spec house with upgraded features or as kick off to a new strategy/brand	• Understand limits of cost and value to consumer & cash flow (What are they willing to pay for high performance?) • Evaluate "brand" value to buyer vs. performance of product and cost with purchasing • Determine specific name with which to brand prototype • Do competition analysis of HP strategies and marketing methods			• Schedule introduction meeting/presentation and follow-up with city officials on construction of prototype house & how it compares to T-24 • Investigate water reduction offsets
HP 'Tools' Needed					

	Planning & Development				
	6	6			
	Financial Pro-Forma	**Team Resources / Coordination**			
High Performance Best Practices	• Assess cost impacts of HP homes – construction-related costs, as well as organizational cost of change, and evaluate cost tradeoffs (construction and operational)	• Create detailed program plan with specific guidelines, timeline, criteria, and best practices • Develop corporate roll out strategy and communication mechanisms • Assemble trade/expert council • Plan departmental/team incentives • Define implementation approach with internal and external team • Develop HP home customer care process			
K. Hovnanian So Cal Specific Activities					
HP 'Tools' Needed					

Product Design & Purchasing

This stage is where specific home designs that meet the overall corporate strategy and market served are developed. This includes understanding specific customer needs, balancing those needs with cost of construction and land constraints, and coming up with physical designs and ultimately construction documents (drawings, scopes of work, and other construction related or quality management tools). At this stage contracts for labor, services and materials are negotiated for the specific design.

	Product Design & Purchasing				
	1	2	3	4	5
	Market/ Consumer Research	**Initial Design**	**Optimum Value Engineering**	**Budgeting/Development**	**Final Design**
High Performance Best Practices	• Survey consumers asking about high performance features • Evaluate what others in the local and regional market are building • Assess local or regional green building or energy efficiency initiatives driving consumer awareness	• Hold team integration sessions • Integrate performance criteria	• Evaluate designs for constructability, cost trade-offs and trade input • Look for improving quality of product at same costs • Hold systems design integration/ team sessions • Conduct energy modeling analysis • Ensure HVAC design integration	• Ensure trades understand and are pricing for cost trade-offs, warranty reductions and first time quality	• Ensure documentation includes enough detail to adequately describe construction sequencing, proper assembly, and other aspects needed for trades and field supervisors to achieve performance criteria • Coordinate with construction on specifications and purchasing on scopes of work • Hold code review with permitting officials
K. Hovnanian So Cal Specific Activities	• Understand limits of cost and value to consumer and cash flow (What are they willing to pay for high performance?)	• Integrated design process (based on corporate template) • Investigate what must be modified in the design process to support the HP home strategy; for example: mechanical/plumbing system centralization • Interior designs that support moving ducts inside conditioned space without penalizing aesthetics • Consider architectural design issues that work or don't work in favor of the Thermal Bypass Checklist • Home designs with consideration of street orientation to accommodate future PV upgrades	• Work with purchasing to establish the various HP component strategies and pricing implications for use during design process		• Develop scope and construction document details, step-by-steps, etc. to document HP strategies
HP 'Tools' Needed					

Product Design & Purchasing

	6	7	8		
	Specification	**Scopes of Work**	**Bidding/Contracts**		
High Performance Best Practices	• Select products to achieve cost and performance criteria • Accept product substitutions only if they meet performance criteria	• Ensure scopes clearly describe (word/pictures) the performance criteria and how it is expected to be implemented by trades • Describe interaction of trades with respect to performance criteria • Define inspection protocols/ measurement	• Verify bids meet performance criteria • Contract for transitional pricing – taking in account the cost of change for the trades and anticipated benefits from implementing high performance approach • Confirm with construction that a transfer of information process from construction to field and from sub-contractor pricing to field implementation is in place		
K. Hovnanian So Cal Specific Activities	• Consider the value of national contracts vs. local buy for specific needs • Develop new product evaluation protocol • Does it meet the HP home criteria? • Does it support ongoing replicability?	• Make revisions to the current scopes of work • Evaluate current practice scope vs. 50% performance improvement requirements • Evaluate scope language for adequacy and accuracy • Review Landover scopes (contact Chris Payne, IBACOS to provide what we did with Landover to support scope development) • Training all files CCM's on new HP approach and monitoring results • Develop ways to effectively communicate issues and needs in the field • Develop scope and construction document details, step-by-steps, etc. to document HP strategies	• Define "first time quality" to trades • Expectations for verification testing (job ready/job complete) • Obtain early feedback on constructability prior to implementing		
HP 'Tools' Needed					

Marketing & Home Sales

This stage is where the general market positioning of the company is refined to specific messaging for the consumer, and the activities to generate traffic to the communities take place. This also involves development of marketing and promotional materials, model home merchandising, sales presentations, and brining the customer to contract on a house.

	Marketing & Home Sales				
	1	2	3	4	5
	Market/ Consumer Research	**Marketing Plan/ Positioning**	**Promotional Campaign**	**Options & Upgrades**	**Model Homes**
High Performance Best Practices	• Evaluate how performance criteria compare to others in the market • Learn buyer response to messaging relative to performance criteria • Compare messaging against other local, regional, and national builders	• Define how homes meet consumer needs and desires relative to performance criteria • Develop marketing message relative to performance criteria	• Integrate high performance messaging into promotional campaign	• Determine if a further upgrade package from high performance platform is appropriate, working with construction and purchasing	• Design model homes and associated marketing to tell story of high performance approach (i.e. cutaways, silent salesmen, interactive displays, etc.)
K. Hovnanian So Cal Specific Activities	• Tell HP prototype story and survey interest • Develop layman's translation for telling HP story	• Consider an MPG label and HP strategy brand (coordinate with corporate) • Create a comparison of features list (by community) • Develop ideas for website (coordinate with corporate)	• Using data collected to help tell HP story for community deployment • Develop a HP home brochure (by community)		• Consider a mock-up display of house construction (by community)
HP 'Tools' Needed					

Marketing & Home Sales

	6	7	8	9	10
	Sales Team Formation	**Realtor Program/ Relations**	**Sales/ Design Center**	**Customer Sales/ Financing**	**Customer Education/Communications**
High Performance Best Practices	• Focus training on high performance aspects	• Train realtors on high performance homes and product differentiation	• Create sales center displays of high performance home aspects • Create design center displays of high performance home aspects	• Negotiate better financing options for high performance homes with preferred lender	• Hold monthly or bi-monthly prospect and contracted buyer sales dinner with high performance home presentation • Reinforce high performance features during all customer contact touch points • High performance home orientation in sales / design center
K. Hovnanian So Cal Specific Activities	• Develop sales staff training on HP homes				• Develop a HP presentation for the "Meet the Team" event. • Develop exit survey questions for non-buyers on HP issues • Gaining buyer agreement to monitor energy performance of house • Develop necessary feedback loop for sales and marketing • Documenting the Monitoring Agreement (provided by IBACOS and involving K. Hovnanian legal department) • Provide a single house disclosure for prototype
HP 'Tools' Needed					

Home Construction

This stage is where the contracted or spec house actually gets built. Houses are permitted for specific lots, construction activities scheduled, performed, and checked, and customers given various mid-point orientations, and the buyer closes on the house.

	Home Construction				
	1	2	3	4	5
	Permits	**Scheduling**	**Contractor Relations**	**Home Construction**	**Inspections**
High Performance Best Practices	• Provide any code-related documentation pertaining to high performance approach	• Ensure transfer of information from design / purchasing to field	• Train trades on HP systems • Verify trade skill; evaluate if new / additional trades are needed • Share feedback with purchasing on trade performance	• Support on building science areas • Ensure consistency (QA/ QC)	• Monitor/Verify built performance • Implement/Capture measurement data •
K. Hovnanian So Cal Specific Activities	• Gain municipal cooperation on the prototype development and construction process	• Determine the effect of HP strategies on scheduling and lead times	• Coordinate trade partner, leadership training for HP homes • Coordinate training at trade field implementation level. • Use top trade team	• Work with IBACOS on monitoring of energy performance • Obtain production trade feedback during construction (continue for ENERGY STAR process)	• Push for "first time quality" results from trades • Add HP features to quality checklist • Develop a better way of capturing field feedback
HP 'Tools' Needed					

	Home Construction				
	6	7			
	Customer Communications	**Closing/ Home Handover**			
High Performance Best Practices	• Train customer service on new HP program	• Educate customers on HP home features			
K. Hovnanian So Cal Specific Activities	• Develop a customer orientation walk for HP houses: demonstrate vs. discuss • Prototype features • Standard features • Modification of WOW program • Establish pre-construction, pre-drywall, site super knowledge/understanding for customer walks on HP features	• Develop a project specific manual with all specific features and disclosures for buyers • Modify documentation in homeowner's manual for HP community strategy			
HP 'Tools' Needed					

Customer Care

This stage start from the moment the closing takes place, and can last as long as the builder has a warranty on the house, or when the builder, trades or manufacturers are required to repair or replace items that were faulty during the construction of the home.

	Customer Care				
	1	2	3	4	5
	Customer Relations/ Communications	**Service Requests/Resolution**	**Customer Satisfaction Surveys**	**1st Year Warranty**	**On-going Warranty**
High Performance Best Practices	• Reinforce high performance during entire home customer care process	• Track service jobs using high performance metrics and building science for root cause analysis	• Ensure survey mechanisms evaluate high performance aspects of customer satisfaction	• Implement high performance aspects of home customer care process • Track warranty jobs and root cause analysis	• Track warranty items using high performance metrics and building science for root cause analysis
K. Hovnanian So Cal Specific Activities	• Evaluate the current customer satisfaction survey for HP questions (Are they the right questions? Asked at right time? Are they specific enough?) • Develop necessary feedback loop for sales and marketing • Develop new system training with customer service reps	• Document defect/trend analysis on issues relative to building science approach	• 30 day, 4 mo, 10 mo survey changes for prototype homeowners	• Decommissioning of any monitoring systems on sold homes	
HP 'Tools' Needed					

Team Leads and Objectives

The following teams and team leaders have been identified to provide solutions, support, documentation, and training to achieve the goals listed previously in the report. IBACOS can provide support at no cost to the Division as part of the DOE Building America program, provided the 50% Prototype House achieves a 50% whole house energy savings, and that the solution looks like a reasonable strategy to move to a full scale community deployment in at least 10 houses over the 2011 – 2012 timeframe. These activities must be integrated into K. Hovnanian So Cal's existing process maps to determine the priority and order in which they should be undertaken.

Planning: Angela Wilson

For Prototype House

- Gain municipal cooperation on the prototype development and construction process.
- Schedule introduction meeting/presentation and follow-up with city officials on construction of the prototype house.
- Educate the city/county building officials on the K. Hovnanian HP platform.
    - How does it comply with or surpass T-24, Tier I or Tier II

For HP Community-Scale Deployment

- Investigate what must be modified in the design process to support the HP home strategy. For example:
    - Mechanical/plumbing system centralization.
    - Interior designs that support moving ducts inside conditioned space without penalizing aesthetics.
    - Consider architectural design issues that work or don't work in favor of the Thermal Bypass Checklist.
    - Home designs with consideration of street orientation to accommodate future PV upgrades.
- Work with Purchasing to establish the various HP component strategies and pricing implications for use during design process.
- Investigate water reduction offsets.
- Use an integrated design process (based on corporate template).
- Define difference between 2x6 framing relative to existing product.

Purchasing: Ruth Stickley, Allen Donnelly

For Prototype House

- Make revisions to the current scopes of work.
    - Evaluate current practice scope vs. 50% performance improvement requirements.
    - Evaluate scope language for adequacy and accuracy.
    - Develop scope and construction document details, step-by-steps, etc. to document HP strategies.

- Review Landover scopes (contact Chris Payne, IBACOS to provide what we did with Landover to support scope development).
- Define "First Time Quality" to trades.
  - Expectations for verification testing (job ready/job Ccmplete)

For HP Community-Scale Deployment

- Consider the value of national contracts vs. local buy for specific needs.
- Coordinate trade partner, leadership training for HP homes.
- Develop new product evaluation protocol.
  - Does it meet the HP home criteria?
  - Does it support ongoing replicability?

Marketing: Kari Roland (Division), Cheryl Contreas (Group)

For Prototype House

- Understand limits of cost and value to consumer and cash flow. (What are they willing to pay for high performance?).
- Develop a HP presentation for the "Meet the Team" event.
- Evaluate "brand" value to buyer vs. performance of product and cost with purchasing.
- Develop exit survey questions for non buyers on HP issues.
- Determine specific name with which to brand prototype.
  - Determine if first Prototype will be sold unbranded, simply as spec house with upgraded features, or as kick off to new strategy / brand.
- Work with IBACOS on monitoring of energy performance.
  - Gaining buyer agreement to monitor energy performance of house
  - Using data collected to help tell HP story for community deployment
- Do competition analysis of HP strategies and marketing methods.
- Evaluate the current customer satisfaction survey for HP questions (are they the right questions? Asked at right time? Are they specific enough?).
- Develop necessary feedback loop for sales and marketing.
- Tell HP prototype story and survey interest.

For HP Community-Scale Deployment

- Consider an MPG label and HP strategy brand (coordinate with corporate).
- Develop a HP home brochure (by community).
- Consider a mock up display of house construction (by community).
- Create a comparison of features list (by community).

- Develop ideas for website (coordinate with corporate).
- Develop sales staff training on HP homes.
- Develop layman's translation for telling HP story.

Customer Service: Mike Rothnie

For Prototype House

- Document defect/trend analysis on issues relative to building science approach.
- Develop a project specific manual with all specific features and disclosures for buyers.
- Will be responsible for the decommissioning of any monitoring systems on sold homes.
- Will be responsible for documenting the Monitoring Agreement (provided by IBACOS) and involving K. Hovnanian legal department)
- 30-day, 4-month, 10-month survey changes for prototype homeowners.

For HP Community-Scale Deployment

- Modify documentation in homeowner's manual for HP strategy.
- Develop a customer orientation walk for HP houses.
    - Demonstrate vs. discuss
    - Prototype features
    - Standard features
- Modification of WOW program.
- Develop new system training with customer service representatives.

Field Construction: Paul Hepler, Wally Miller

For Prototype House

- Coordinate training at trade field implementation level.
- Obtain early feedback on constructability prior to implementing.
- Determine the effect of HP strategies on scheduling and lead times.
- Obtain production trade feedback during construction (continue for ENERGY STAR process).
- Push for "first time quality" results from trades.
- Use top trade team.
- Provide a single house disclosure for prototype.
- Add HP features to quality checklist.

For HP Community-Scale Deployment

- Training all CCM's on new HP approach and monitoring results
- Develop a better way of capturing field feedback.

- Develop ways to effectively communicate issues and needs in the field.
- Establish pre-construction, pre-drywall, site supervisor knowledge/understanding for customer walks on HP features.

About IBACOS®

Since 1991, IBACOS has helped builders address issues in the field so they can deliver better homes today and conducted forward-thinking research that leads the industry to great homes tomorrow. The goal is an industry that delivers high performance homes that are designed and built to new standards of quality. IBACOS is an Industry Team Leader of the U.S. Department of Energy's (DOE) Building America program.

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Appendix 1.C: Professional Builder Blog Postings

Professional Builder Magazine Blog Entry 2/11/10

I got into energy efficiency and business processes during the oil embargo of the 70's. My father, a school teacher with four sons, made ends meet by cultivating a nice little side business taking us all in our beat up 1963 Ford F-250 dump truck to cut down trees for our more affluent neighbors. We'd then take the wood home, cut, split, stack, and eventually burn it to heat the house. Dad figured if he couldn't get cheap oil, at least he could get his money's worth out of us kids and use up the local biomass resource. 8 to 10 cords a year of the stuff. I learned about production methods of splitting wood (gas powered splitter, five people, one weekend per year, 10 hour days), the most efficient means of stacking, and how to load the cart with the most wood my younger brother and I could haul to the house to minimize trips. That experience burned two things into my mind.

1. There has to be a better way to build houses that need a lot less energy to operate than our c. 1790 house with three additions built in the 60's, and
2. Don't waste time doing the things you *have* to do, because it eats into your fooling around time.

Fast forward to 2001, and I'm working with builders teaching them the building science fundamentals I learned in the early 1990's from people who learned it from Canadian researchers who for all I know are dead now. Basic stuff like "lots of insulation" and "build it tight, ventilate right" and "drain the rain." It dawns on me that we have gained a lot more sophisticated technical knowledge on how to build energy efficient houses over the years, but residential home building companies seem to have institutional barriers to successfully adopting those technologies and being profitable doing it. This lead me to my current work looking at the operational models of production homebuilding companies, the business practices that top performing building companies use, and understanding the intersection of "Building Performance" and "Performance Management."

So what have I found so far? You can have a company with great operational practices and performance management that cranks out code housing. If you are small, and have a dedicated team who all understand the whole-house systems-approach to higher performance housing, you can successfully build high performance houses consistently (just hope one of your staff doesn't get hit by a bus). But if you want to build higher performance housing on a production scale (more than 70 houses per year) you need an operational system that delivers consistency and profitability coupled with the technical know-how and systems thinking processes that get the greatest synergy from all of the interrelated parts of the house. I've found a core set of principles associated with those builders who are at the top of their game organizationally and who can consistently deliver houses that routinely exceed the minimum energy code by 30% or more:

- Cultural and corporate alignment
- Clear intent for quality and performance
- Increased collaboration strategies across internal and external teams
- Better internal and external communication practices and systems (team, trades, and customers)
- A disciplined approach to quality control
- Measurement and verification of performance (the building and the company)
- Continuous feedback and improvement
- Whole house integrated design and specification

So take a look at your company and the product you produce. Do you know how you stack up from a Performance Management standpoint? Take the NHQA or Malcolm Baldrige self assessment. How about your product? How does it score from an energy standpoint? Durability? Occupant health and safety? If you are feeling slow like Kevin Estes these days, this might be a worthwhile project to "fill your garage" with.

Professional Builder Magazine Blog Entry 2/17/10

Builders generally use a “spec and purchase” mentality when implementing energy efficiency. This treats building performance as a simple technology swap (i.e. tankless water heater vs. tank water heater). Alternately, using a “systems approach” where all the interrelated parts of the house are synergistically evaluated, builders can get the highest possible energy performance at a lower net cost than simply looking at product substitution. It is not just the parts and pieces. To achieve the systems integration assumed in BEOpt analysis for 40%+ levels of efficiency, builders must use a systems approach to BMS. Inherent in the systems approach to a BMS is a common vision, interdisciplinary teams, cross functional communications systems, a collaborative work environment, design integration, systems tradeoffs / synergies, performance verification, feedback systems, and continuous improvement. These attributes are also found in Quality Management System (QMS). A QMS is the system a builder uses to manage consistency of product to continually improve toward a set of business metrics. A QMS is typically used to support the builders BMS. There are significant gaps in the body of knowledge in this area related to:

1. The organizational and operational structure of a systems approach to BMS and supporting QMS for a profitable building company.
2. The issues, level of effort, and costs associated with transformation from a “spec and purchase” to a systems approach to BMS and QMS.

Professional Builder Magazine Blog Entry 3/3/10

I went to the RESNET conference in Raleigh NC last week to try and keep up with what’s going on with the trade partners who provide builders ENERGY STAR for Homes and green certification. The place was buzzing with talk of Home Star, Recovery through Retrofit, and how to put energy labels on houses. Some of what I picked up:

The Home Star program if that is starting to emerge from the Senate Energy and Natural Resources Committee could be HUGE. Upwards of $ 5.1 Billion dollars for rebates for energy efficiency retrofits on existing homes. Seems like a great opportunity for remodelers and small builders who are flexible enough to get BPI certified, and go back to all your previous customers and see if they want a whole house energy upgrade with the latest technology. From some numbers I’ve heard, there are up to 15 million “natural” replacement events that happen each year in the US- HVAC, windows, siding, water heaters, stuff like that. Build alliances with trade partners who do this work, and you may have an way to a whole new customer base. Or reinvent yourself like the Grupe Company did, spinning off a new company called Green Home Solutions. Grupe is a leading high performance homebuilder in CA, but when the market tanked, they made the decision to use some of their best people to aggressively go after whole house performance contracting. Who was it that said “Follow the money”?

Raters have a big opportunity to perform QA on these Home Star projects, which could lead to a shortage for the new construction market. Back of the envelope numbers for rater QA inspections on Home Star is in the neighborhood of 100,000 – 150,000 in the next 12 – 18 months. That’s almost as many ENERGY STAR certifications that took place at the height of the market in ’07. It could mean that your rating trade partner (you do think of your rater as a trade partner, right?) is going to be distracted, and it might be worth having a chat to discuss how you fit into his business plan for the next few years.

RESNET is working with DOE on a variety of labeling schemes - online survey, in home survey, diagnostic survey, HERS rating, and comprehensive audit. RESNET is developing different levels of certification for each of these approaches. This will mean multiple certifications for various skills and types of work , RESNET has finally gotten to the point where they realize raters need health and safety certification for things like Combustion Appliance Zone pressure testing. The presumed business model is for raters to do comprehensive audits and develop scopes of work that consumer can then go out and buy from any number of contractors or from the rater (if the rater is also an installing contractor). Expect to see remodeling customers with an energy upgrade list when they call you.

Coming out of the gates it looks like there will be two national home performance companies – Masco Home Services and Green Homes America. Both of these companies are looking for the right contractors to partner with or are providing franchise opportunities. I wouldn't be surprised to see Lowes and Home Depot jump in the game soon as well.

Professional Builder Magazine Blog Entry 3/16/10

In studying homebuilding companies, I've found that a lot of builders use a "spec and purchase" mentality when implementing high performance homes (healthy, safe, durable, comfortable, efficient, HERS index of 70 or less, green, etc.). Spec and purchase thinking looks at building performance as a simple technology swap (i.e. tank-less water heater vs. tank water heater). But, to achieve significant gains in energy efficiency at the lowest first cost, whole house thinking and systems integration are critical.

Operationally, this means going beyond handing a checklist to Purchasing or your trade partners and asking for a price, and it requires a different thought process within your company. Just as the house is a system of interrelated parts, operationally, your company is a system of interrelated people and processes. Isolating one aspect (i.e. energy efficiency) to one person or process can cause failures in other parts of the company. For example, if Purchasing makes an individual decision related to a single system, will Sales and Customer Care know how to communicate this to the homebuyer? Will the decision cause a construction headache for a trade partner? Will it cause a health and safety problem for the occupant?

To fully embrace systems integration for high performance houses, a homebuilding company needs a common vision, interdisciplinary teams, cross-functional communications systems, a collaborative environment for all stakeholders, design integration and systems tradeoffs/synergies, building and system performance verification, feedback systems, and continual improvement.

The first step in this process is to identify key goals and document current and future strategic initiatives and processes that can provide an overall framework for moving toward the consistent delivery of high performance houses. The creation of this "High Performance Blueprint" is important to facilitate the development of an executive vision, foster inter-department understanding and communications, and drive toward successful implementation and continuous improvement in the field.

With this in mind, I've seen companies have some real "ah ha" moments when the key management team gets together and collectively answers the following questions regarding the actual technical performance of their houses:

- Where do we want to be technically in three years (i.e. HERS 50? NAHB Silver? LEED Gold? Top tier of a local utility program?), and why? How does that fit into our overall strategic objectives for the company?
- What do we do today in each activity area of each department that supports the three-year goal (i.e. we currently build to ENERGY STAR®, we ask our trade partners to bring us innovative solutions, we incorporate trade partners early in our design process, we continually seek out learning opportunities to achieve this goal, etc.)?

Below is a standardized methodology for characterizing the major functions within a homebuilding company, large or small. Each company typically does things a little differently and labels major phases and work activities by different names. However, I generally find that there are more similarities than differences from one company to another. I believe that in order to implement a significant change in its business, a builder has to create a holistic picture and plan of how it will transform the company or division from its current state into a sustainable, competitive position in the market.

Professional Builder Magazine Blog Entry 3/26/10

I attended Scott Sedam's "Lean Design" webinar this week and was overjoyed to hear him speaking about the same thing we here at IBACOS have been working on with our builder clients for years. I call it the Integrated Design Process (IDP). I firmly believe that the overall operational profitability of a company building high performance homes can be as good as or better than a company building simply to code. One way to help pay for higher performance strategies and get the most bang for the buck is through IDP. Below is one part of a flow chart I created as a generic process map for IDP, which is available for download here:

For builders moving toward high performance homes, this process starts to clarify all of the interrelated systems in the home and the tradeoffs that may take place. It also helps to rally everyone around the goal. It is critical for builders to have a set of overall performance criteria or a specific performance metric for the team to achieve. This could be meeting ENERGY STAR® requirements, participating in the Department of Energy's Builders Challenge, following the EEBA Criteria, or selecting the performance criteria from the green building program of your choice. Meeting these requirements will be much easier when everyone involved has a voice in the initial design and agrees on decisions that significantly impact performance (number of windows, home orientation, thermal enclosure options, mechanical system routing, and structure), which are also balanced with aesthetic goals and cost constraints.

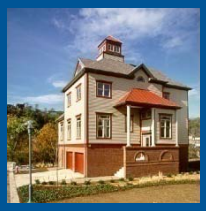
An important aspect of IDP is to not assign blame for things in the past and to work collaboratively to achieve the goals for the project. IDP will not work if everyone at the table is unable to be open and honest and can't "Face the Brutal Facts" (as Jim Collins puts it).

Furthermore, it is critical with high performance homes to have specific and detailed sets of plans, as you need to be clear where the rain control, air control, vapor control, and thermal control layers are in the home. All these layers must be understood by the entire team, clearly detailed, and properly executed in the field for the home to actually achieve the desired level of performance.

Hyperlinks:

http://www.ibacos.com/media/69775/ibacos%20integrated%20design%20process%20flow%20chart.pdf.
http://www.housingzone.com/info/ca6312276.html?q=scott+sedam+webinar
http://www.energystar.gov/index.cfm?c=bldrs_lenders_raters.nh_2011_comments
http://www1.eere.energy.gov/buildings/challenge/bcqc_criteria_glance.html
http://www.eeba.org/resources/criteria.htm
http://www.buildingscience.com/documents/insights/bsi-024-vocabulary/?topic=/doctypes/building-science-insights

Appendix 1.D: Trade Partnering Guide Outline



Quality Management for High Performance Homes

DRAFT Outline of Trade Relationship Best Practices for High Performance Homes

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December 1, 2010

IBACOS®
| Home Quality + Performance |

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Outline of Trade Relationship Best Practices for High Performance Homes

Introduction

When building high performance homes the materials, products, testing and analysis are all important. However, without the trade partners the house would not actually get built. Transitioning to high performance homes from code homes or increasing the standards of existing energy efficient/green homes takes communication, planning, change management and a range of other skills to ensure the changes are accomplished in an effective and efficient manner. Based on a literature search and interviews with leading homebuilding companies constructing energy efficient homes, the following key best practices emerged for builders to maximize their trade relationships to ensure the delivery of high performance homes. These are given in a specific order and each activity logically builds off the previous one.

- Scopes Of Work
- Checklists
- Toolbox Training
- Involving Trades in Proactive Corrective And Preventative Action
- Including Trades In Improvement Teams
- Trade Meetings
- Trade Councils

A summary of each of these best practices is provided in the reminder of this outline. The discussion here is not meant to be exhaustive, but a high level overview of the strategies to utilize with trade partners. While presented in a generally preferred order of implementation, these strategies can be mixed and matched, and are not necessarily linear or “all or nothing”. Those builders who have been most successful at implementing energy efficient whole house strategies are using some or all of these strategies to some degree.

Integration of Builder Operations

It is important to recognize the interdepartmental dependencies and relationships within builders’ operations that can provide feedback and input with respect to trade partner activities. Each department must support the others in executing the company’s high performance home strategy. Organizational “silos” can significantly restrict the flow of information that is the basis of this support. When identifying core processes to implement a high performance home strategy, it is important to break down departmental and functional silos to help ensure an integrated approach. This means that marketing and sales, design and purchasing, construction, and customer care must all be involved in a multi-disciplinary project team for the development, design, construction, sale, and occupancy of high performance homes. Operationally, a business is an interconnected set of processes and not a series of isolated blocks of activity with the minimum amount of overlap to “get the job done.”

Using a matrix or spider diagram concept of creating and visualizing such teams can be more effective than the traditional hierarchical organizational chart approach. Operational processes should involve input from a variety of sources within the company. Getting this level of input can help make sure the appropriate level of documentation and scopes of work are created to enable site supervisors and trade partners to succeed in the field, ensure that the houses are designed to incorporate buildable solutions that will achieve the company's high performance home standards and meet customer needs, reduce long-term warranty items and associated risk, and increase customer satisfaction.

Examples of areas where organizational silos can create challenges with implementing a high performance home strategy include:

- Design creates a product that does not facilitate cost effective implementation of the company's performance goals by the trade partners
- Implementing high performance as simply a group of individual measures to be purchased and applied to the house by the trade partners like a coat of paint or a granite countertop, as opposed to a set of interrelated systems with inherent synergies and tradeoff opportunities
- Understanding customer satisfaction and warranty issues that high performance strategies may solve, and the role trade partners play in implementing those strategies and their impact on customer satisfaction

The activities listed in this outline are assumed to be implemented with a cross functional team from within the builder's organization. In many instances, this will be lead by Construction and Purchasing, but other departments will have input and feedback that should be integrated in the process of working with trade partners.

Defining Trade Partners

Traditionally, trade partners have been those subcontractors who are directly responsible for the construction of the house. Designers, architects, HERS Raters, and building officials are not typically considered part of the "trade base," but they are integral players in how well the end product performs and meets the builder's internal standards and performance targets. They can provide valuable insight and data on the successes and challenges of implementing various high performance home strategies, as well as facilitate streamlined inspections and verification processes.

Consider including other members of the extended team to participate as trade partners in the activities listed in this outline. Designers should be informed of changes in scopes of work to prevent recurring problems that can be eliminated at the design phase, and should receive trade feedback on the constructability of designs. HERS Raters have a wealth of information related to a building's tested performance and may be able to assist with documenting recurring building performance issues, transferring best practices from other builders, and providing input into scopes of work, checklist, or schedules. A proactive dialogue with local building officials can provide them with insight into key building science-based strategies being considered for implementation. This type of dialogue can garner their feedback and reveal any concerns to address prior to construction. Taking this step can also proactively stop building officials from issuing stop work orders because they are unfamiliar with certain constructions

practices. In addition, creating an environment of accountability and self-inspection by trades performing the work dramatically reduces the likelihood of failing third-party inspections. However, in order for this to be effective, trades must have a very clear understanding of what is being inspected, what the pass/fail criteria are, and how their work impacts and interacts with others'.

Strategies for Trade Relationships

This outline is based on several underlying assumptions. One is that there is mutual trust and respect between the builder and the trade partners. Over time that trust will need to be extended from trade to trade, but initially the trades must feel the builder has their best interest in mind, and vice versa. Another is that the builder recognizes the trades are also a business, and that for the builder to stay in business, the trade partner must also stay in business, and be paid appropriately for the work that must be undertaken to build a high performance house. This does not mean they should not cooperatively look for all opportunities to eliminate waste and drive cost out of the process, but a builder cannot simply drive cost out by driving a trade company out of business. Finally, most of the practices here are relevant for long term relationships. A builder who regularly changes trades will likely not be able to implement many of the practices included in this outline.

Scopes of Work

A key way to ensure that trade partners understand the new materials, products and installation methods involved in constructing high performance homes is for the information to be clearly documented. By creating a Scope of Work, the builder and trade can mutually agree to the work to be done, the process of construction, and desired outcomes. If properly developed, scopes also become the basis for field training, and help to gain consistency from house to house. Well developed scopes help avoid rework, defects or failing key energy related performance tests.

By involving the trades in the writing of the scopes, the trades can input their recommendations and best practices, and bring new products, materials and methods to the table to achieve the overall energy goals. The builder needs to work across trades to synthesize the information on the new approaches and maintain an overall awareness of the system interactions between trades. This ensures that both the trade and builder both understand each other and creates a learning opportunity. Without a scope of work, miscommunication, inconsistency, disagreements, misunderstandings, delays in constructing to standards can become the norm, impeding the profitable and successful achievement of high performance homes. A well developed scope can include:

- General Conditions
- Statement of Work, including a discussion of systems interactions with other trades' work related to achieving the overall building performance goals
- Material Specifications
- Installation instructions, including:
    - Manufacturers recommendations
    - Drawings
    - Cross sections
    - Photographs

- Details
- Step by step descriptions of how to construct or install
- Pre, in progress, and post construction checklists

Checklists

Checklists ensure that all of the key steps at job ready, in progress (i.e. rough and final) and at job complete are confirmed as completed correctly. This ensures that no critical element is overlooked that would result in rework, defects, or the failure of key performance tests or energy related inspections. The critical aspect of checklists is having the most important elements included and having them checked at the correct time. A checklist should only be addressing critical issues, and not an exhaustive list of every possible component of the work put in place. Checklists for high performance homes may also include verification that critical systems installed by previous trades have not been damaged, or if damaged they have been repaired. It can also be helpful to include how the work that is being checked off as complete impacts the performance of future trades work. The goal is to get the job done correctly and profitably the first time, with no rework and waste. Checklists should include:

- Pre-work such as set up, material delivery and storage, work conditions (i.e. temperature, humidity, precipitation, etc.), and work completed by previous trades.
- Work in progress, which may include the confirmation of work at various stages or hand over points. This can also include taking photographs of work prior to being covered up.
- Job completion, to ensure that before leaving the work that it is correct and no costly return visits are required.

The data from checklists should be summarized by the builder so that recurring issues or problems can be identified and the problem solved.

Toolbox Meetings

The roll out of a new product or construction method is not the only time that training and communication with trades is required. At the same time, classroom training is not always necessary or effective. To that end, implementing a series of “toolbox” or “tailgate” meetings with trades can create an environment of collaboration and open lines of communications between the builder and the field crews. Some examples of topics for these include:

- Updating of key changes
- Safety training
- Training on new products, materials, or installation practices
- Providing praise regarding work
- Passing on results from performance tests
- Builders customer satisfaction scores, and specifically scores that relate to a specific trade group
- Reviewing recurring problems
- Updating on issues found from checklists

- Gathering feedback from crews to communicate to the builder regarding, materials, equipment, scheduling, errors, plans etc.

Involving Trades in Proactive Corrective and Preventative Action

The identification of problems, delays, rework, defects or the root causes of poor performance in the testing of the home are opportunities to improve the process of building a high performance home. This can only come from a focus on correcting problems when discovered and ensuring that they are prevented from recurring. This approach can be supported by data coming from checklists, but it can also come from feedback from trade partners in regard to problems with plans, suggestions on construction schedules, and being involved in redlining new plans during their development. One goal here is the work cooperatively with the trades to identify issues that the builder can solve to enable the trades to do their job correctly the first time, at the greatest operational efficiency. Another goal is for the builder and trade to work together on business or operational issues that the trade may have that prevents them from doing the work done correctly.

Plan, Do, Check and Act (PDCA) is a key approach to having a mind set for addressing corrective and preventive actions.

Improvement Teams

The implementation of a new set of techniques and technologies is not as simple as a single change by either the builder or the trade. It is valuable to create teams where both the trades and builder work closely together to achieve the desired energy efficiency goal and arrive at buildable solutions. Creating an improvement teams to focus on energy efficiency should consist of:

- Staff from the builder's construction, design, and customer relations team
- Staff from key trade partner's site and office staff.
- HERS Rater
- Energy / building science consultant
- Outside designers or engineers

This can be a powerful team for creating solutions to the energy efficiency goals at the lowest first cost. It is important for this team to have good communications, as a strategy from one trade may dramatically impact another. An example would be the substitution of low SHGC glass in windows, which can dramatically reduce the size of the air conditioning unit, and require a redesign of the duct sizes and potentially register locations. These teams can also be used to address the top construction defect and/or warranty issues, and have been shown to create significant reductions in defects and costs or a reduction in cycle times.

Define, Measure, Analyze, Improve and Control (DMAIC) can be an effective step by step approach for such teams to follow to find and implement a solution.

Trade Meetings

The most knowledgeable resource a builder has is their trade base. With decades of experience and expertise this should not be overlooked. The introduction of building high performance homes or the raising of the bar in performance standards requires regular coordination, education, testing, consistency and improvement. Regular meetings with the owners or lead representative of each of the key trades groups can be a powerful source of feedback for a builder as well as timely and efficient point of education, communication and for the establishment of goals and deadlines. While working with individual trades on specific issues is necessary, every trades work is based on that of the previous trade and the trade that follows them. As buildings reach higher and higher levels of energy efficiency, the interdependence of all the systems and the trades who install those systems become more and more critical. Regular meetings with key trades or groups of trades (i.e. site work through foundation, framing through rough mechanicals, insulation through paint, and finish trades) can enable coordinated changes, smooth implementation, and provide a high level training environment. This is an area where implementation and hand off issues associated with high performance homes can be discussed and appropriate changes to scopes of work made. It can also help to build relationships between trade company owners, who may begin to work among themselves to resolve issues as opposed to requiring the builder to act as a referee.

Trade Council

The most sophisticated and perhaps intimate relationship a builder and trades can share is through the formation of a trade council. This goes beyond simple individual relationships and business interests, and can come about when there is a common trust and realization that “we’re all in it together”. The builder can help the trades maintain or grow their business, and the trades are a key factor in delivering a quality product that can drive profitability and customer satisfaction for the builder. Formation of a trade council is not necessarily easy, and should be considered when then the teams sees a benefit in taking business relationships to the next level. A builder should be prepared to lead a council to start, with the goal of having all the members create their own structure and vision, with an autonomous set of operating principles and mission. For example, the Trade Partner Council of Virginia has the following mission statement:

“K. Hovnanian Trade Partners are committed to working together with one another and K. Hovnanian to identify business performance improvement opportunities and implement positive change to produce increased homeowner, Trade Partner, builder, and employee satisfaction. Candid constructive communication between K. Hovnanian Homes and their Trade Partners is key to the success of our mission. We are dedicated to working together to be THE BEST home building team in the Washington Market.”

A trade council can be a mechanism to help institutionalize a builders energy efficiency and building performance goals throughout the trade base, and to provide a platform for continual improvement and cost reductions to make energy efficiency more affordable. Benefits of a trade council include:

- Reduction in waste
- Reduction in expenses

- Reduction and even elimination of job-site accidents
- Improvement in production scheduling and cycle times
- Improvement in customer satisfaction
- Improvement in quality
- Delivery of homes with zero defects
- Improvement in communications and camaraderie between everyone involved in the home-building process
  (from http://www.housingzone.com/pb/article/trade-partner-council-meeting-first-person-account)

Resources

General

- Whitten, Bob. Building Partnerships: How to Work with Trade Contractors. 1999

Scopes of Work

- IBACOS High Performance Scopes of Work: http://www.ibacos.com/resources/publication (to be used alongside Linda Haas Davenport's "Scope of Work Program")
- NAHB Research Center Scopes of Work: http://www.toolbase.org/ToolbaseResources/level3.aspx?BucketID=5&CategoryID=62
- BuildIQ Toolbelt: http://toolbelt.buildiq.com/
- Atlanta Homebuilders Association Trade Partnering Guide
- http://www.housingzone.com/pb/article/trade-partner-council-meeting-first-person-account)
- Hass-Davenport, Linda. "Scopes of Work Program" The Homebuilder Press
-

Checklists

- IBACOS High performance Scopes of Work: http://www.ibacos.com/resources/report (used in conjunction with the "Scope of Work Program" by Linda Haas Davenport)
- NAHB Research Center Scopes of Work: http://www.toolbase.org/ToolbaseResources/level3.aspx?BucketID=5&CategoryID=62
- Building Science Corporation's "SNAPSHOT" form http://www.buildingscience.com/documents/reports/rr-0413b-snapshot-form
- BuildIQ Toolbelt: http://toolbelt.buildiq.com/

Toolbox Training

- Tailgate Training Guide, Driver Alliant Insurance Services http://www.csrma.org/tailgateguide.pdf

Involving Trades in Proactive Corrective and Preventative Action

- Quality Management and High Performance Home Building: A Case Study of Veridian Homes (http://www.toolbase.org/PDF/BestPractices/AppendixBQualityManagementandHighPerformanceHomeBuilding.pdf)
- E. Caldeira, First Time Quality and Safety Management for Home Builders. FTQ Press, Anapolis, MD. 2007.

Including Trades In Improvement Teams

- Quality Management and High Performance Home Building: A Case Study of Veridian Homes (http://www.toolbase.org/PDF/BestPractices/AppendixBQualityManagementandHighPerformanceHomeBuilding.pdf)
- E. Caldeira, First Time Quality and Safety Management for Home Builders. FTQ Press, Anapolis, MD. 2007.

- Building Quality At Veridian Homes, Denis Leonard. Quality Progress, October 2006

Trade Meetings

- Quality Management and High Performance Home Building: A Case Study of Veridian Homes (http://www.toolbase.org/PDF/BestPractices/AppendixBQualityManagementandHighPerformanceHomeBuilding.pdf)
- Big Picture: Labor Pain Management Jeremy Koster, Lennar (http://www.bigbuilderonline.com/Industry-news.asp?articleID=1377209)
- Building Quality At Veridian Homes, Denis Leonard. Quality Progress, October 2006

Trade Councils

- Trade Partner Councils Pay Off for Home Builders (http://www.housingzone.com/pb/article/trade-partner-council-meeting-first-person-account)
- Sequim Businesses Honored (http://www.estesbuilders.com/cgi-bin/press_page.cgi?search_for=10/02/09)

Appendix 1.E: Transferability of Trade Relationships from New Construction to Retrofit Contractors

Letter Report:

Transferability of Trade Partnering from New Construction to Whole House Retrofit Contractors

Prepared by:
Duncan Prahl, IBACOS

December 3, 2010

IBACOS®
| Home Quality + Performance |

Building AMERICA®
U.S. Department of Energy

2214 Liberty Avenue
Pittsburgh, PA 15222
www.ibacos.com
1-800-611-7052

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Subcontractors Role in Home Retrofits 3
Conclusions 4
References 5

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Director of Operations
gcottrell@ibacos.com
(412) 953-2083

About IBACOS

Since 1991, IBACOS has helped builders address issues in the field so they can deliver better homes today and has conducted forward-thinking research that leads the industry to great homes tomorrow. The goal is an industry that delivers high performance homes that are designed and built to new standards of quality. For more information, please visit www.ibacos.com.

Transferability of Trade Relationships from New Construction to Retrofit Contractors

Introduction

Based on research conducted by IBACOS working with production builders implementing strategies for higher performance energy efficient homes in the Building America program, it has become clear that without advanced trade relationships builders cannot succeed in improving the energy efficiency of their homes. Trade partnering as a concept has been around for years, and applies equally to large production builder, smaller builders, and remodeling contractors. The whole house home performance contracting industry is growing with the introduction of new programs and the rapid growth in the number of BPI certified companies and individuals. This leads to the question: Do principles of trade partnering for new construction apply to the retrofit sector, and if so, what level of transferability is there?

Home Performance Company Business Models

According to the PIER Final Report on National Survey of Home Performance Contractors (2003) there are four primary types of business models associated with the home performance industry:

- A company that has internalized all aspects of Home performance, from the audit through installation and post installation service.
- A company that specializes in auditing and installation of one aspect of home performance (typically shell or HVAC) and subcontracts to another company for the remainder of the job.
- A company that does audits, contracts with the customer to do the comprehensive upgrades as a single source supplier, and provides management and quality assurance. This company then has contractual relationships with subcontractors to do all of the installation work.
- An “owner’s representative / advisor” only, where the company staff does assessments, creates work scopes, and may act as the owners representative or construction manager, with the owner contracting directly with installers to have the work done.

Subcontractors Role in Home Retrofits

Given these business models, it is apparent that subcontracting plays a role in the home retrofit industry. The PIER report also contains an analysis regarding the types of subcontractors used and their respective role:

“Nine of the sixteen contractors interviewed use subcontractors to install a significant portion of the improvements required. Subcontracting HVAC work was a significant strategy for most of the larger shell contractors. On the other hand, for HVAC specialists, subcontracting shell work was less common even though the shell work is typically the smaller part of a whole house workscope. One reason for this may be that shell subcontractors are often not certified or using performance testing techniques, which places an extra responsibility for performance testing on the prime contractor. Since there appear to be benefits from offering all services in-house, it will be important to watch the development of these contractors over time, to see if there is a trend towards more work being done by the contractor’s own crews. Since

customer referral is a key factor in business success for home performance contractors, it could be important for job performance and referral that there are quality assurance and quality control processes in place for subcontracted work"

As this report was based on data collected in 2003, further study would be valuable on the number and type of BPI certified technicians and business models being employed, to assess if the authors hypothesis of more work being internalized is becoming the more prevalent model. One national retrofit contractor franchise provider has built their business model upon converting conventional HVAC contracting companies into whole house performance contracting companies. The business proposition is that HVAC companies already have an extensive client base that they regularly touch through annual service calls, which allows for the direct presentation of the whole house contracting service. Whole house contracting can also increase the size of a traditional HVAC replacement job. The relationship with an already trusted professional company may allow for the development of longer term incremental upgrade plans.

It is clear that subcontractors play a similar role in the retrofit market that they do in new home construction. What is unclear is how sophisticated the relationships are in this market sector. The PIER report stated that of the 118 companies in the study, only 24 had 11 or more employees, and only 6 had 30 or more employees. While the detailed financial breakdown of the annual sales volume of the companies in the study was not reported, it was stated that only ten of the companies had $500,000 or more in annual sales. By homebuilding company standards, this is a very small company in terms of revenue, in some cases representing a company that only builds two to four houses per year. However, assuming the larger contractors are doing comprehensive work in house, with average costs of jobs reported at $9333, a company doing $500,000 per year in volume would be doing over 50 jobs per year. A company who subcontracted all their work at this volume would, in homebuilding terms, be considered a small production builder, at approximately 1 start per week.

RESNET has also recently announced the development of "EnergySmart Home Performance Teams." How many of these Teams will actually be formed is going to be based on market demand and program requirements, but it a structure which reinforces the "prime" and "subcontractor" relationships.

Conclusions

It is reasonable to conclude from the general trends in the industry that retrofit contractors and new construction builders have similar types of relationships with subcontractors. Therefore, the same principles of trade partnering that are effective for incorporating energy efficiency in new construction would apply to some segments of the retrofit market. It may also be beneficial to promote and support the development of strong operational models for Quality Management Systems such as the National Housing Quality Award or Malcolm Baldrige Criteria as a means to help build successful and sustainable companies in the retrofit industry. This could be included in BPI and RESNET training curricula. Additionally, it may be of value to DOE to work with Building America teams to develop specific National

Housing Quality Award criteria for Home Performance Companies, to raise the profile of this class of company and provide the opportunity for true third party validation of operational excellence for this fledgling industry.

References

Bevilacqua Knight, Inc. Final Report on National Survey of Home Performance Contractors, PIER Whole House Contracting Study. Sacramento, CA. California Energy Commission Contract # 500-02-011. 2003

Appendix 1.F: 2010 IBACOS Conference Presentations

2010 International Builders Show

X-Ray of The New American Home

Duncan Prahl and Brad Oberg

Quality Processes

The New American Home

Q&A/ Interactive Dialogue

The National Association of Home Builders is a Registered Provider with The American Institute of Architects Continuing Education Systems. Credit earned on completion of this program will be reported to CES Records for AIA members. Certificates of Completion for non-AIA members are available on request.

This program is registered with the AIA/CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product. Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

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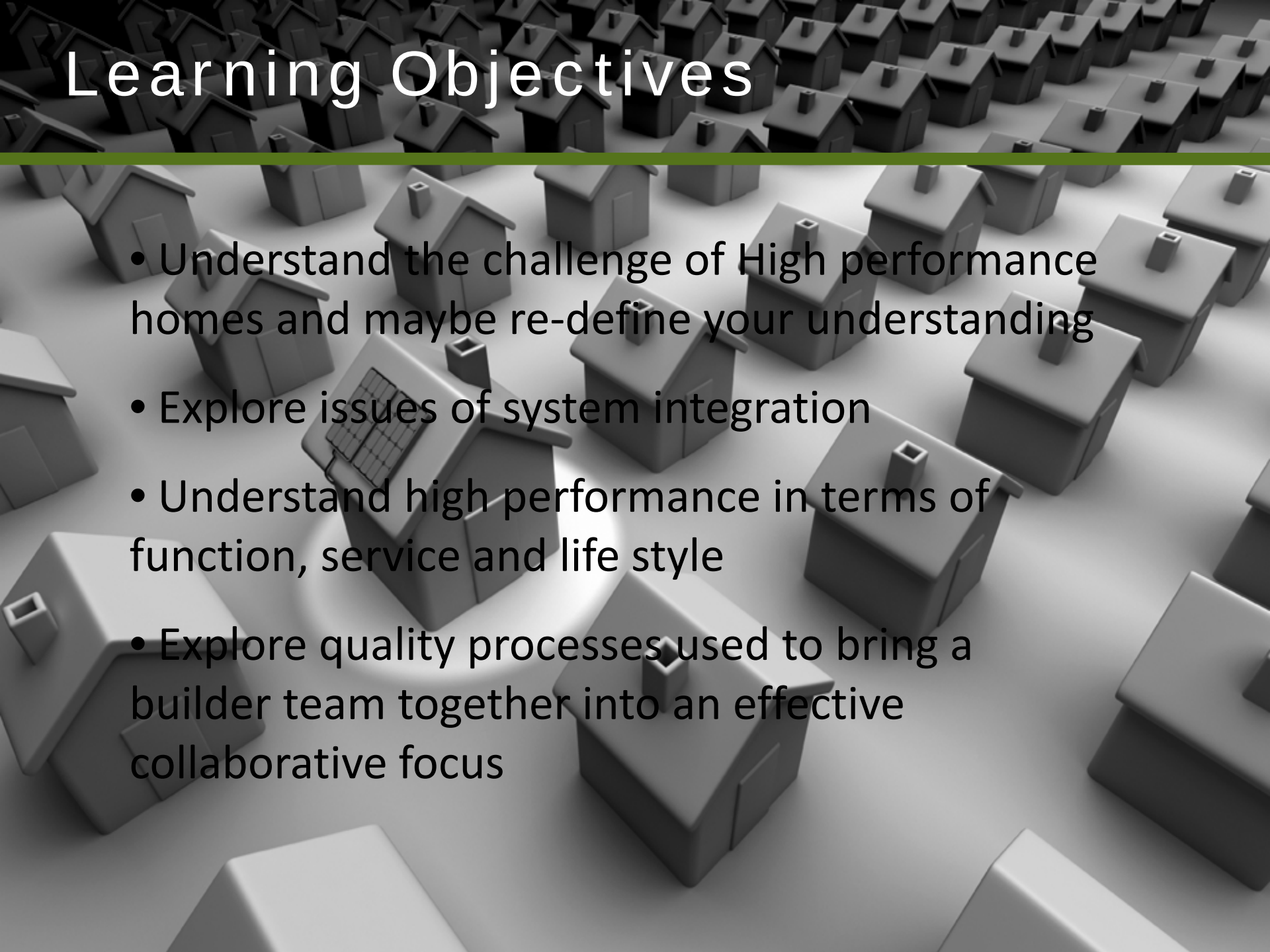
Learning Objectives



- Understand the challenge of High performance homes and maybe re-define your understanding
- Explore issues of system integration
- Understand high performance in terms of function, service and life style
- Explore quality processes used to bring a builder team together into an effective collaborative focus

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable
Building Technologies Program

Building AMERICA SM
U.S. Department of Energy
Research Leading to Zero Energy Homes

The New American Home
A short history through 2010

Hedgewood Properties 2001

A builder committed to highlighting energy efficient & durable housing – Seized the Spotlight – HERS 90

John Wieland Homes 2002

A production builder exploring the concept of system integration and leaning that small things make big differences.

Amland Development 2003

A tale of Three Houses, Three HVAC systems, Three water heaters, No space and trying to cut and paste technology.

Merlin Contracting 2004

Exploring the use of seldom used structural products in this climate and sticking with engineered HVAC calculations

© Copyright 2006

- Sound engineering practices lead to happy builders & customers
- 1 Ton/ 288 ft² (installed)
- 1 Ton/ 383 ft² (IBACOS design)

18 13 9 6.5

© Copyright 2006

Goehring and Morgan Construction 2005

A custom builder with a great team introduced an outdoor room and solar heating.

Second Floor Plan

First Floor Plan

© Copyright 2006

Hannigan Homes 2006

Conditioned attics allowed easier integration of mechanical distribution

This house had 175% of the surface area of an equivalent more compact plan

Homes by Carmen Dominguez 2007

Robertson Homes 2008

Blue Heron 2009

The New American Home 2009

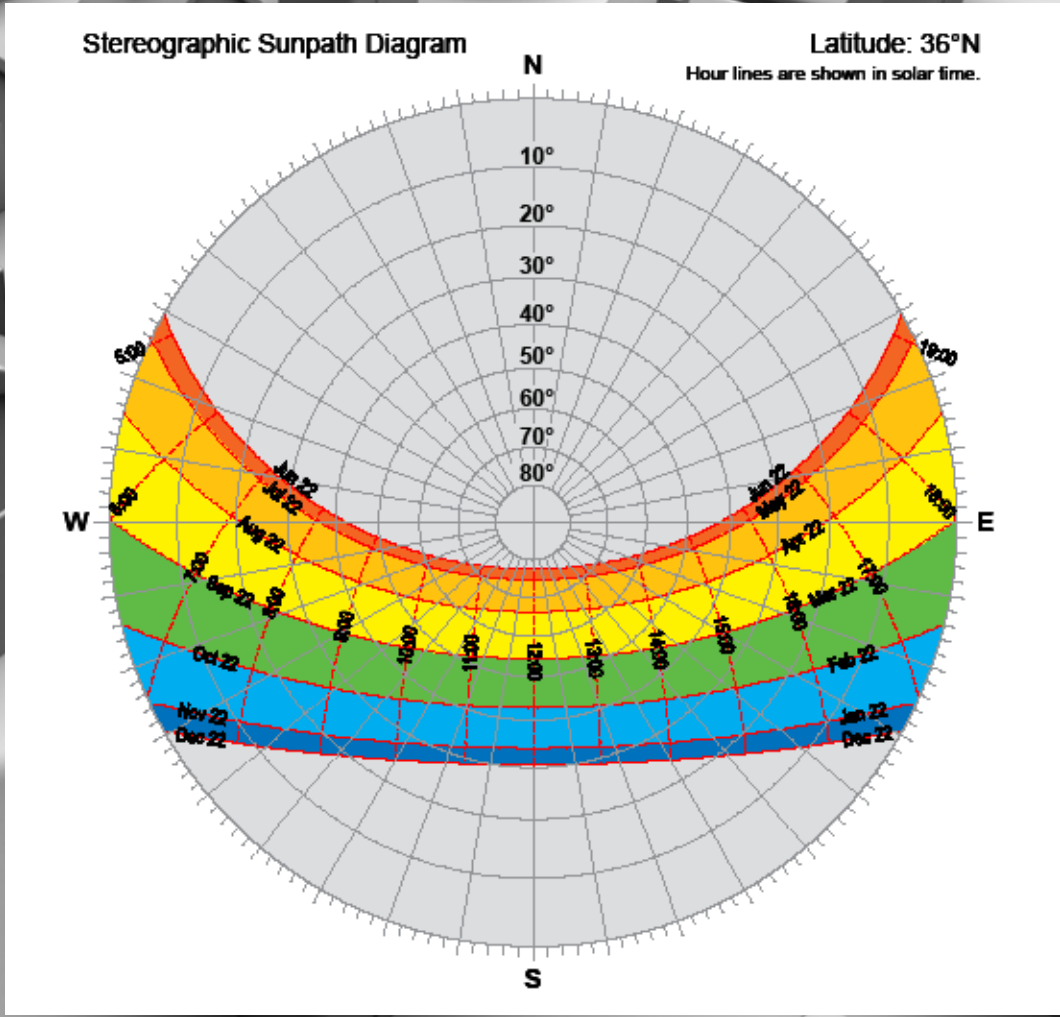
- This home is a clear example of a collaborative process and desire to explore new levels of team coordination.
- Features:
  - Respect of the local climate and Solar environment
  - Clear and sophisticated understanding of when inside is in and when it isn't
  - 25 zone space conditioning with new technology
  - Energy efficient lighting
  - Water, water every where and water conservation too
  - High performance home and team

Architecture, Environment, Energy

Design for solar control

Architecture blended style with critical sun control

The first move to reduce peak cooling allowed many other decisions to be made



Double sided Photovoltaics

This system increases efficiency by collecting from both sides and staying cool as a patio cover.

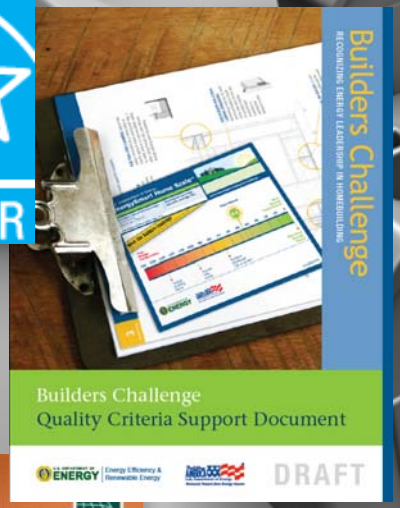
Not only attractive, but practical

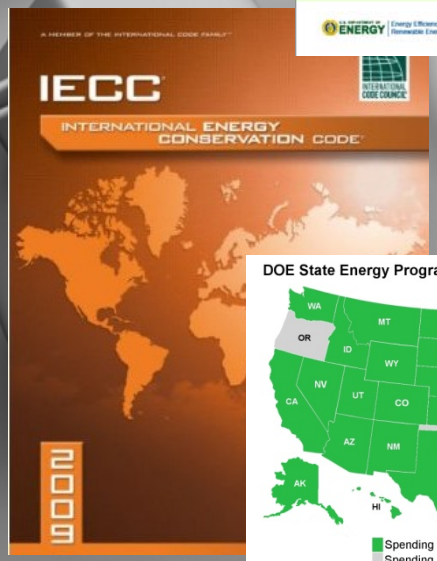
Best Practices Research Alliance®

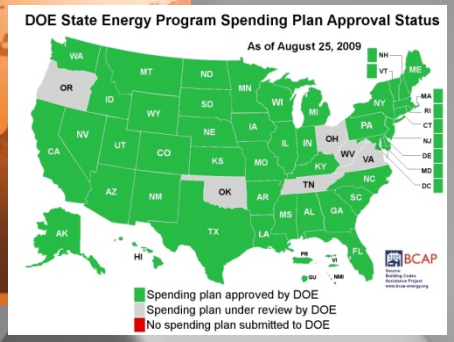
Taking Your Product to the Next Level of Performance

A quick journey describing the Collaborative Process and how builders are creating their own New American Home

Changes Ahead







- Code push for 30% and 50% savings in 2012 and 2015
- ARRA - 90% Energy Code compliance if accepting funding
- Builders Challenge Quality Criteria
- Energy Star Homes 2011 – five checklists

Where Are We Now?

- Technology Research
  - 30% Savings readily achievable
  - Zero Energy homes on horizon

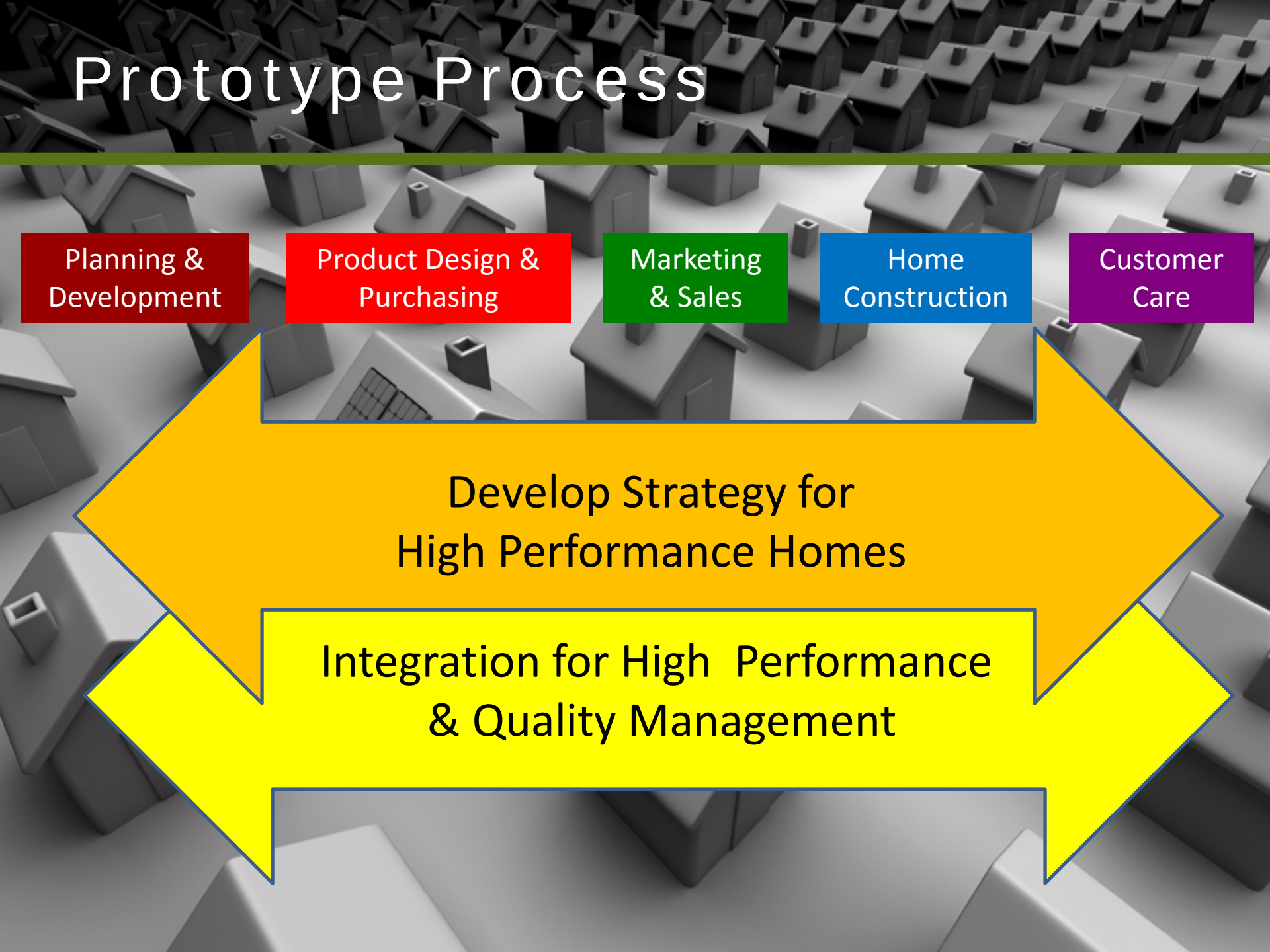
2005 - Ideal Homes builds first “Zero Energy Home” in the U.S. under $200,000

Convergence of operational and building performance

- Energy efficient houses - efficient and effective integration of systems to provide consistent performance
- Quality Management – efficient and effective way to produce something consistently

Operational Integration

Prototype Process



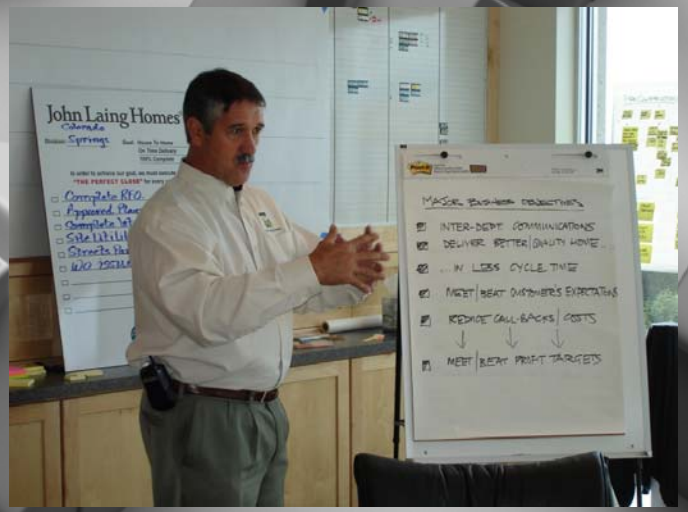
Where Are you?

- Home energy rater
- Building Science “checkup”

Planning & Development

Define goals and objectives

- What does this project represent?
  - Stretch? New standard practice? Key solution on the way to the goal?
- What are all the departments going to have to do to make this a success?
  - For this one house
  - As a standard practice

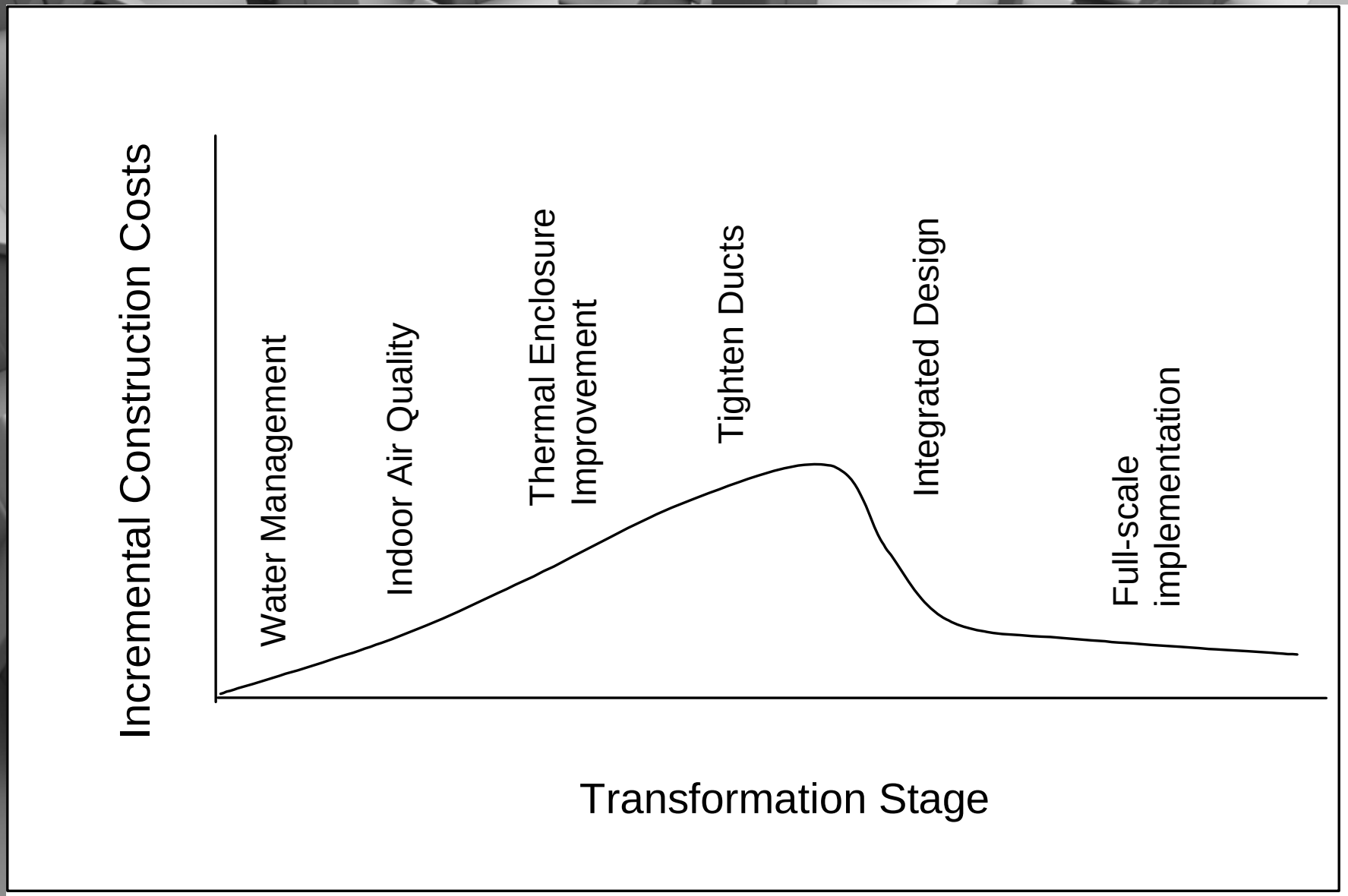


Technical Strategies (in order)

1. Water management
   - Keep the building assemblies from getting wet
2. Indoor air quality
   - Sealed combustion, ventilation
3. Improve thermal enclosure
   - Insulation, windows, air sealing
4. Improve HVAC
   - Higher efficiency, tighten ducts, right sizing
5. Integrated design
   - Bring ducts inside conditioned space, integrate all systems

Product Design & Purchasing

Paying for higher performance



Cost Tradeoffs

	Typical Specs	Prototype Home Specs	Cost
Framing	8’ 2nd floor walls No draftstopping (2) 80% furnaces in attic	9’ 2nd floor walls Bulkhead with draftstopping	⬆
Mechanical	3 Ton AC unit, 12 SEER 2 Ton AC unit, 12 SEER	90% furnace in house, with variable speed fan 3.5 Ton AC unit, 16 SEER	⬇
Ductwork	Flex duct mostly in attic	Duct board trunk, flex duct runs, all in house	=
Ventilation	Flex duct to return plenum	Flex duct to return plenum, with fan cycling control	⬆
		Total Costs	⬇

Product Design & Purchasing

Incremental costs and annual savings

Estimated Annual Source Energy Savings of Proposed Prototype Home	Annual Utility Bill Reduction	Monthly Utility Bill Reduction (*Monthly Savings*)	Monthly cost to consumer per $1,000 borrowed, 7% interest rate, 30 year mortgage (Cost per $1000)	Total Additional Mortgage Available to Pay for Energy Upgrades at Cost-Neutral Point
vs. Current Standard Practice	vs. Current Standard Practice	vs. Current Standard Practice		vs. Current Standard Practice
33.7%	**$802.05**	**$66.84**	**$6.65**	**$10,051**

Product Design & Purchasing

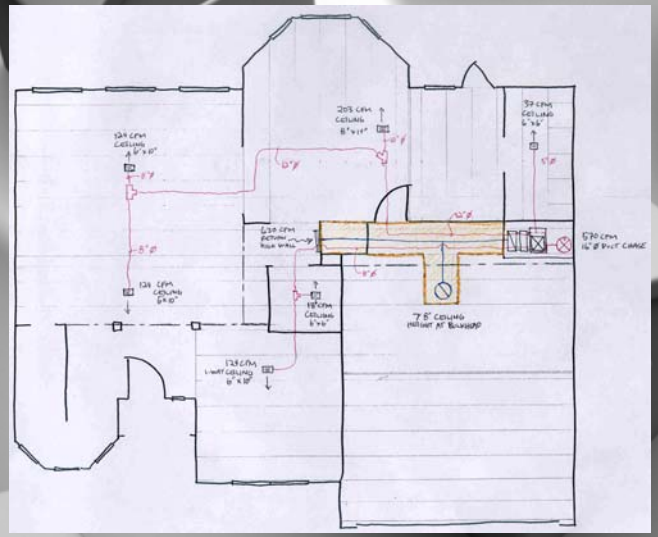
Gap Analysis

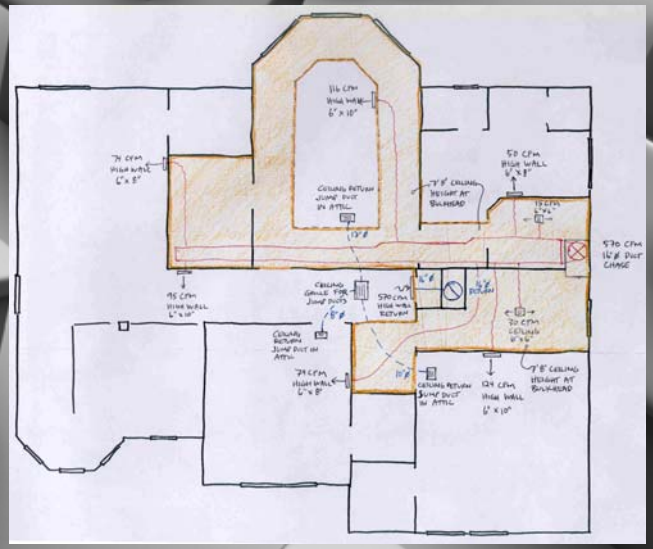
- What is impact on the team?
  - Can trades perform?
  - Who else do I need?
  - How much training is needed?
  - What does it cost?
  - How do buyers react?
  - What has to change operationally?

Product Design & Purchasing

Pick a house

- Existing plan? New design? Custom?
- Apply strategies
- Understand issues on paper first
- Study and evaluate specifics with trade partners

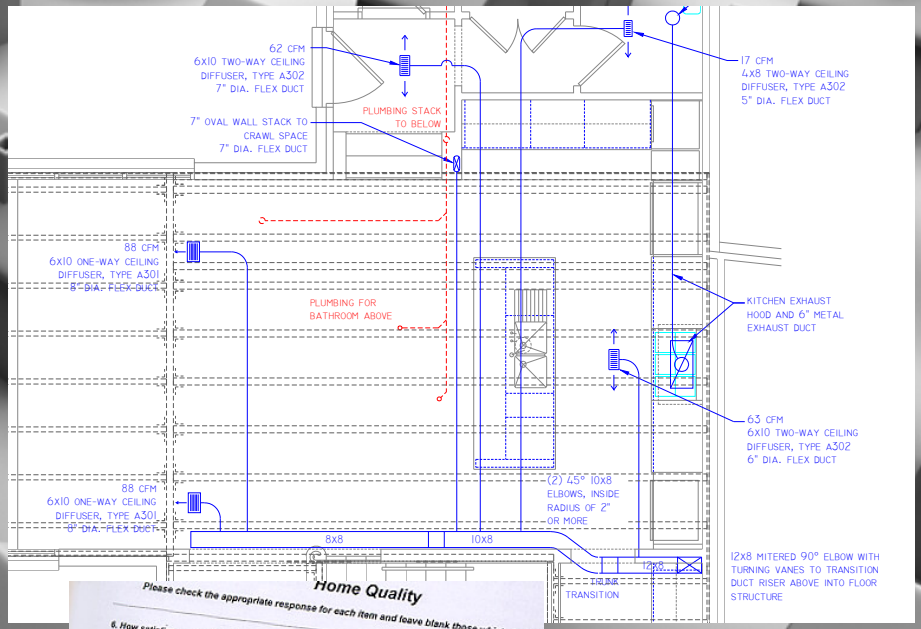


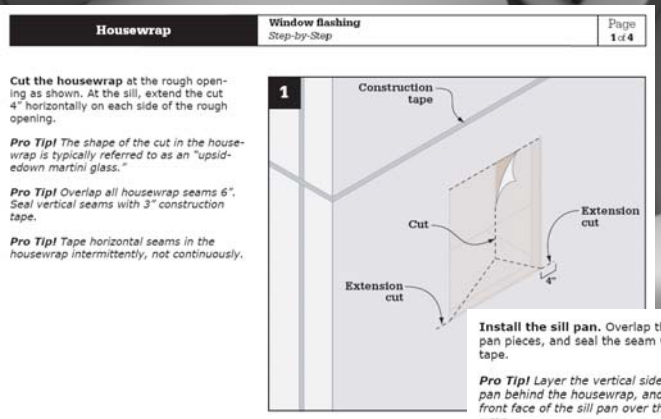


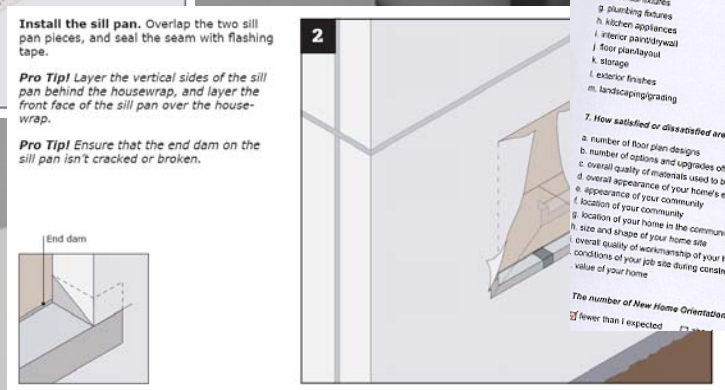
Product Design & Purchasing

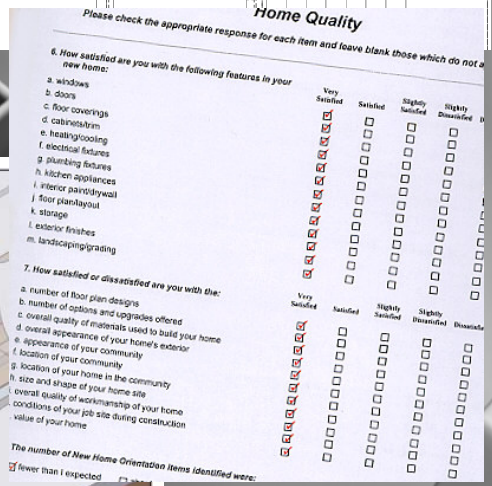
Document Your Decisions

- Construction Docs
- Scopes & specs
- Step by Steps
- Other field tools









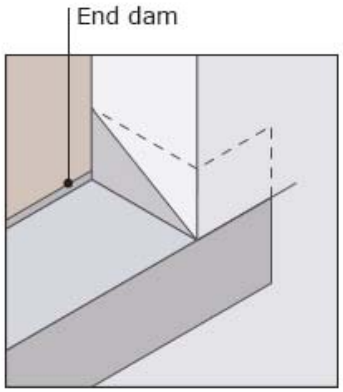
Product Design & Purchasing

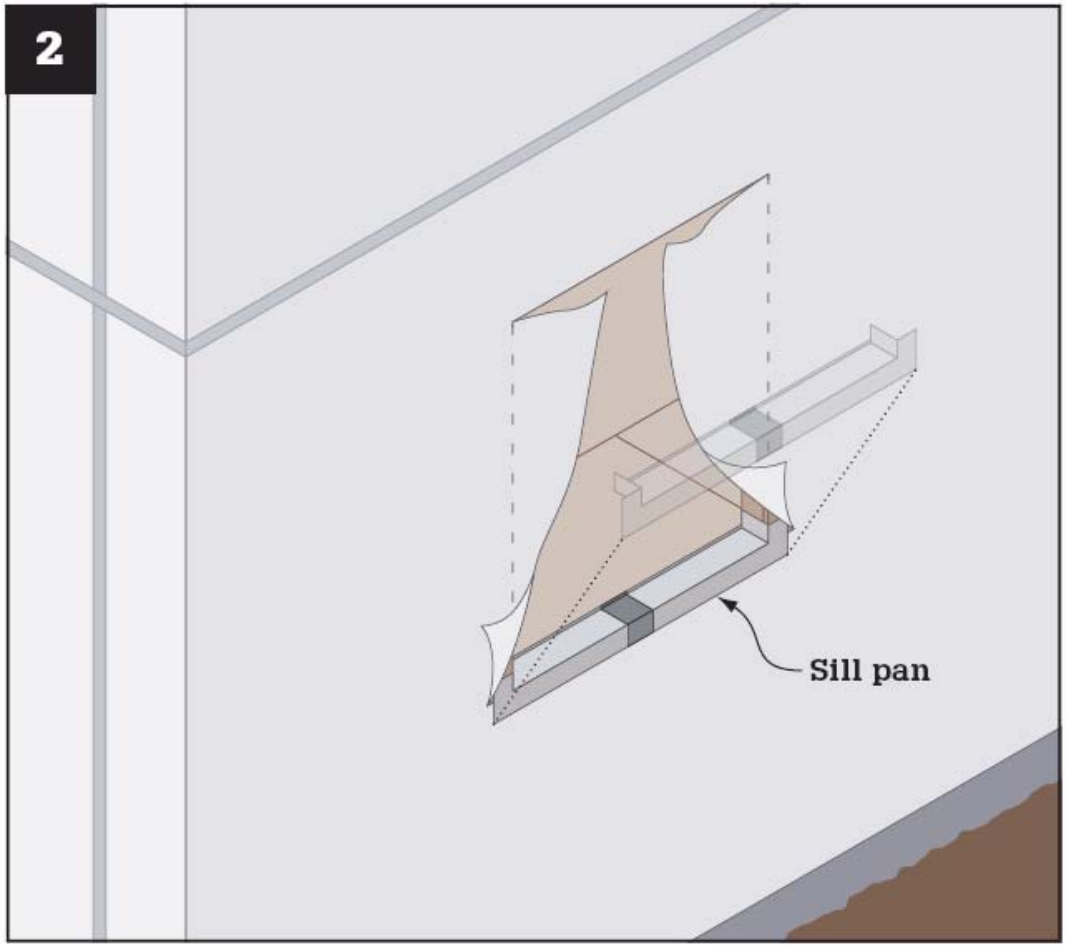
Example Detailed Work Step

Install the sill pan. Overlap the two sill pan pieces, and seal the seam with flashing tape.

Pro Tip! *Layer the vertical sides of the sill pan behind the housewrap, and layer the front face of the sill pan over the house-wrap.*

Pro Tip! *Ensure that the end dam on the sill pan isn't cracked or broken.*





Training, Training, Training

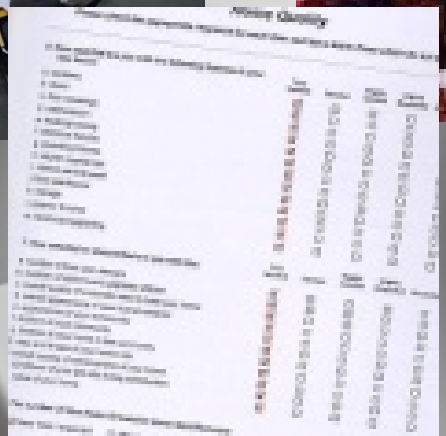
- Who?
  - Your staff
  - Trade owners, Trade supervisors, Mechanics, Laborers
- When
  - During strategy development Before house starts construction, before each major stage
- What
  - The big picture, Their role, Respect work of others

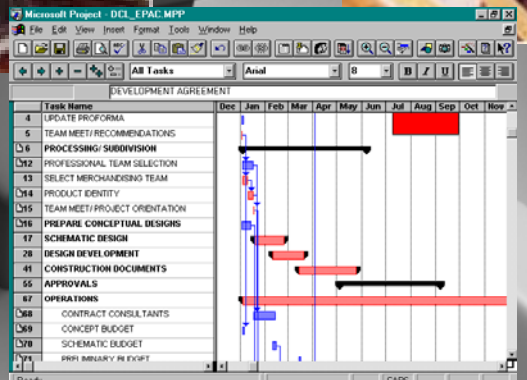
Build

- Document what you did for future training
- Evaluate how key strategies worked or didn't, and how to improve
- Celebrate successes

Evaluate

- What is replicable?
- What is not?
- What does it cost? Can these costs be reduced?
- What's ready for Prime Time?





Planning & Development

Building Performance and Operational Excellence

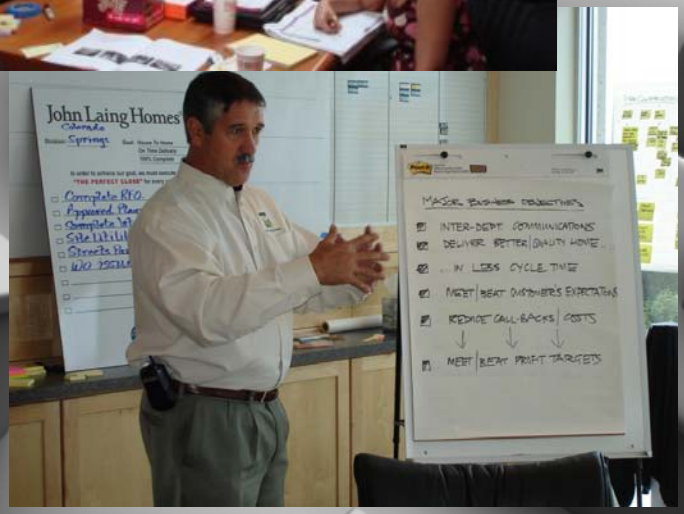
- Energy efficient houses - efficient and effective integration of systems to provide consistent performance
- Quality Management – efficient and effective way to produce something consistently

Operational similarities to achieve high performance

1. Cultural and corporate alignment
2. Increased collaboration across internal and external teams
3. Clear intent for quality and performance
4. Whole house integrated design and specification
5. Better communication practices and systems
6. Disciplined approach to quality control
7. Measurement and verification of performance
8. Continuous feedback and improvement

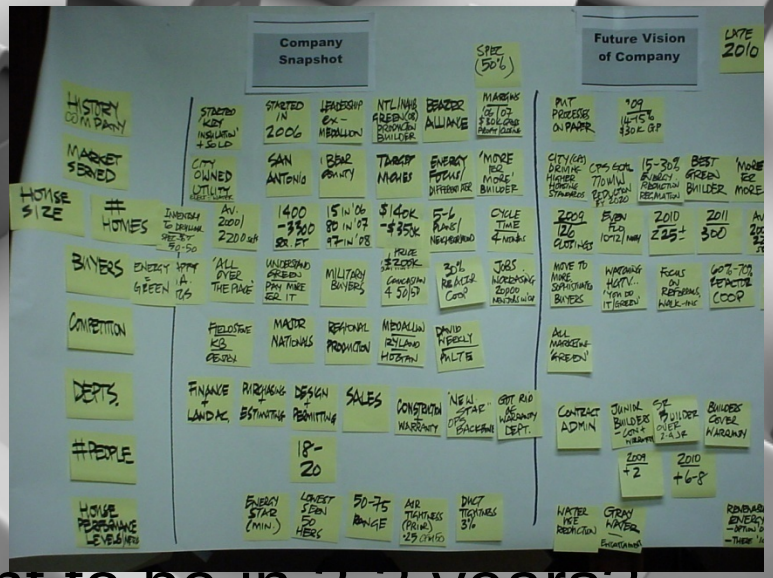
1. Cultural and Corporate Alignment

- Strategic planning for High Performance
  - Why are you doing it?
  - What are your goals?
  - How does this align with you core company mission?
  - What will it take technically?
  - How will that impact all aspects of the company?



Strategic Planning

- Where is the company today?
  - History, Markets Served, Target Buyers, Annual Sales/ Revenue, Av. Home Price/ Size, Competition, Home Performance Level, Key Issues, Organization Design, # People, Profit Margins, etc...

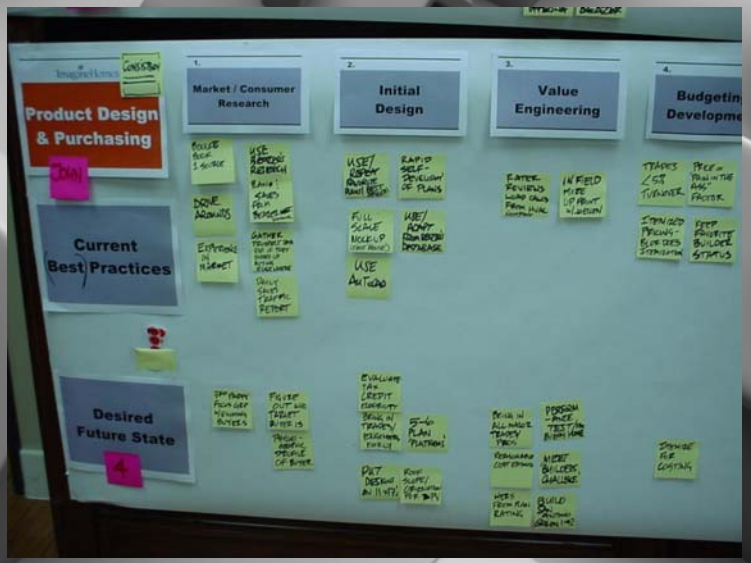


- Where does the company want to be in 2-3 years?
  - Vision and Business Goals in same areas, looking out
  - What are the major Barriers to Success?

Strategic Planning

Planning & Development | Product Design & Purchasing | Marketing & Sales | Home Construction | Customer Care

- What are the company's operating strategies and practices in each of the 5 operational areas?
  - Current State?
  - Desired Future State for each?
  - Where are Opportunities for Improvement?



Strategic Planning

- What are the priority opportunities to pursue?
  - Group/ Multi-Voting
  - Initial Ideas Screening

2. Increased Collaboration

- All departments are involved
- Work with trades, designers, realtors, buyers

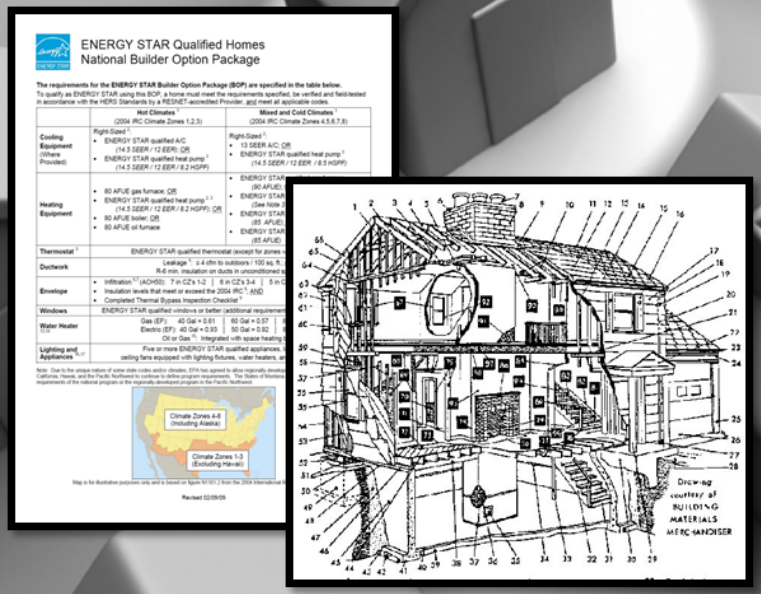
Veridian Homes Trade Partner Interactions

Collaborate with your customers

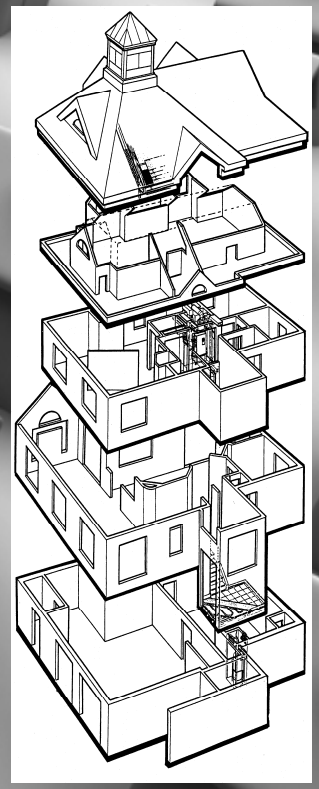
- Ask questions to fully understand customer' needs.
- Analyze situations from the customers perspective.
- Always consider the customer before taking action
- Always keep customers informed about planned and emerging developments related to their interests and requirements.

3. Clear intent for quality and performance

- Avoid simple product & specification focus
  - "Purchasing" mentality
  - Does not necessarily gain inherent synergies of a Systems Approach
  - All parts of the operational system are involved


ENERGY STAR Qualified Homes
National Builder Option Package

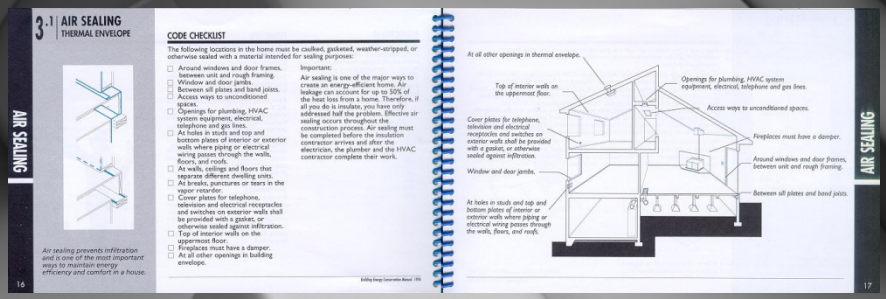
"Spec and Purchase"

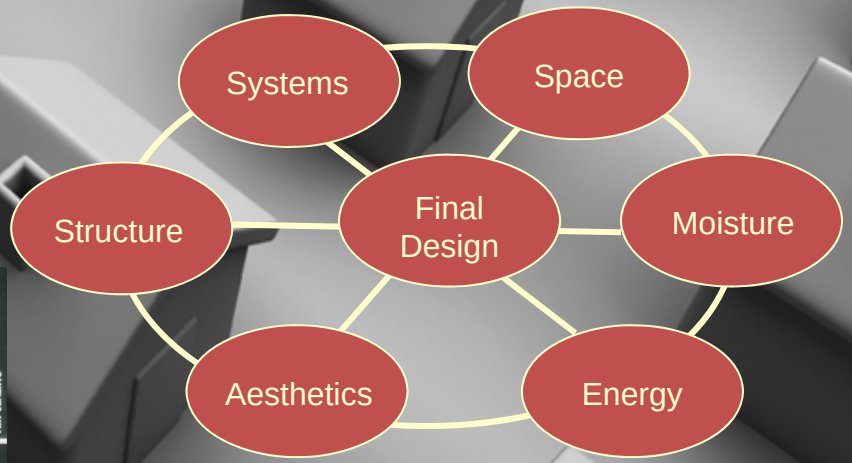


"Systems Approach"

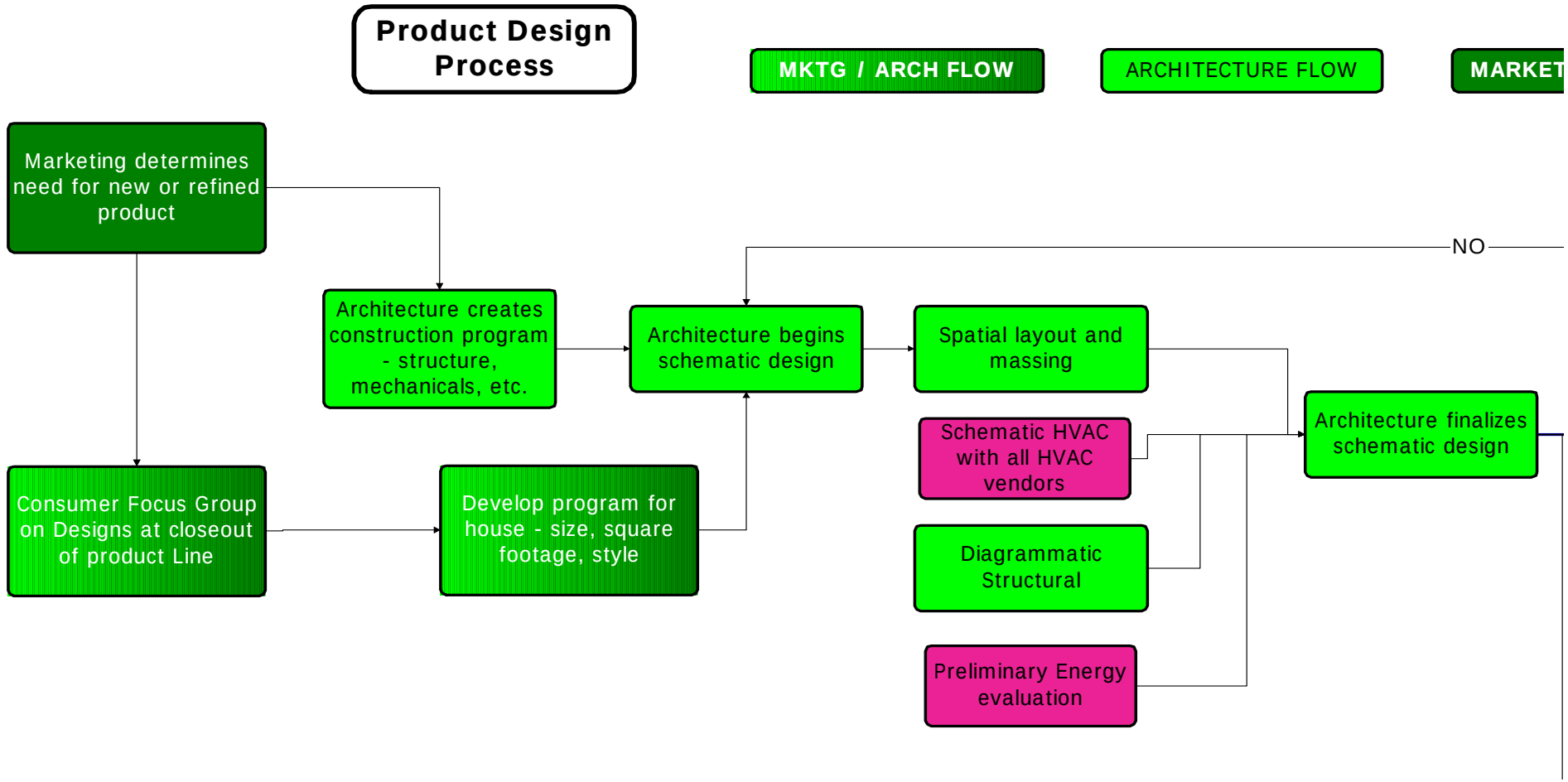
4. Integrated Design

- Design doesn't happen in a vacuum – all parties should be involved from Day 1
- Programming – use performance standards
- Develop initial designs, including participation from engineers and trades
- Conduct energy modeling
  - Early and often



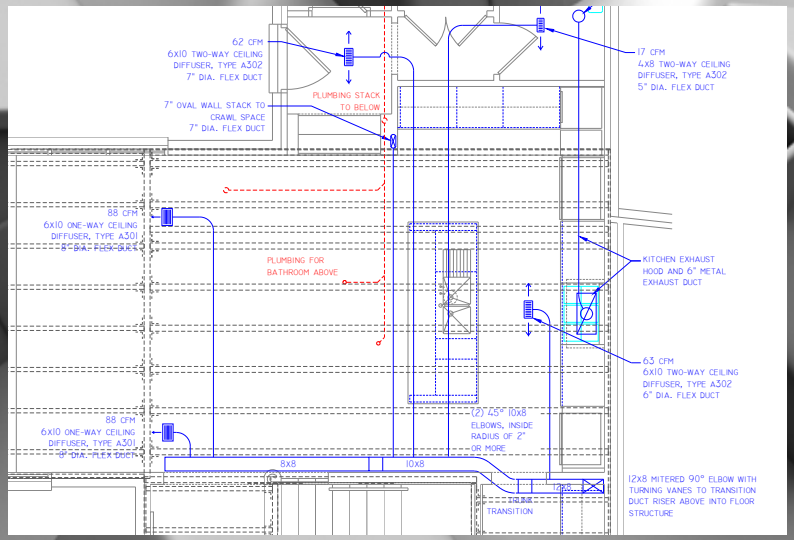


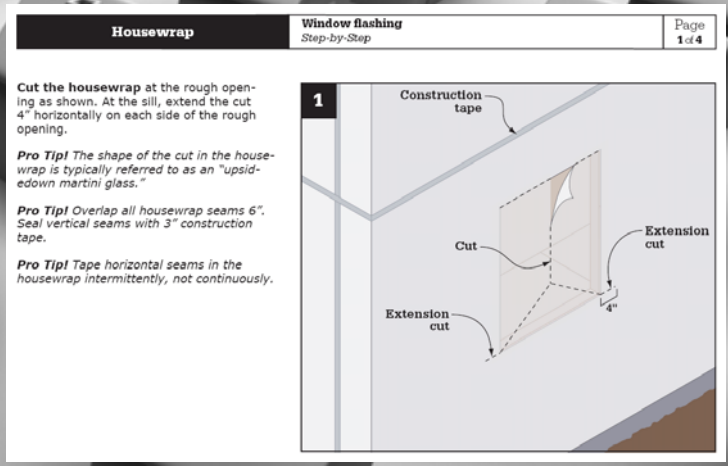
Integrated Design Process Approach

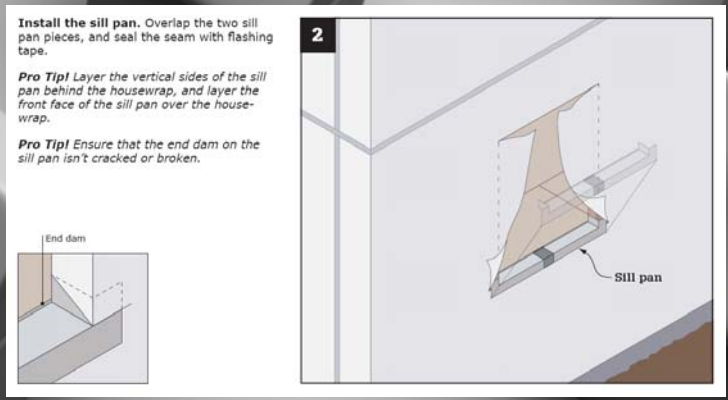


5. Better communication practices and systems

- Scopes
- Construction documents
- Field tools
- Step by step instructions for critical details

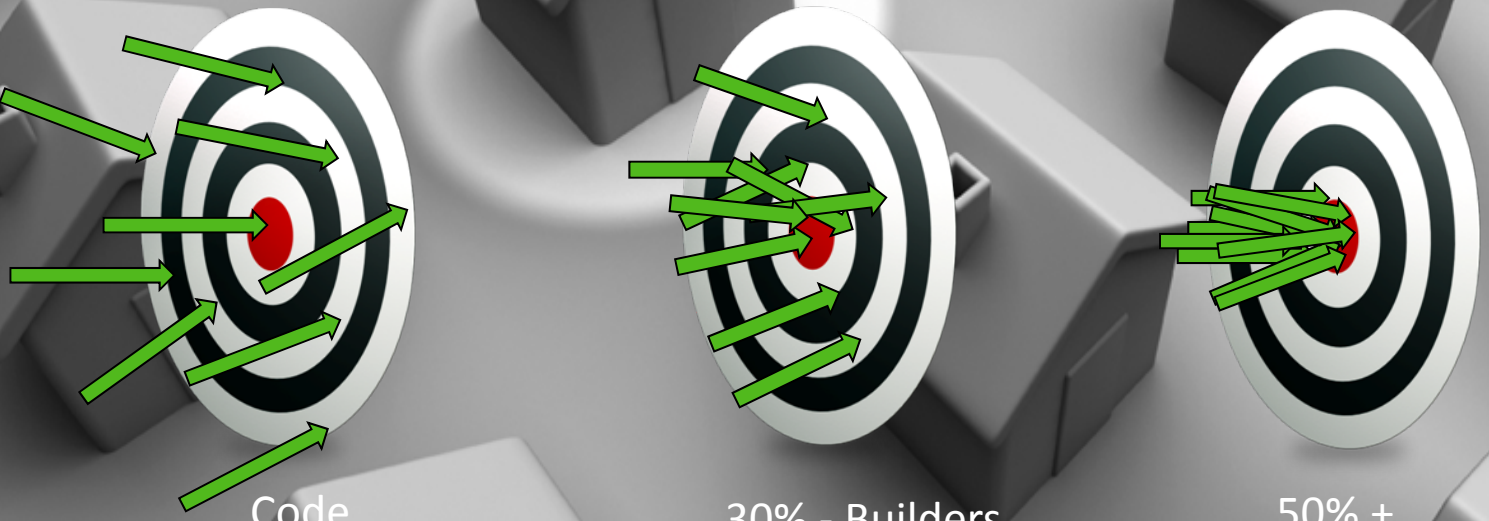






6. Quality Control

- Increased energy efficiency requires greater attention to detail in design and execution
  - Water management, HVAC design, thermal enclosure, comfort, IAQ



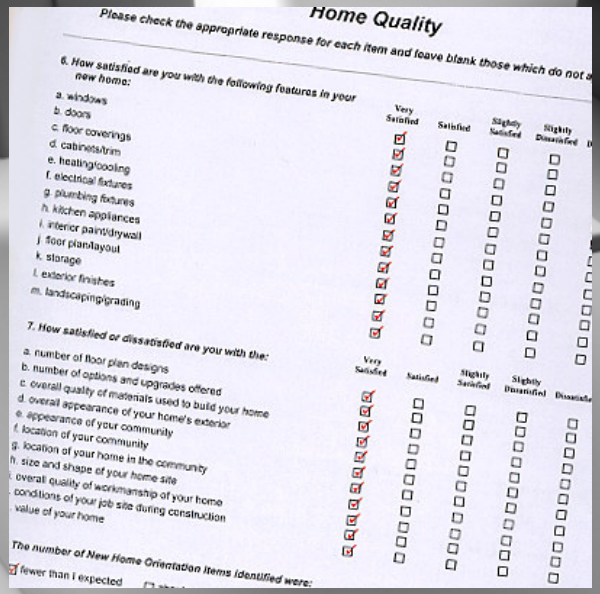
Code

30% - Builders Challenge

50% +

Construction Quality Assurance

- Trades have to be brought on board
- Trades should be checking work – Job Ready, Job Complete
- Supervisor is managing process and exceptions, not managing the rules


Home Quality

Please check the appropriate response for each item and leave blank those which do not a

6. How satisfied are you with the following features in your new home:

	Very Satisfied	Satisfied	Slightly Satisfied	Slightly Dissatisfied
a. windows	☑	☐	☐	☐
b. doors	☑	☐	☐	☐
c. floor coverings	☑	☐	☐	☐
d. cabinets/trim	☑	☐	☐	☐
e. heating/cooling	☑	☐	☐	☐
f. electrical fixtures	☑	☐	☐	☐
g. plumbing fixtures	☑	☐	☐	☐
h. kitchen appliances	☑	☐	☐	☐
i. interior paint/drywall	☑	☐	☐	☐
j. floor plan/layout	☑	☐	☐	☐
k. storage	☑	☐	☐	☐
l. exterior finishes	☑	☐	☐	☐
m. landscaping/grading	☑	☐	☐	☐

7. How satisfied or dissatisfied are you with the:

	Very Satisfied	Satisfied	Slightly Satisfied	Slightly Dissatisfied
a. number of floor plan designs	☑	☐	☐	☐
b. number of options and upgrades offered	☑	☐	☐	☐
c. overall quality of materials used to build your home	☑	☐	☐	☐
d. overall appearance of your home's exterior	☑	☐	☐	☐
e. appearance of your community	☑	☐	☐	☐
f. location of your community	☑	☐	☐	☐
g. location of your home in the community	☑	☐	☐	☐
h. size and shape of your home site	☑	☐	☐	☐
i. overall quality of workmanship of your home	☑	☐	☐	☐
j. conditions of your job site during construction	☑	☐	☐	☐
k. value of your home	☑	☐	☐	☐

The number of New Home Orientation items identified were:

☑ fewer than I expected ☐

7. Measurement and verification of performance

- HP houses need verification –visual, performance tests, etc.
- These can be in house, third party, or a combination of each.
- With a rigorous quality management system, how much could a builder self certify?

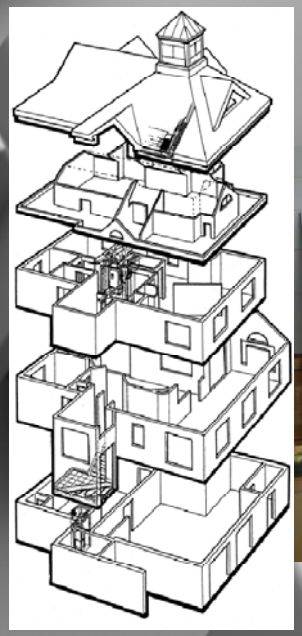
Tools are there – Use them!

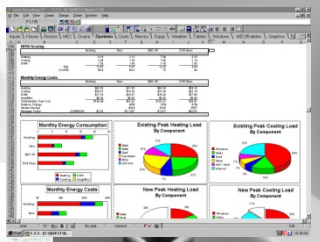
- Operational Excellence & Quality Management – known but not widely utilized
  - Increase Productivity – More with Same or Less
  - Standardize Systems and Processes
  - Continual Improvement
  - Cultural and Corporate alignment
  - e.g. Even Flow, Cycle Time, Customer Satisfaction, Return On Assets, First Time Quality, Trade Relations…

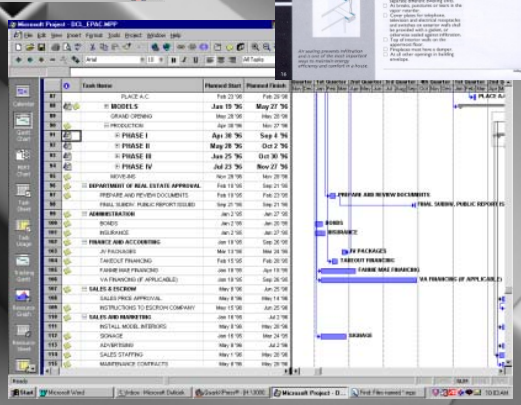
NAHB RESEARCH CENTER NHQ CERTIFIED

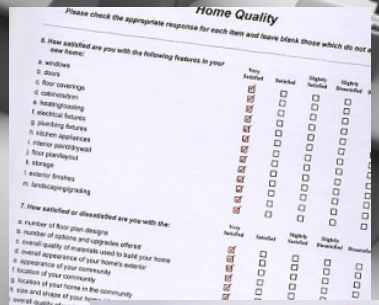
8. Continuous feedback and improvement

- Know what you are striving for
- Know how you are doing
- Set goals and stretch goals
- Figure out how to improve the process









Transition

Key Points

- Get your team’s arms around the project
- If the project is too big, you need control
- Know why your doing the project
- Know when you're done
- Know how to measure the impact

The New American Home 2010

Completing the Green Oasis

The New American Home 2010

Designed to be a Zero Energy Home Reflecting the Nation's goals of Energy Independence

Western Gated Community

Domanico Homes
The perfect storm of Home Building

Building the New American Home has become a massive challenge of keeping it real and integrating all the new technologies being introduced.

This year the homebuilding financial crisis was the final wave.

Architecture and style

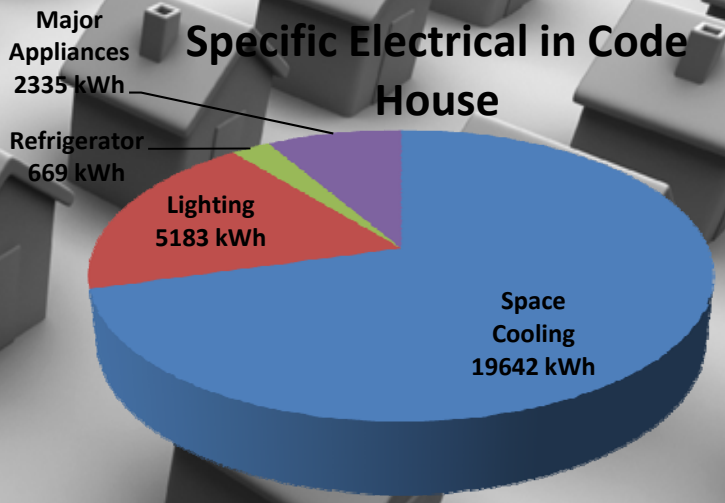
The quality of spaces in both large and small homes is important. Maybe even more important in small spaces

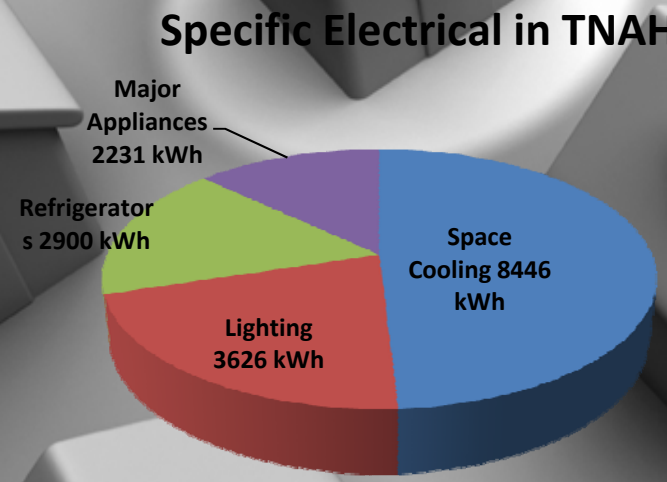
“affordable elegance?”

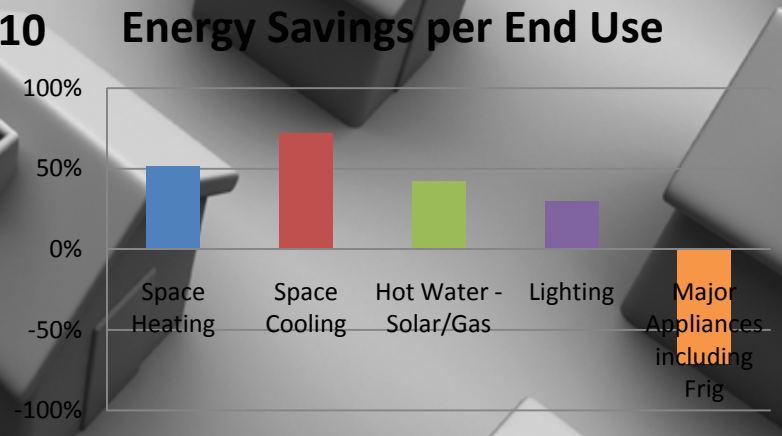
Craftsmanship is king, but we don’t have that many craftsmen anymore. How can we translate the emotion an message with the same care for cost that we apply to energy efficiency decisions?

Savings close to half

If we can save 50% of this homes energy, just think what we can do in every home across the US

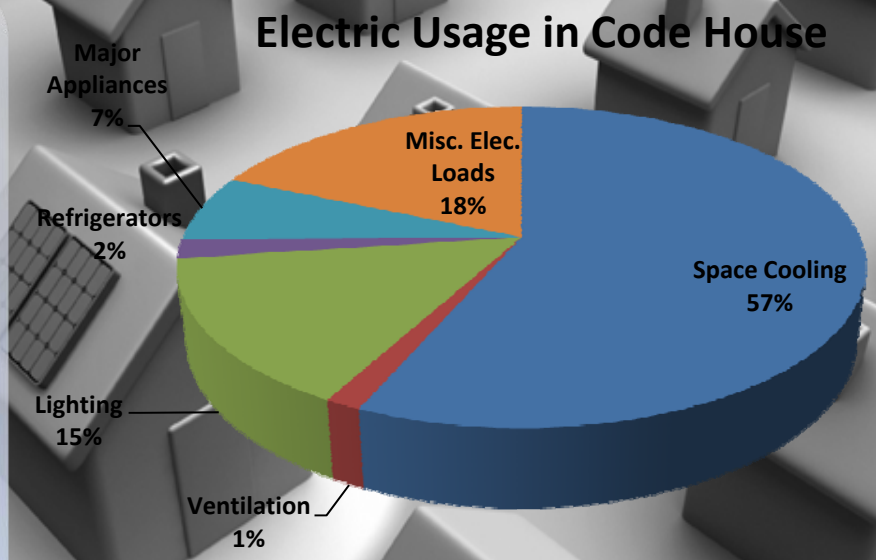


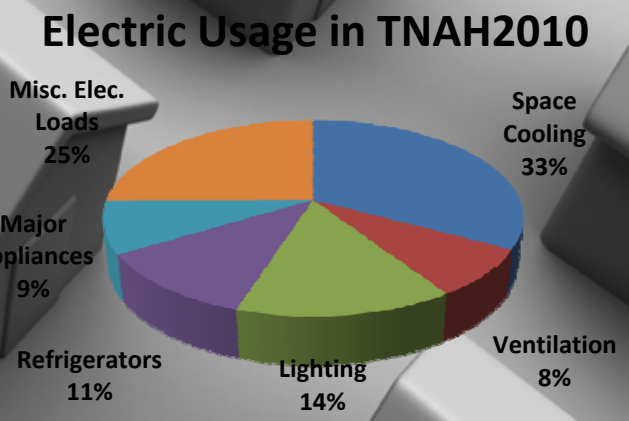




Lifestyle electrical demand

The challenge of both new and existing home's energy use is to get control of the increasing electrical usage to support entertainment, communication and food storage and preparation





High R-value walls

Exterior walls consist of 10” thick insulated concrete form system by APEX with R-23 performance. A portion of the walls are wood framed with R-20 insulation. Dryvit exterior insulation and finish system adds R-7 insulation to the base wall systems.

Innovative structural slab

CUPOLEX® which is a patented structural dome flooring system made of recycled plastic modular elements.

Shading from roof elements

Combined with good windows, architectural shading keeps the peak heat out of the home

Mixture of materials

Understanding the values of each possible material will challenge builder teams as we adapt to higher energy performance

Apex walls carved for convenience

Roof water collection and drainage piping was carved into the wall exteriors.

This minimized the need for chases and roof penetrations

What is the R-value of pipe?

Sometimes convenience can over trump a good material. Just because you can, doesn't mean you should.

Roof Garden “a cool idea”

Planting areas on the roof reduce heat gain to the roof structure and provide shade to adjacent windows

In small urban lots this also allows more natural connection

Exterior insulation adds 33%

We are all going to see increasing use of exterior insulated board components

This is a very effective way to increase the thermal performance of energy efficient homes

This isn’t your 2x4 wall

Builders in the Southwest have been building thick walls, but 12” plus is big for even here. Builders in the next decade will be figuring out how to build High R walls

Not for every climate

Direct application of manufactured stone can work in drier climates
When using natural stone or manufactured stone, water management and potentially active drying should be considered

Mass connected to the interior

The use of mass in an integrated way will become a design element that supports energy efficiency and comfort.

The energy efficiency community is seeing benefit from mass and phase change materials

Water management vs Architecture

These are the areas where builders must have clear intent. Multiple trades do their own tasks, but who owns the interface between?

Where the Scary Things live

Water hits all the surfaces equally, but each surface drains at different rates.

Rough surfaces hold gallons of water

Doing a roof right

This difficult area of water management has come a long way. Excellent flashing integration to multiple enclosure technologies

Transitions between conditions

"smaller" homes of the next decade…

Break for laugh here…..

Will need to find ways to connect interior space to the outside, and understand the impact on energy and comfort

Transitional spaces

Handled well, these spaces can enhance smaller interiors and provide a larger sense of the conditioned environment.

Windows are for seeing through!

Shocking concept, if you can't see through the window, make it a wall.
Under a visible light transmission of 45% a window is just a bad wall

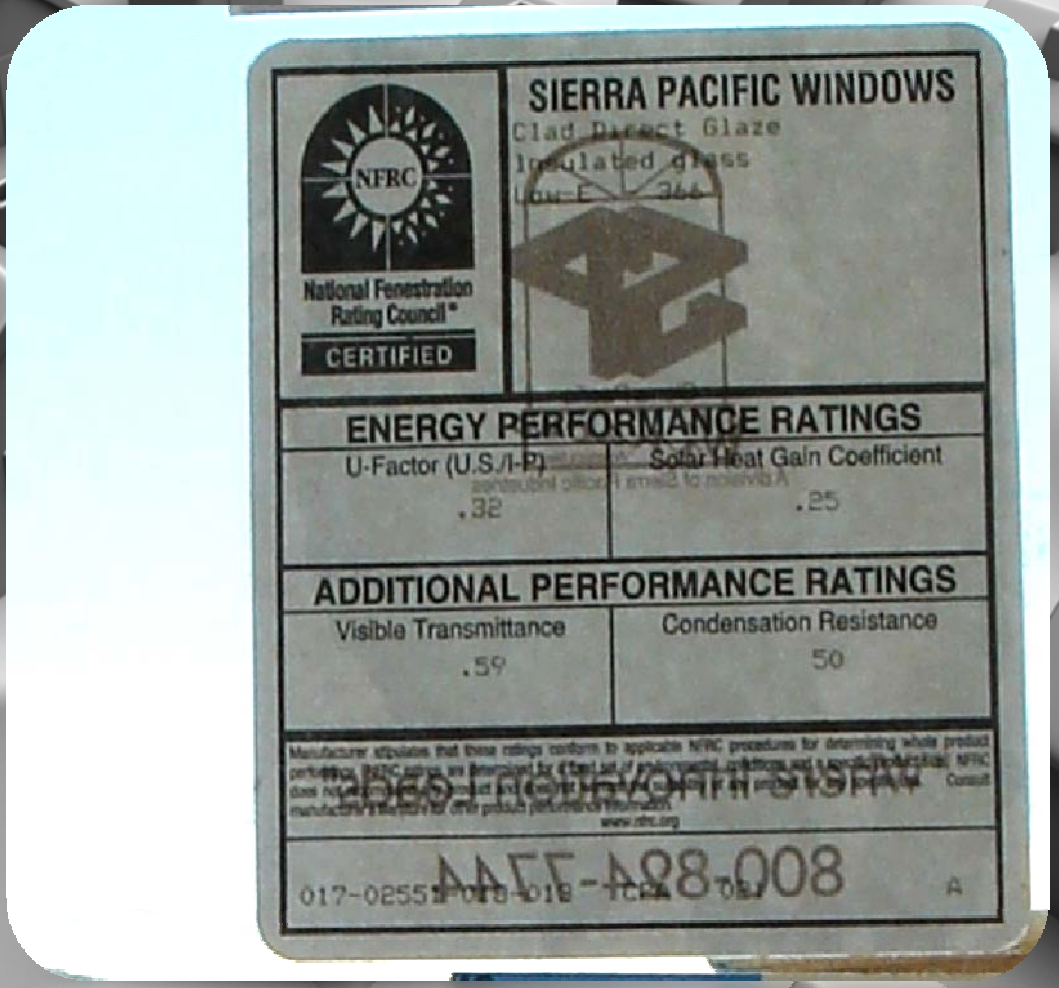
These are windows

U-Factor 0.32

Solar Heat Gain Coefficient 0.25

Condensation Resistance 50

Visible Transmittance 0.59



Great comparison

There are many glazing systems currently being sold that have similar performance, but as a builder you need to ask

A quick survey of mechanicals

Bringing ductwork inside the conditioned can return 15 to 20% reduction in equipment sizing, and 10 to 15% energy savings

In the new world...

Structure and mechanical integration will continue to be a fight. Designers and engineers will need to learn work together in strange new ways.

Integrated systems or entombed

This is a an emerging problem. Even now Southwest AC units require demolition in order to replace them. How are these serviced?

New ways of delivering comfort

Conditioned air will enter spaces at lower volumes, lower velocities, and at lower temperature differences. These linear slot registers are commercial technology transitioned to residential

And a new aesthetic..

With high performance windows and good local control, does this register need to be here?

Planning return air path

Correct sizing of return air paths is a "technology" that applies to both large and small homes.

It could be the most under addressed design issue

This is a service access?

As builders, trades, manufacturers, and designers, we really need to talk about the life cycle issues of how we build

Coordination?

Did the framer install the pipe after the sprinkler? No, but someone will have to re-work this, for not value added cost

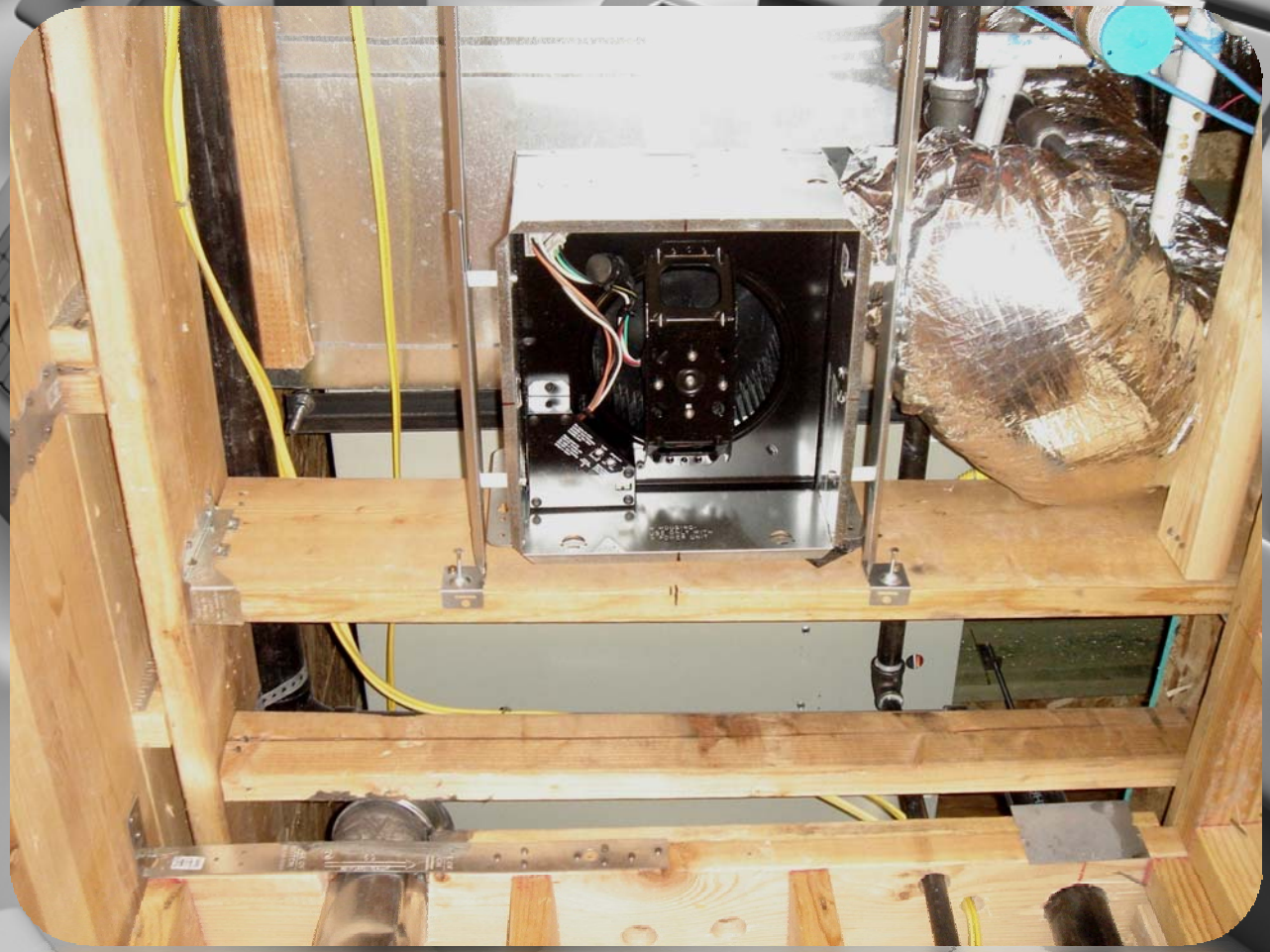
Just More....

And More….

KISS
Or
Kill?

Selecting technology

Difficult routing for ventilation can be overcome by selecting fans with higher static capacity, or adaptable motors



Lead or follow the trades?

Selecting infrastructure systems and materials has become complex. Where do we get the information defining quality of installation?

When is enough, enough?

Control of lighting and other electrical loads can be achieved by centralized systems. But, does this really make sense?

This is not just a Big house problem.

Enough?

Enough!!!

Is this enough?

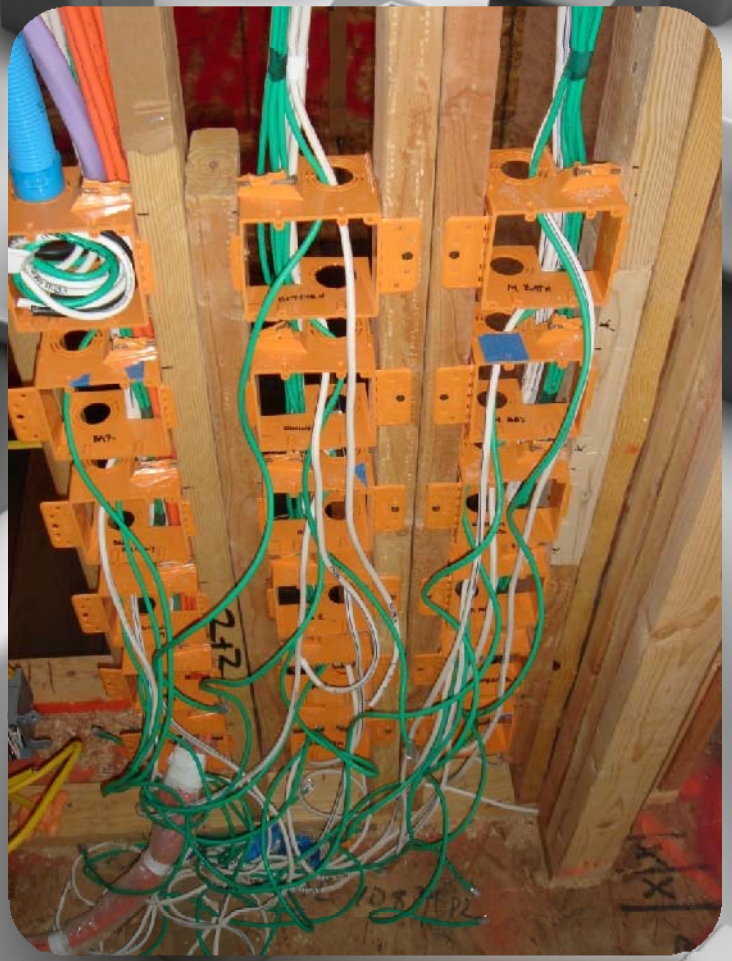
Lighting, appliances, and Miscellaneous electrical loads are the only load segment of housing still growing

Low voltage wiring and controls

This is a technology that is here for keeps.
Increasing demand for control to enhance lifestyle does little to save energy

When one just isn't enough....

Manufacturers, designers, builders and trades will be blasted with integration challenges as we embrace home controls in this decade



Who will hold the roadmap?

Who does the as built drawings?
Who knows where they are?
Who knows how to read them?

Radiant floor systems

Comfort will always challenge energy efficiency, but hydronic delivery of heating and cooling is in the future

Ventilation….

We must embrace ventilation as a necessary element of residential design. Integration of systems must start early in the process

Getting the most for our $

The balance between first cost and high performance is not an intuitive decision. Builders will need to rely on more early design and modeling interactions

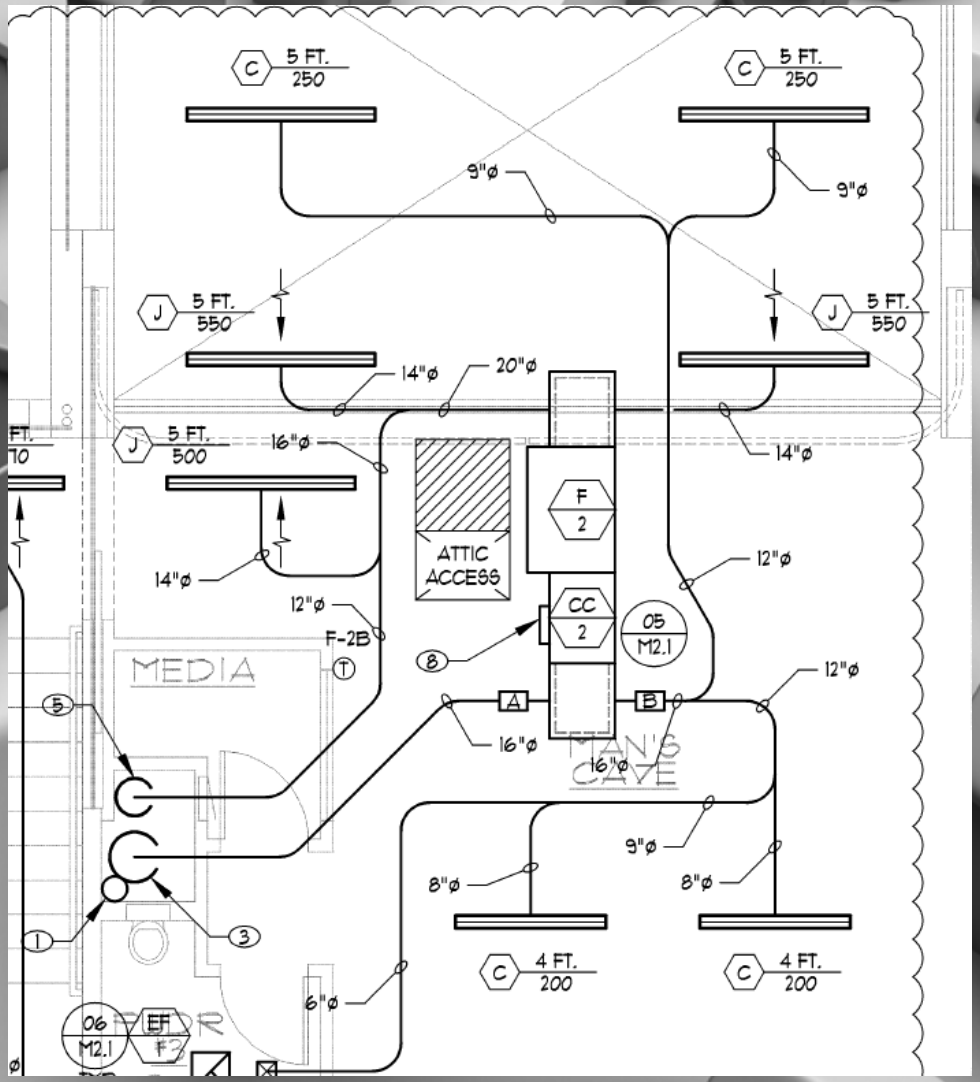
Five units serving tight zones

Five air handling systems in conditioned space. Variable speed gas furnace 95% AFUE, MERV 8 air filtration, and variable speed dual-compressor condensing units with an average of SEER 17 performance.

Zoning

Many benefits from good zoning

- Local Control
- Short Ducts
- Less conflict with structure
- Serves similar orientation
- Minimized acoustic connection



Understanding air sealing....

Spending our air sealing dollars wisely continues to be a challenge. Stucco seals the wall, but what seals the windows?

Commissioning ....

Testing is not just for acceptance, but is a great educational tool. There are no people on the site that know it all. Testing can inform everyone and help eliminate waste

Final views of integration

If we can really design a house for 100 years minimum life cycle, we need to consider 100 years of service

Your challenge should you choose…

Change the ballast

Service the fan motor

Trace a pipe

When the condensate pan leaks

It is not our nature to plan for failure, yet things do go wrong, and it must be our nature to plan for service

The Good news.. There is a buyer and it will be finished

Thank You

Questions?

This concludes The American Institute of Architects Continuing Education Systems Program

IBACOS

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BEST 2 2010 Portland CONFERENCE
Building Enclosure Science & Technology

Energy Efficient Lighting Strategies

Sharing a vision on High Performance Lighting in the Pursuit of Zero Energy

Brad Oberg, Chief Technology Officer

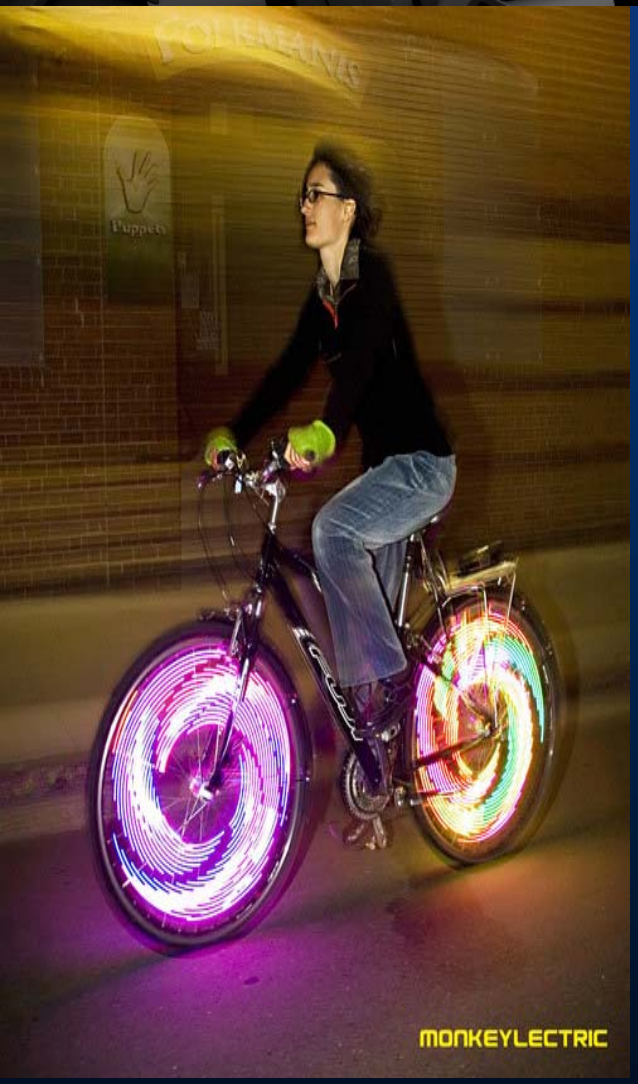
IBACOS | Home Quality + Performance |

Best Practices Research Alliance®

Big Picture

- We are about creating the confidence for builders to make energy efficient lighting choices
- Codes and incentive programs create an interest
- Lighting historically has been an underutilized design feature and many times is relegated to an allowance and a showroom sales person.
- It wouldn't take much to include good lighting design in more homes
- An integrated design-build-sell process is needed

Lighting in the High Performance Home



- LED lighting has become a major medium for art, because of its vibrant color and low energy demands
- Battery powered displays are used in point of sale through safety and more!
- Energy efficient lighting may soon become the norm in homes as well

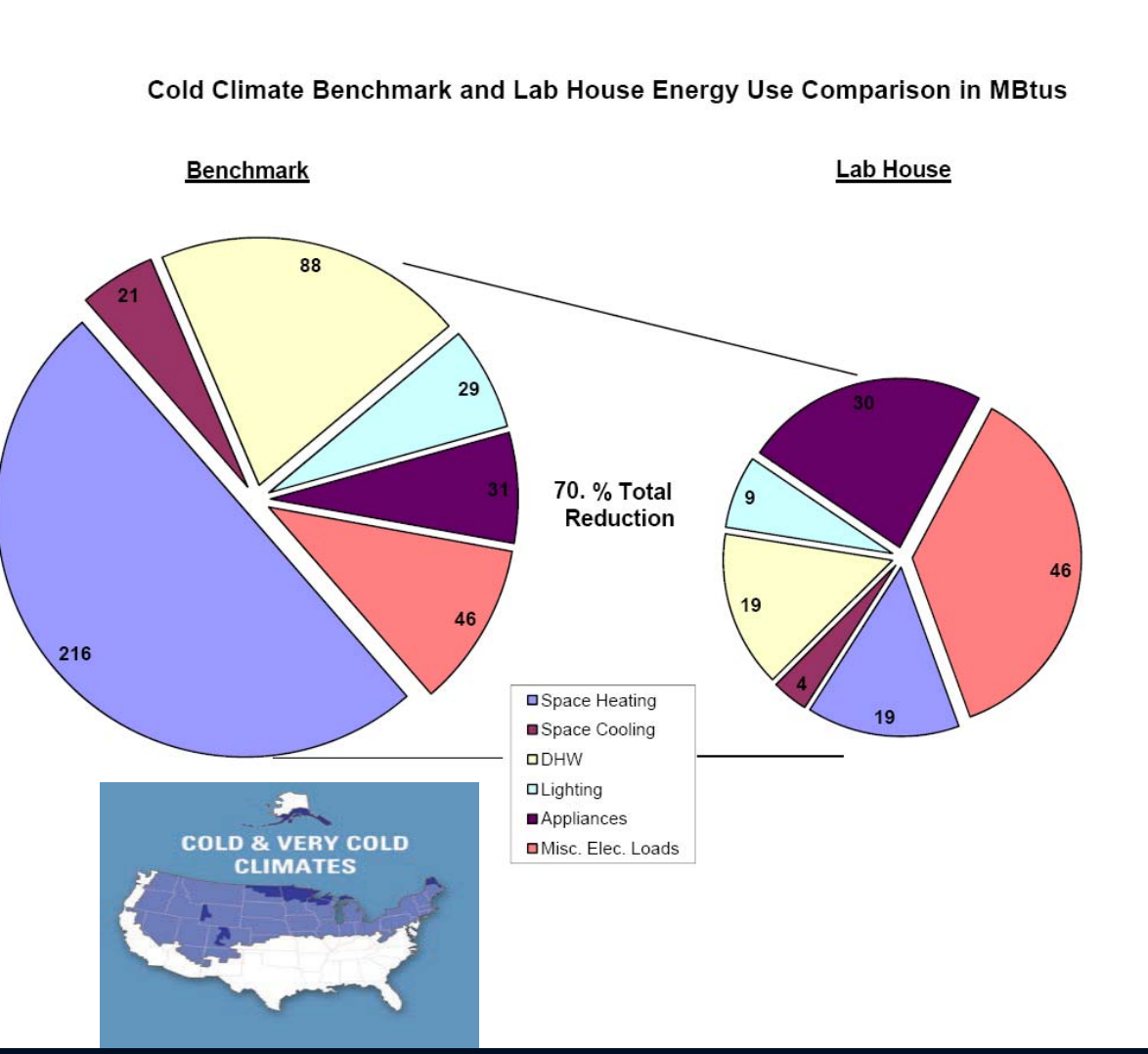
LAMEL

Lighting, **A**ppliances, and **M**iscellaneous **E**lectric **L**oads

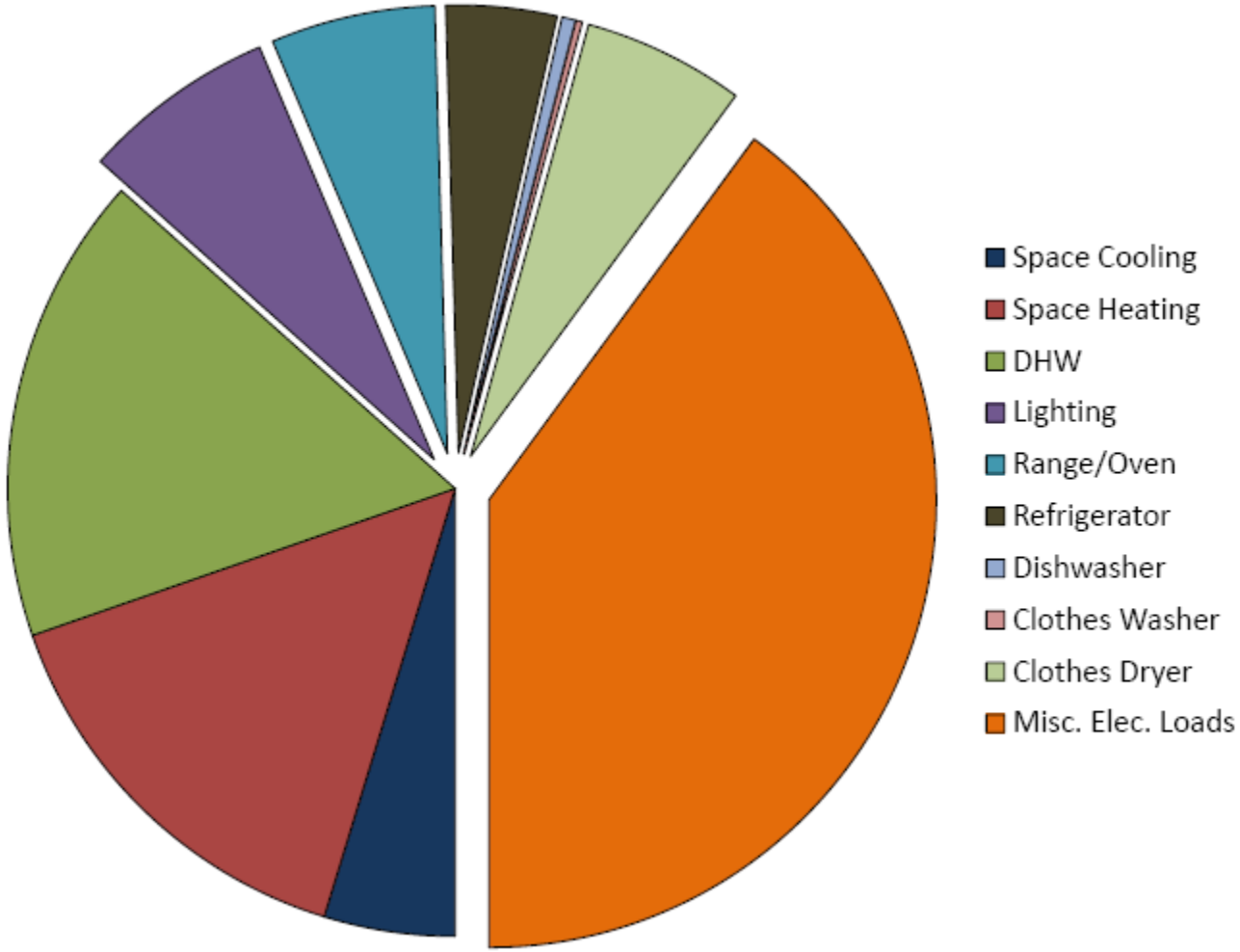
- Lighting: hardwired and plug-in
- Appliances: big 5 major appliances
- MELs: plugged in equipment and other loads

Cold Climate

- Large variances of rain, temperature & geography
- Lots of basements and crawl spaces
- Lots of moisture stresses
- Forced air systems – metal ductwork
- Chicago, Denver, Minneapolis, Pittsburgh, Indianapolis



LAMEL


Space Cooling
Space Heating
DHW
Lighting
Range/Oven
Refrigerator
Dishwasher
Clothes Washer
Clothes Dryer
Misc. Elec. Loads

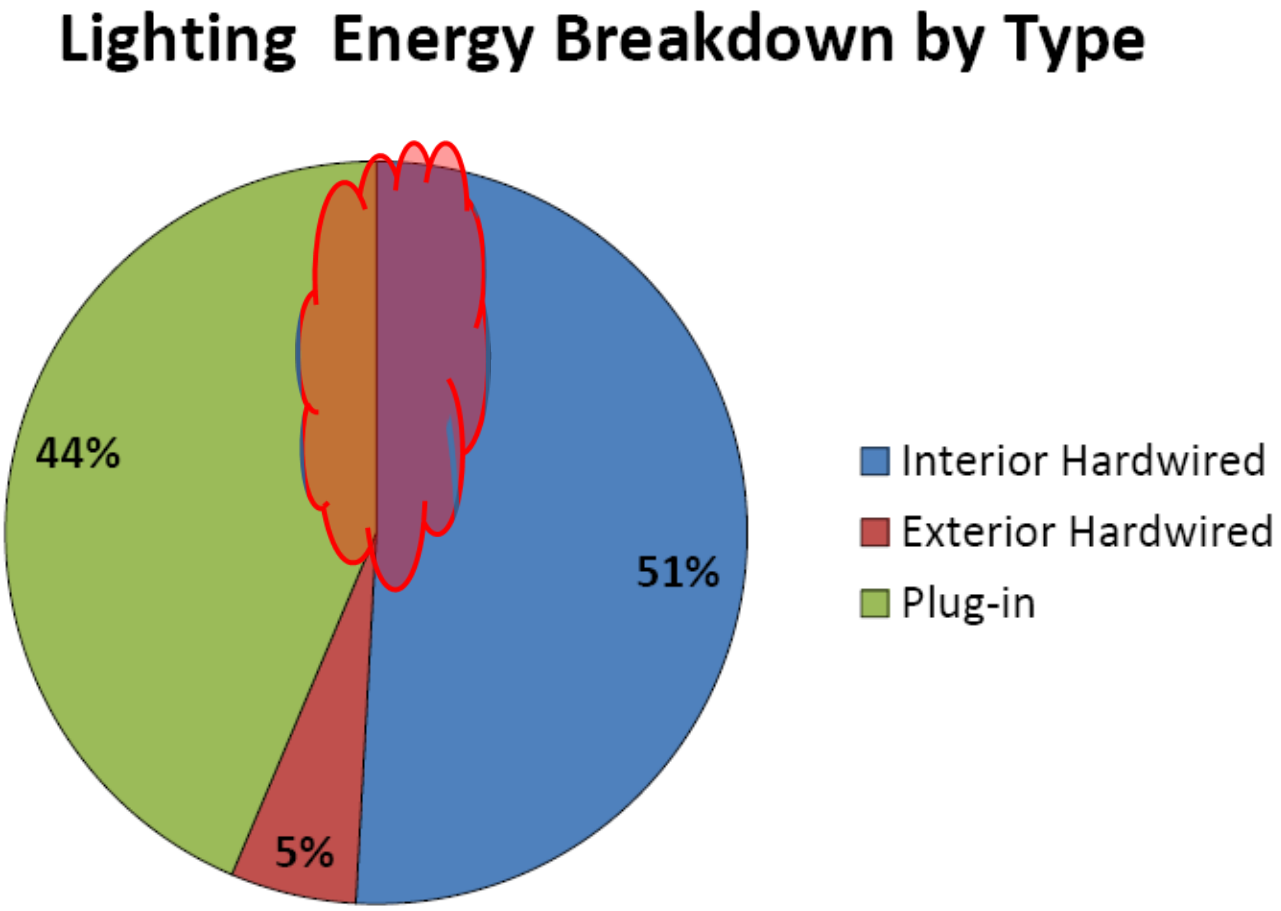
Lighting

Interior Hardwired

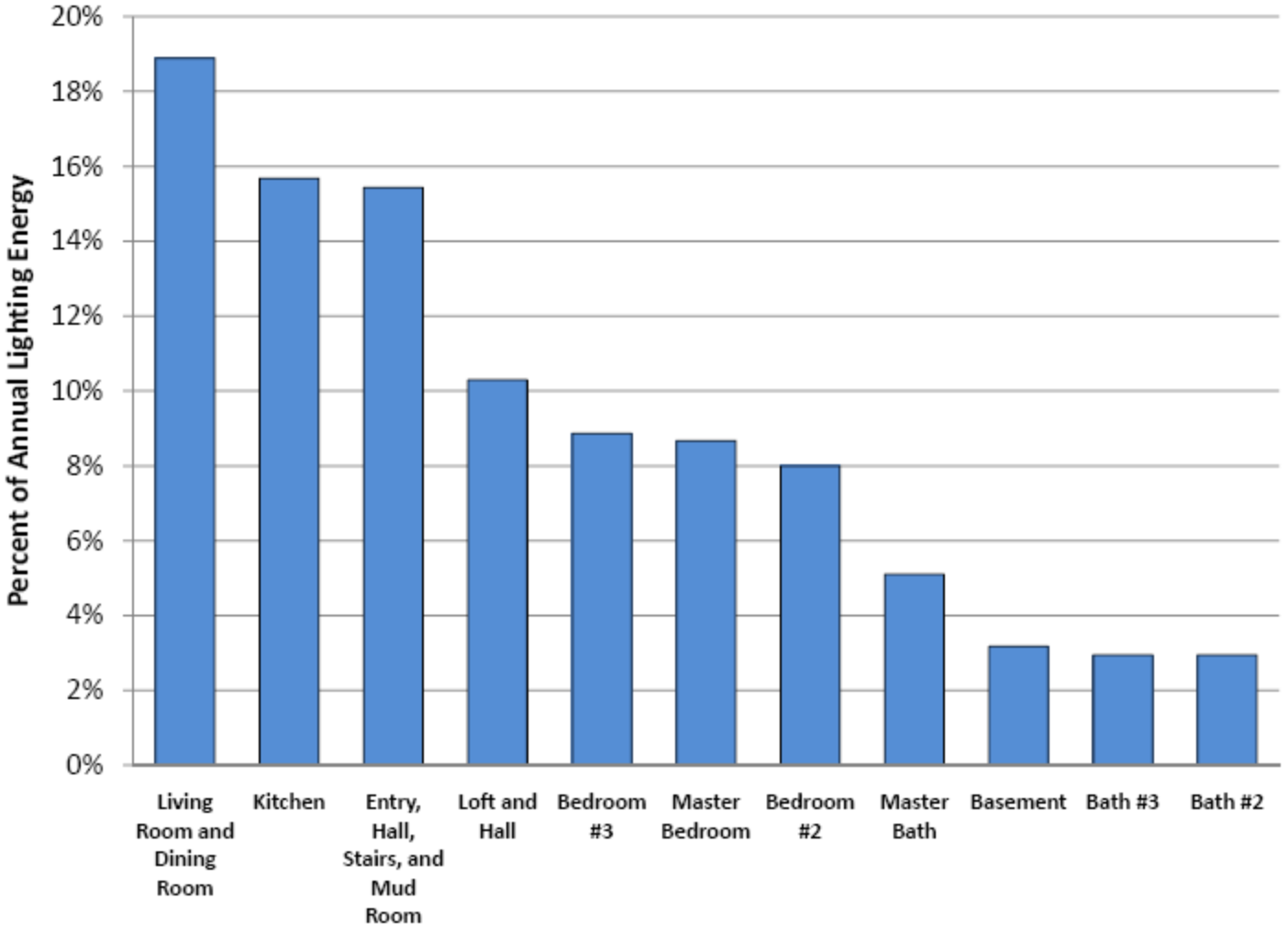
Exterior Hardwired

Plug-in Lights

Lighting


Lighting Energy Breakdown by Type
44%
51%
5%
Interior Hardwired
Exterior Hardwired
Plug-in

Lighting: Interior Hardwired Distribution



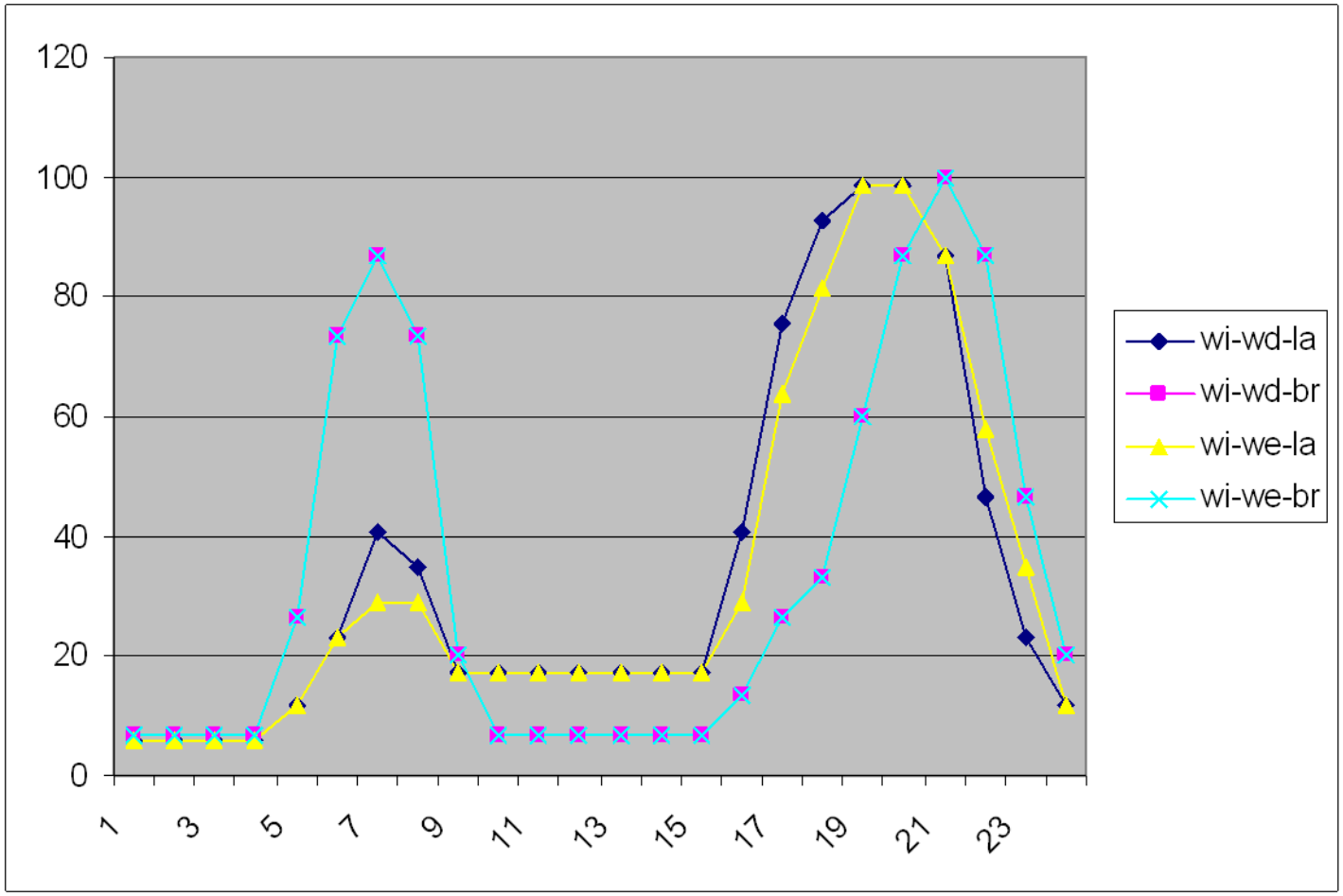
Whole House Model

Lighting Power Densities

	Areas	Base Lighting	Efficient Lighting
0-Basement	1191	0.6	0.2
1-Dining	242	2.4	1
1-Family	245	1.8	0.4
1-Hall	141	1.28	0.26
1-Kitchen	251	2.7	1.3
1-Laundry	75	1.6	0.7
1-Library	148	2.7	0.7
1-Powder	30	4.8	1
1-Stair	60	1.2	0.2
1-Garage	442	0.4	0.2
2-Bath 2	45	2.5	0.9
2-Bedroom 2	167	1.6	0.4
2-Bedroom 3	161	1.6	0.7
2-Bedroom 4	149	1.8	0.8
2-Closet	65	1.2	0.6
2-Foyer	81	1.9	0.5
2-Hall	112	1.5	0.3
2-Master Bath	124	2.1	0.9
2-Master Suite	228	1.2	0.6
2-Stair	60	0	0
Attic	1191	0	0

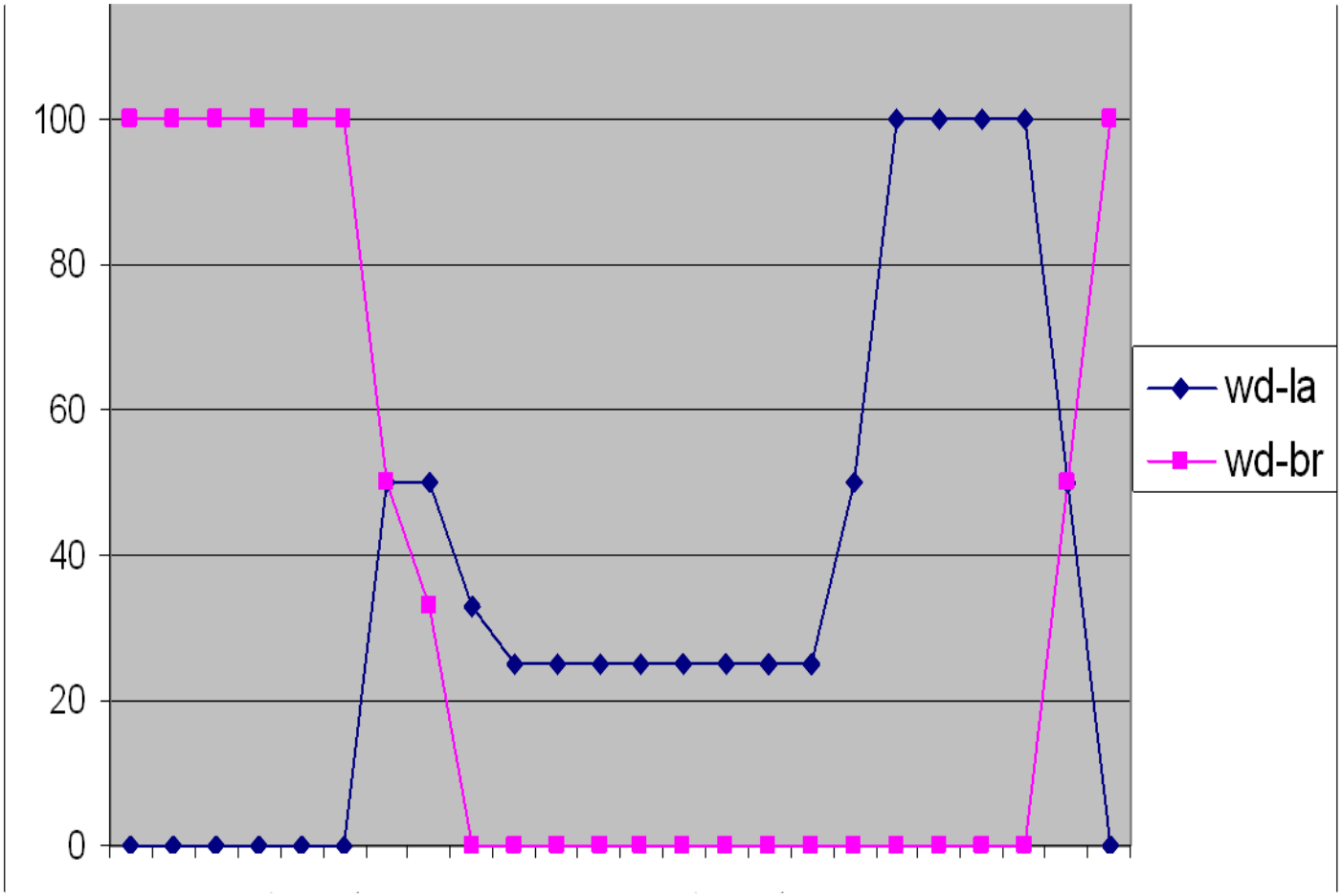
(Note: 1 indicates first floor; 2 indicates second floor.)

Whole House Model



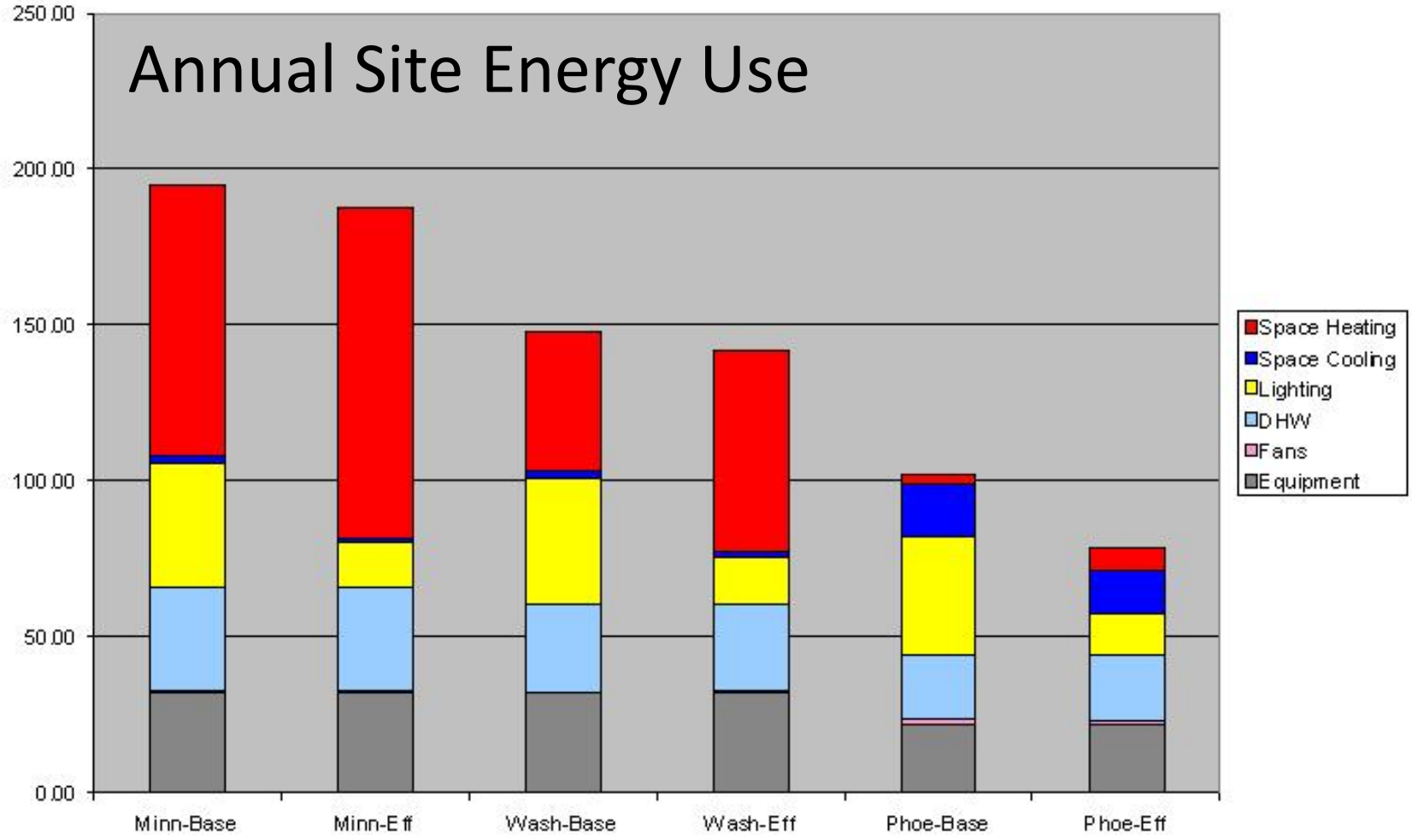
Schedules - Lighting

Whole House Model

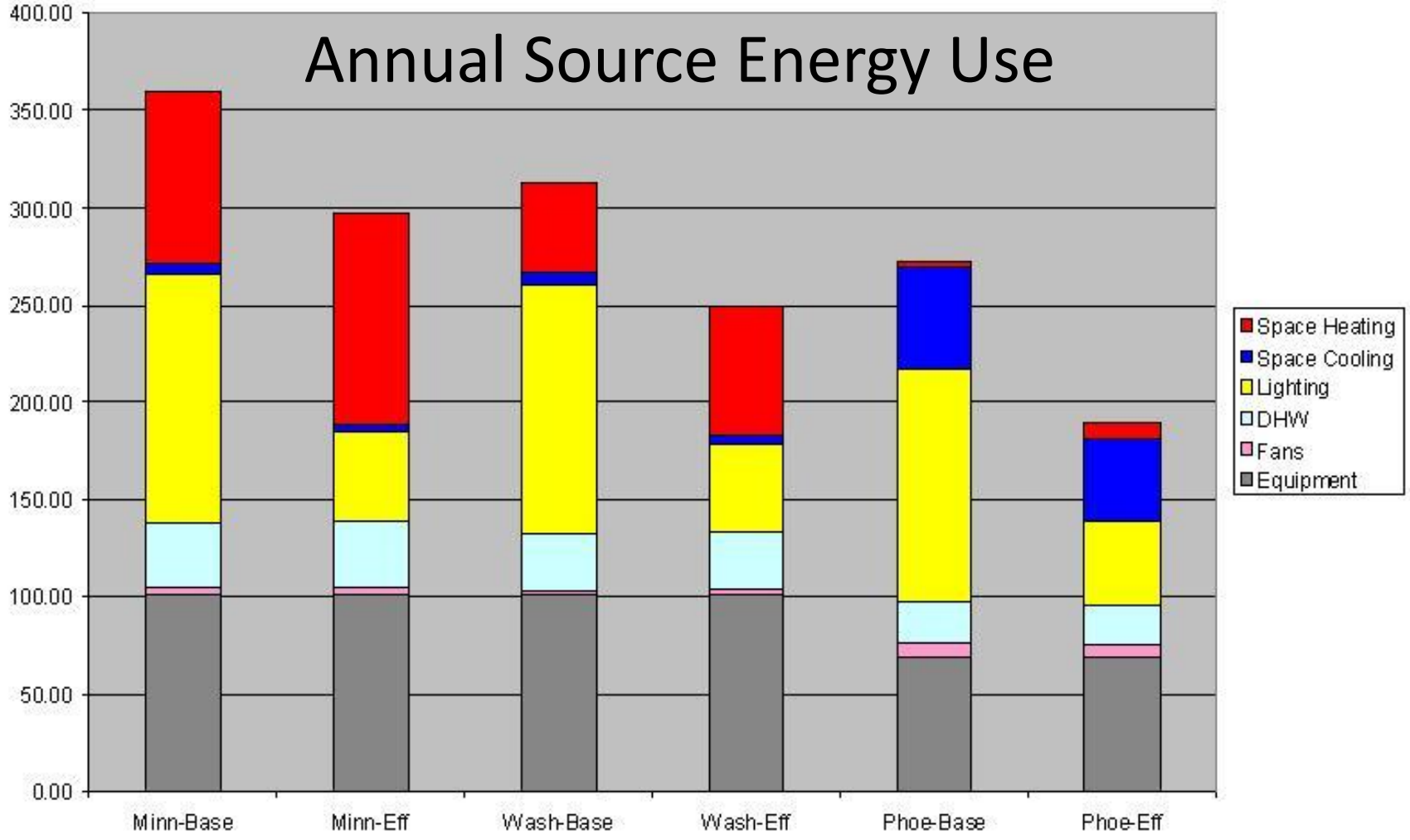


Schedules - Occupancy

Whole House Model



Whole House Model



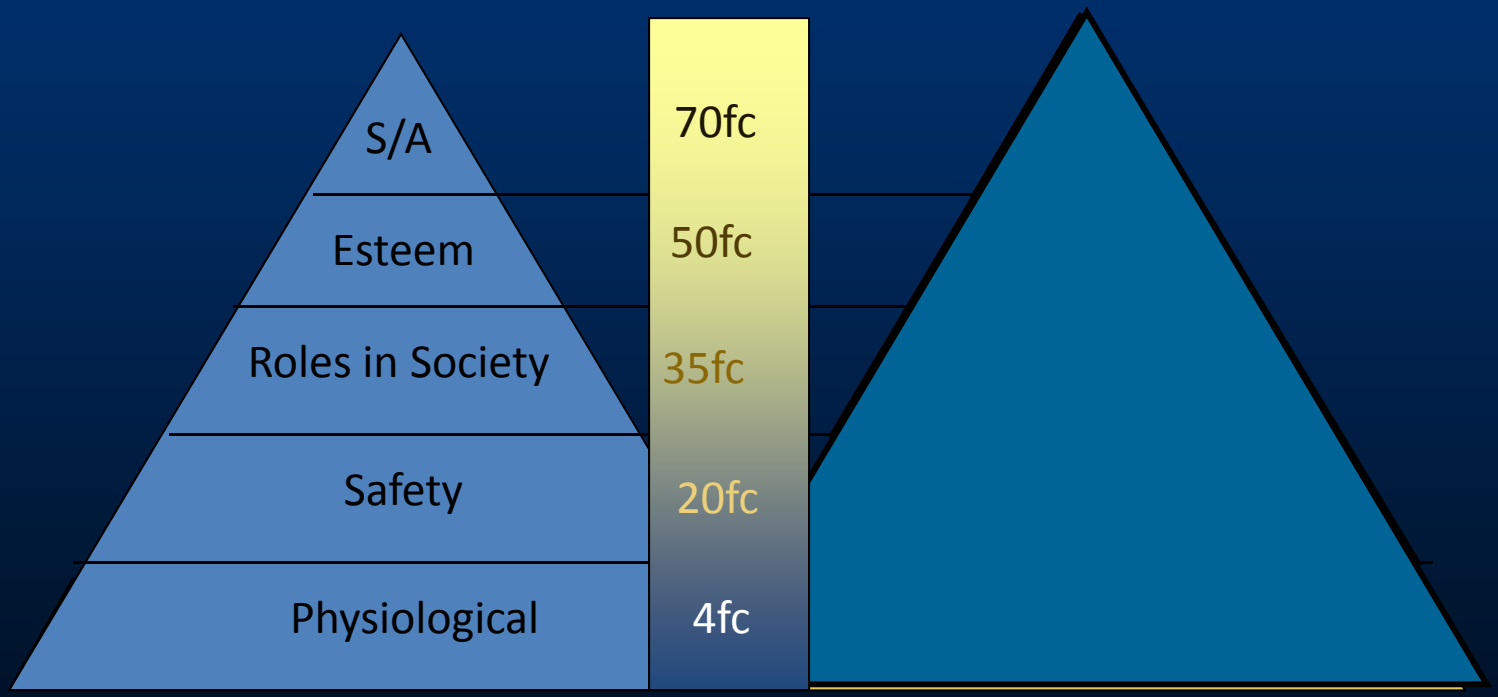
Why is lighting so personal?

Vision is a partnership between the brain and the eyes

We have been conditioned since pre-history to manage that partnership for survival

Big Picture

Lighting quality is measured subjectively by our reaction based on deeply trained responses



DESIGN CONSIDERATIONS : COLOR

Fluorescent: Energy Star QC Test

Color shift and short life issues plagued the CFL market in the last 2000's

ENERGY STAR "Durability" Testing
Work ongoing at Lighting Research Center

Source: US EPA

Fluorescent : New fixture and design choices

Fixture Inventory on Website

Strip Light in Cove

Recessed Downlight

Wall Washer

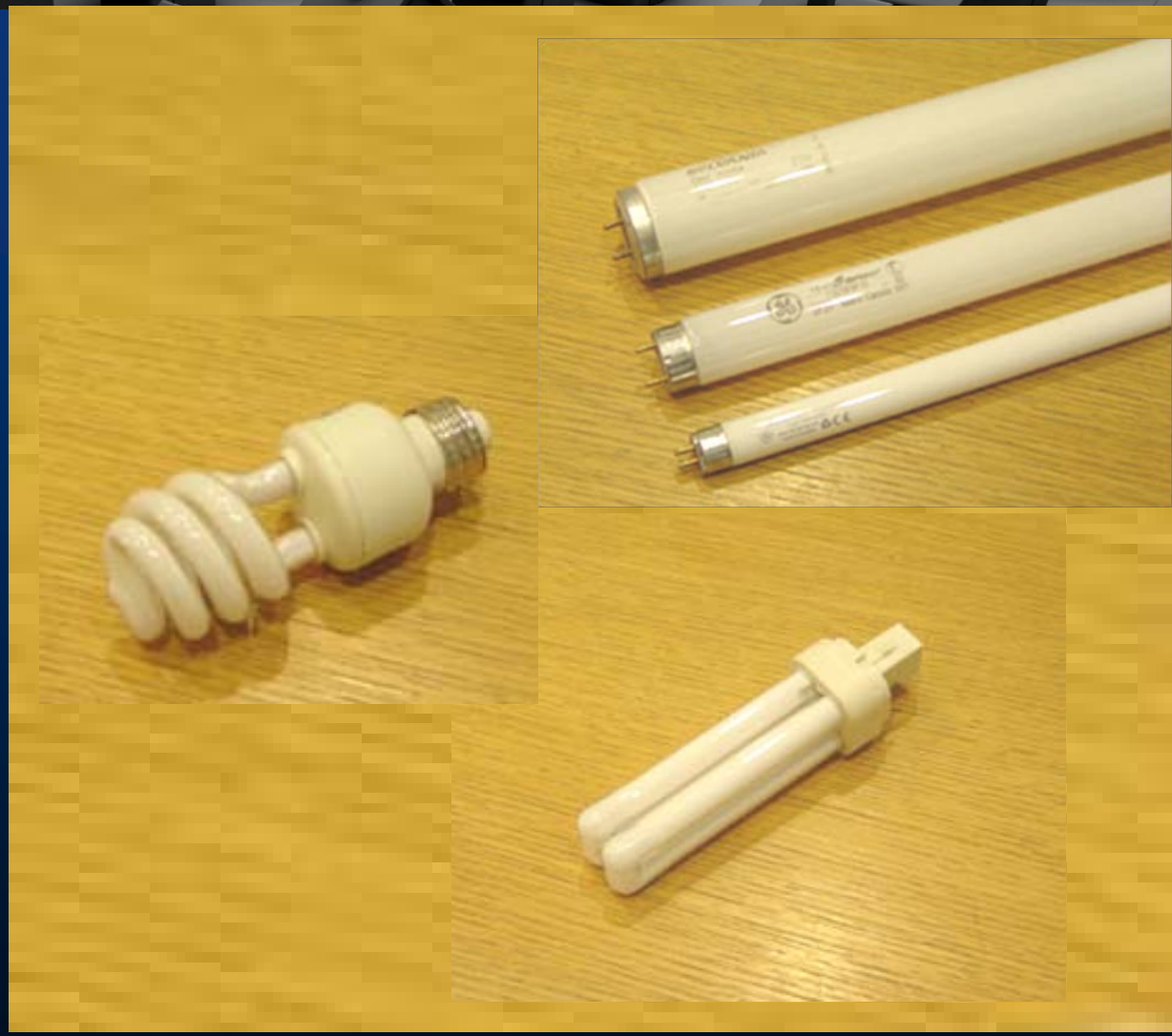
Under-Cabinet Light

Ceiling Surface Light

Fluorescent

Light Sources and Options

- Change Bulb
- Change Fixture
- Change Design



LED

Model E27-WLX3
3 Watt Luxeon (3 x 1 Watt)
LED Medium Base Spot
Light - 120 VAC

light output comparable to
25~30 watt incandescent

50,000 Hours Life Time
Warm White (3400K) –
49 lumens

Available with 10 or 30
degree beam pattern
Housing Material:
Aluminum and ABS Plastic

UL listed

LED

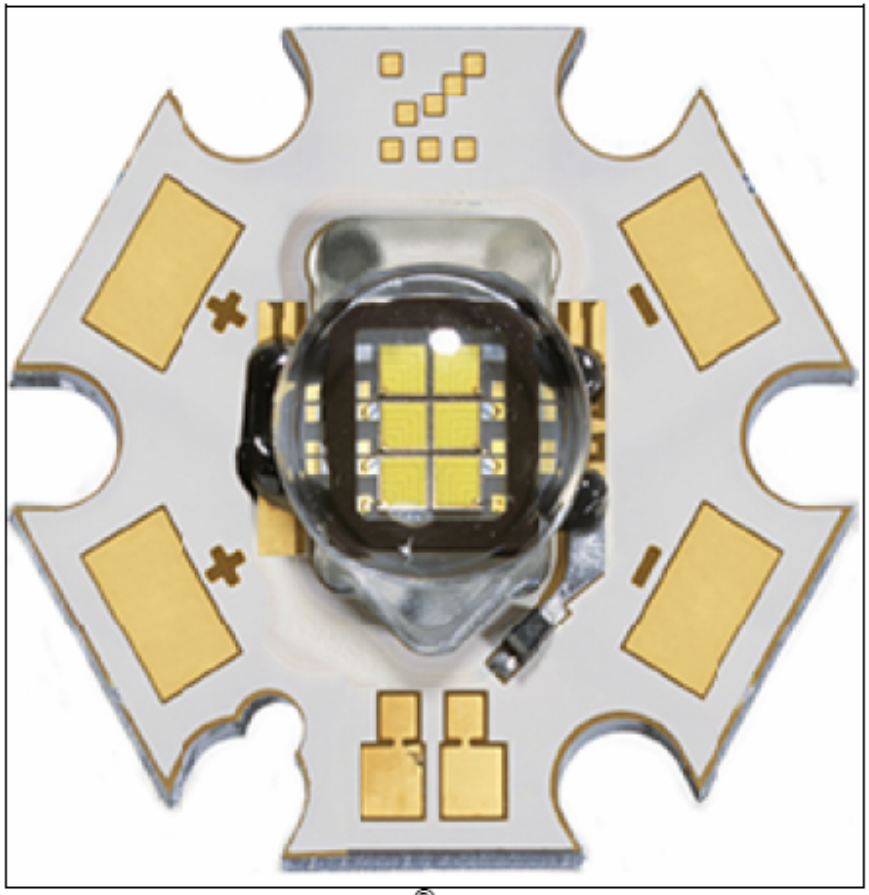


Figure 2: OSTAR®-Lighting with lens (LEW E3B)

OSTAR®-Lighting LED Light Source

The OSTAR®-Lighting LED light source was developed with an emphasis on the areas of general lighting such as:

- Room Lighting
- Architectural/Effect Lighting
- Industrial Lighting
- Radiators and Spot Lighting
- Flashlights

However, it is also suitable for special applications such as:

- Microscope Lighting
- High-quality Flash Lamps
- Traffic Signs
- Operation Lighting in Medical Technology

LED

The advantage of the chip coating is that the converter can be applied to the chip surface in a homogeneous layer with uniform concentration. This causes the converted light to be nearly constant across the entire chip surface.

Typically, the color temperature of the OSTAR®-Lighting lies in the range of 4500 to 7000 K (daylight white), with a color reproduction index (CRI) of 80.

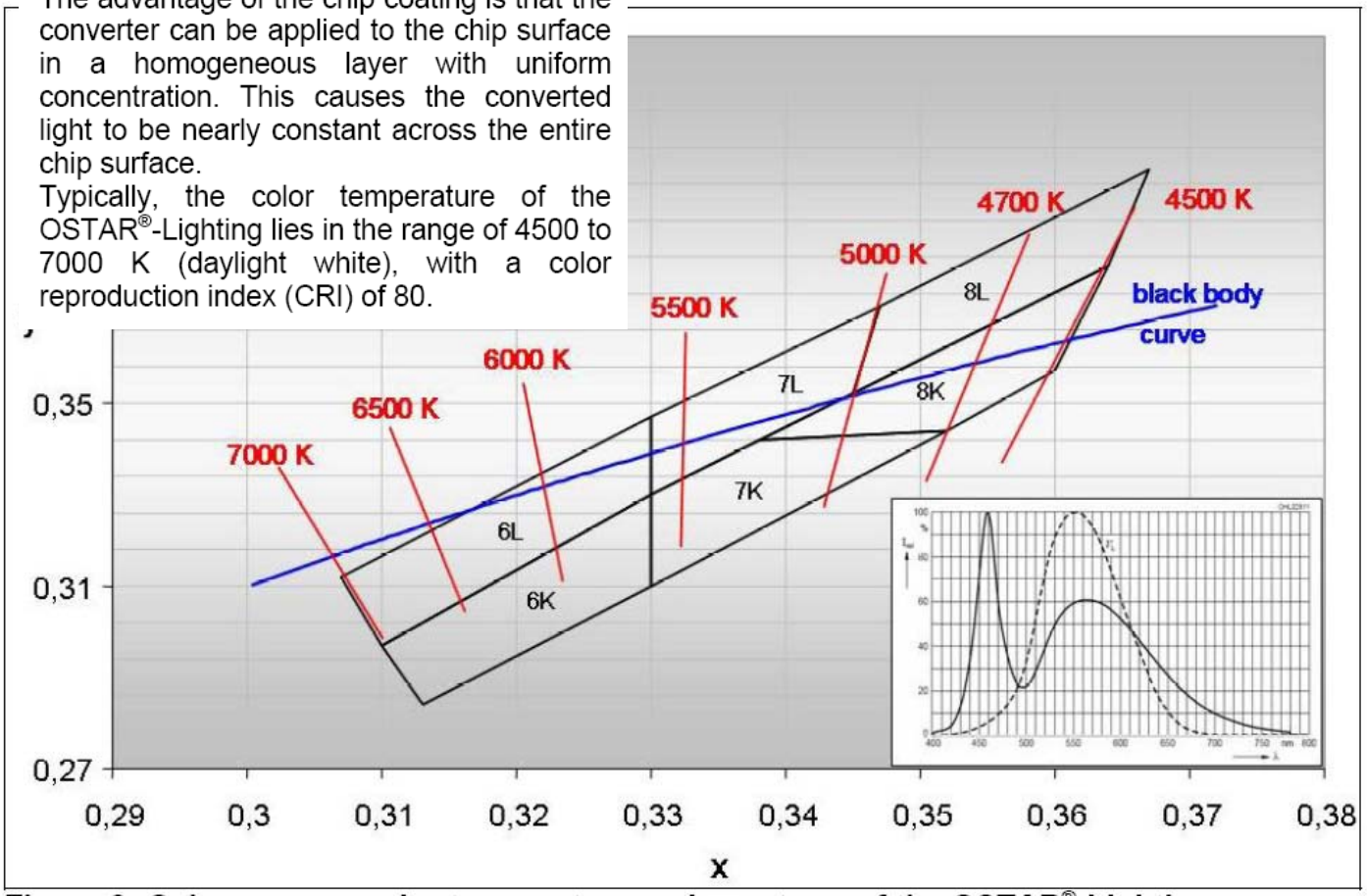


Figure 3: Color groups, color temperature and spectrum of the OSTAR®-Lighting

Color Rendition Is a Barrier

Color Temperature

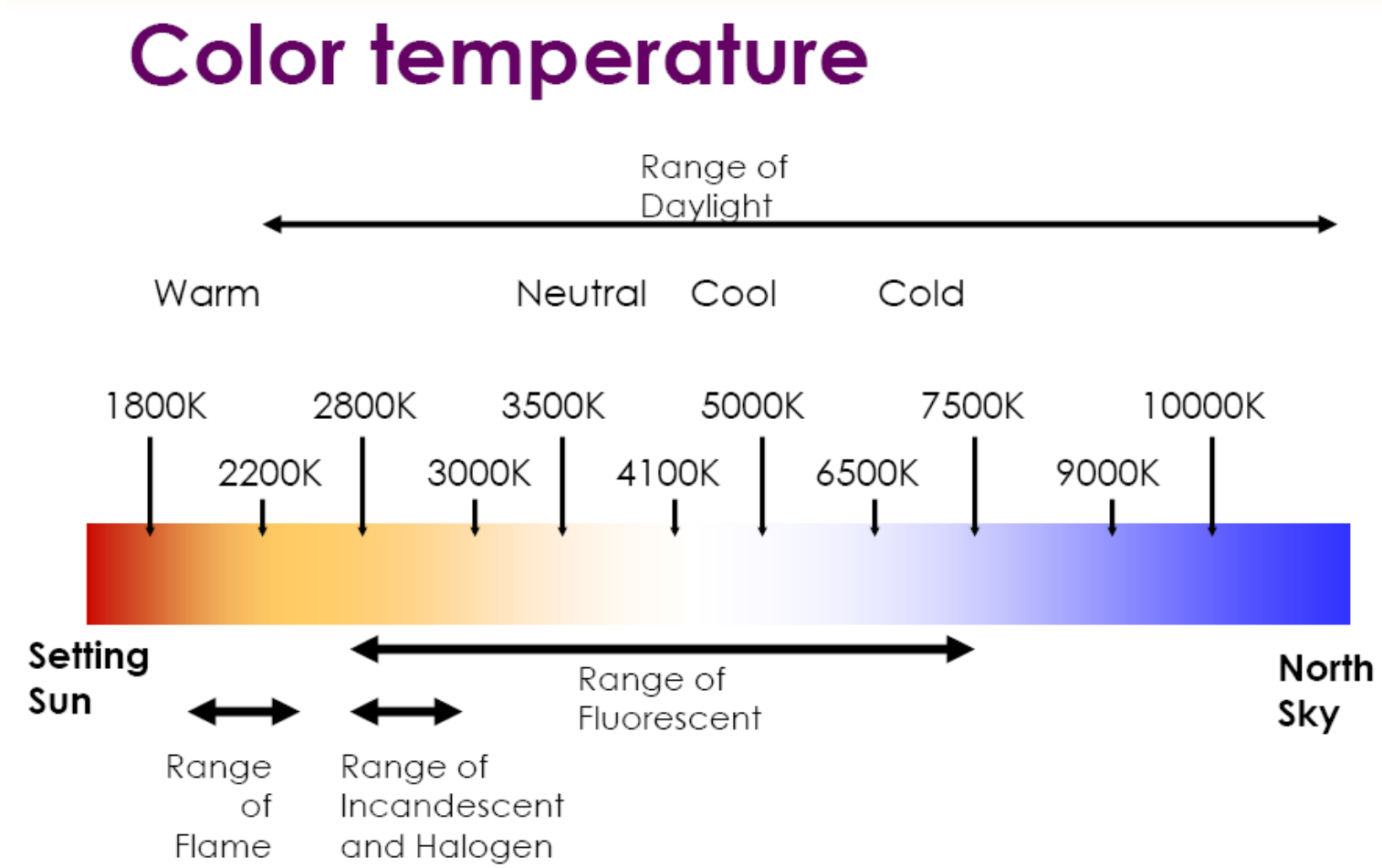
- Not consistent in market
- Leads to consumer dissatisfaction
- Murky yellow at 2700K
- Greenish cast at 4100K

2700K

4100K

3000K

Color Temperature



Know the lamp code

Recommended Fluorescent Lamps for Common Use

Desired Lamp Color	Lamp Color Designation
• Warm 2700K	• "827"
• Warm 3000K	• "830" or "930"
• Neutral 3500K	• "835"
• Cool 4100K	• "841"
• Cold 5000K	• "850" or "950"

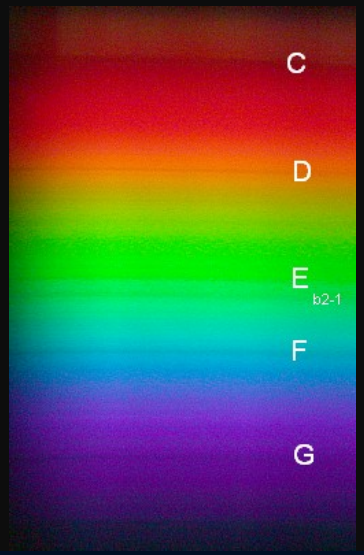
Example: F32T8/830 is a 3000K, 32 watt tubular fluorescent lamp 8/8" in diameter

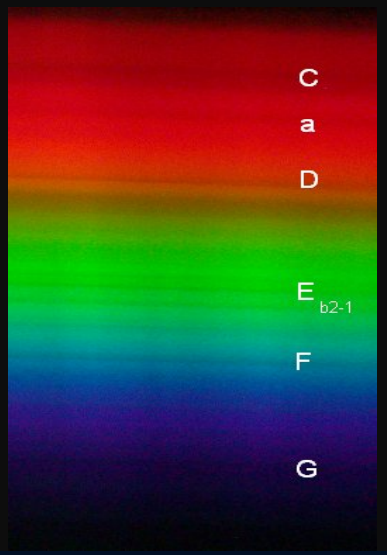
Note the diminished power at the purple end of the spectrum

UV is absorbed by the longer path through the atmosphere

afternoon sun, altitude 24 degrees

setting sun, altitude 0.5 degree

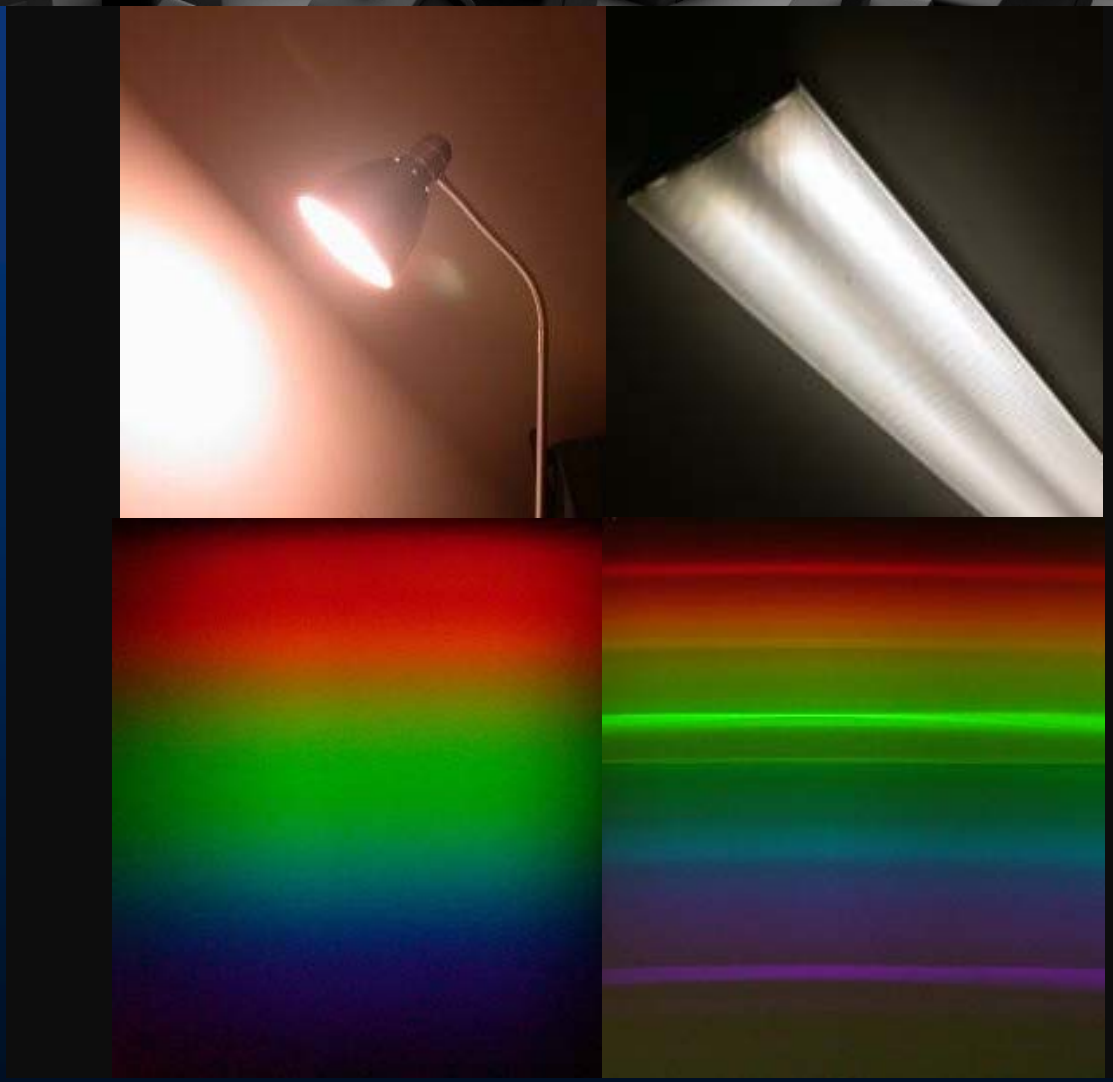




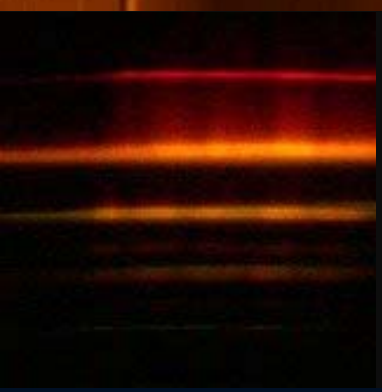
Color Temperature

Incandescent spectrum is continuous with an emphasis at the red end

Fluorescent spectrum is dominated by the phosphors used as the coating on the tube. Some fluorescent lamps have three or four phosphors, creating different results when viewing an object



High Pressure Sodium Light Source



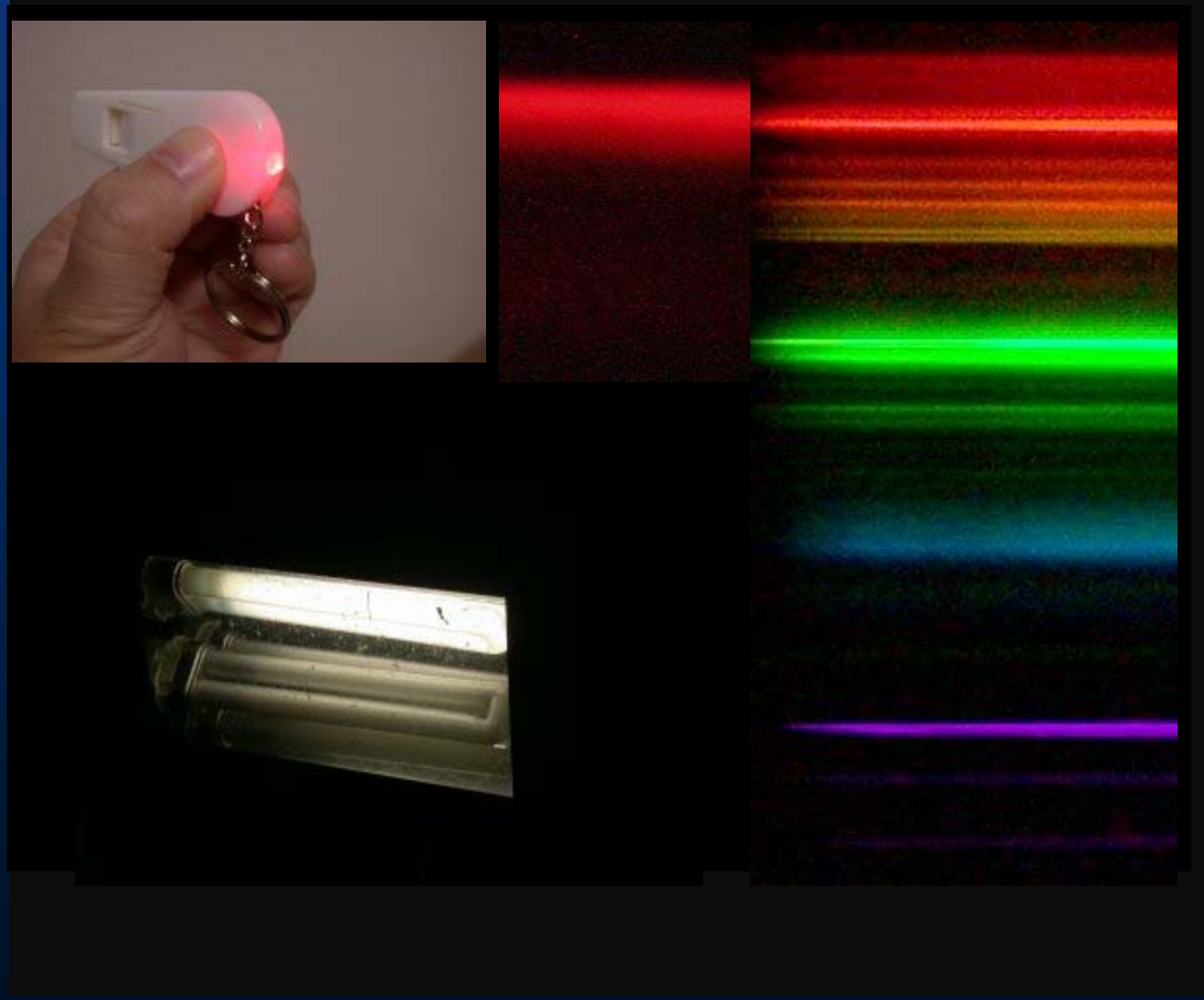
Color shift during warm up

Intro to LED light source

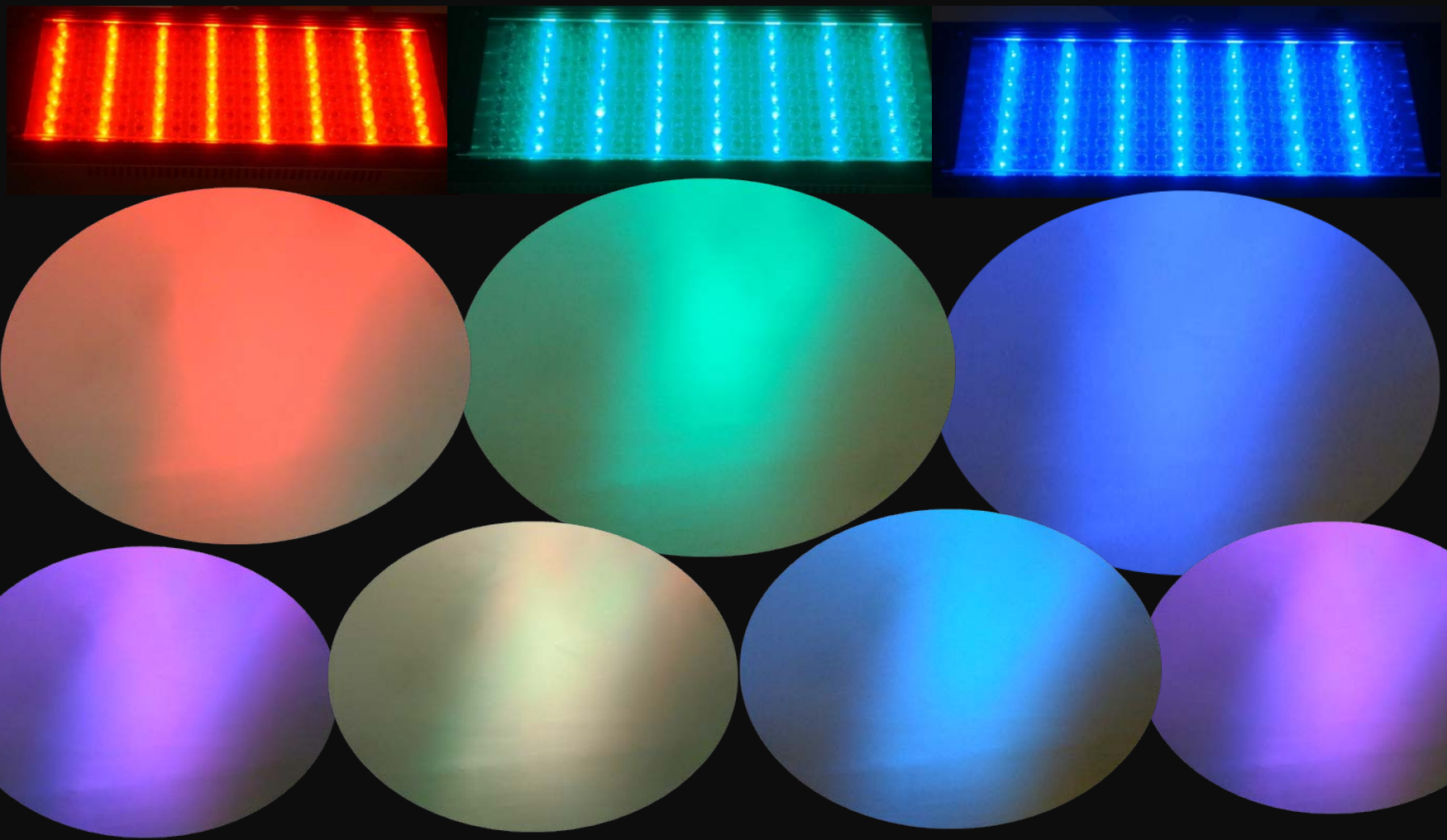
Early LED's are one color chip. CFL is a tri-phosphour source with multiple bands

Newer LED's can excite different base chip to form white light

Best to date is a white chip at 130 lumens per watt



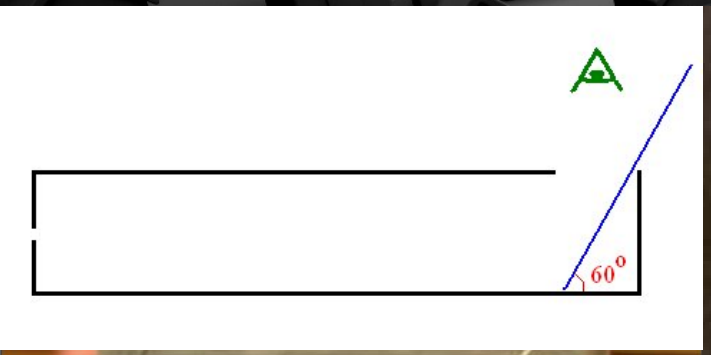
LED Color

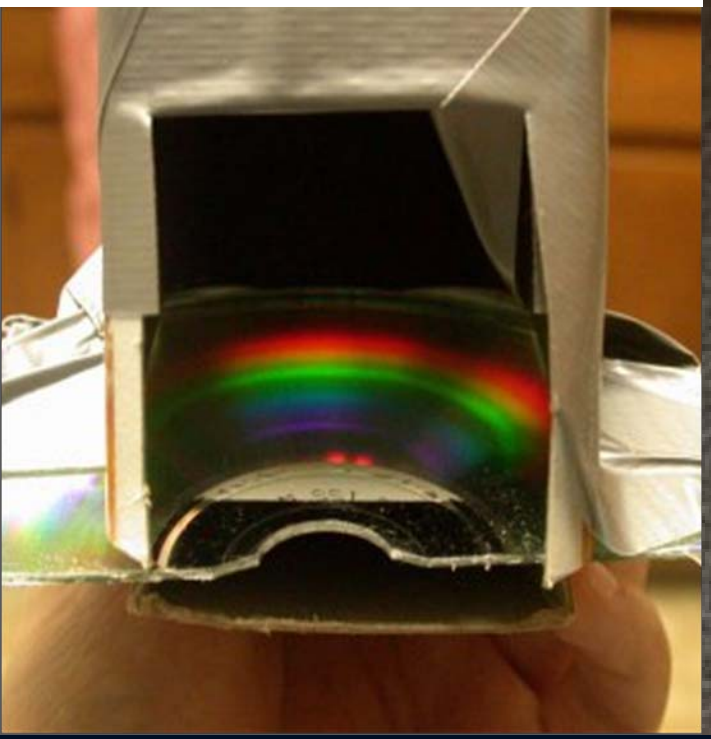


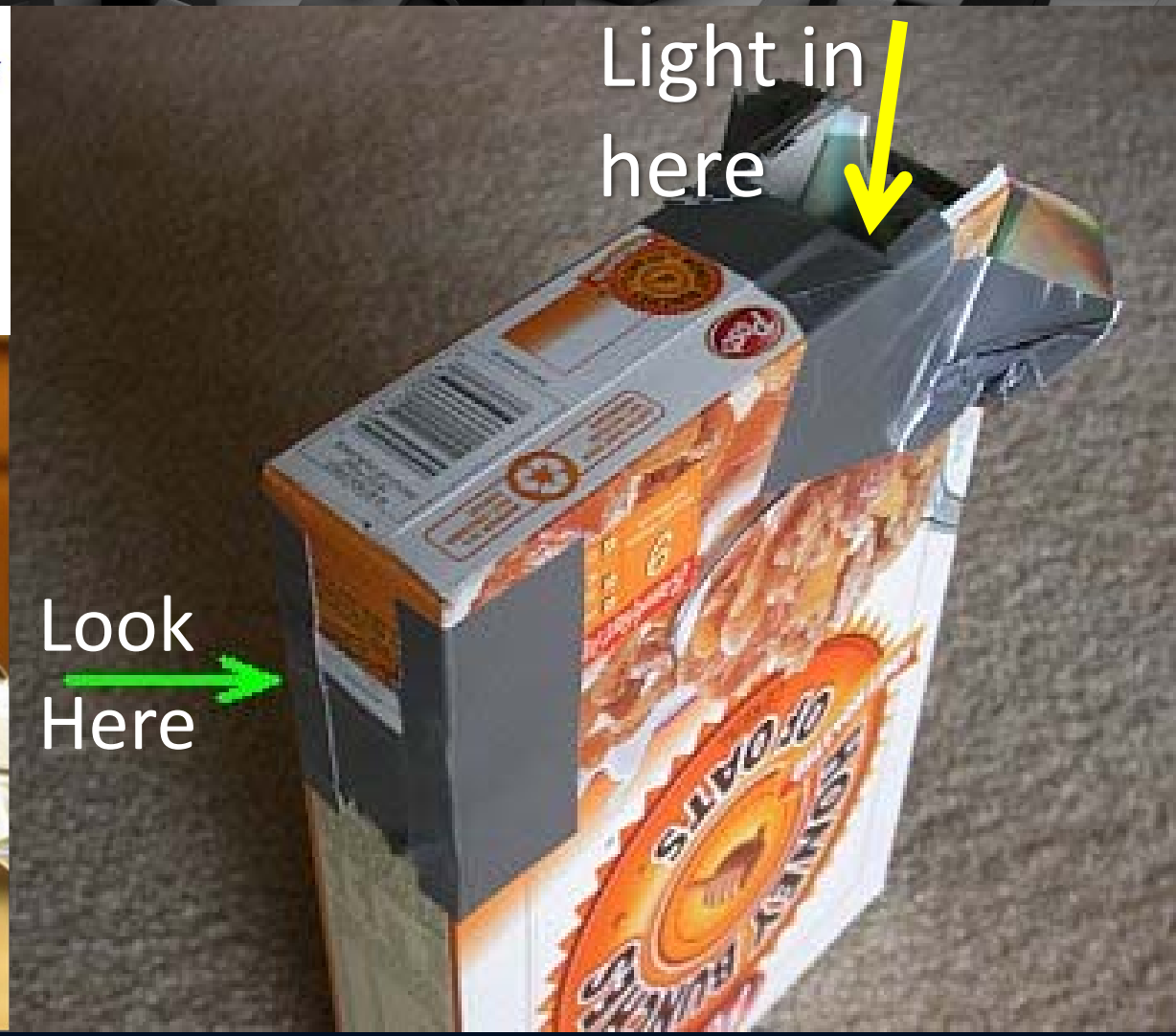
Metal Halide

Metal Halide is a broad spectrum based on the base metal materials

You can see the spectral distribution too!



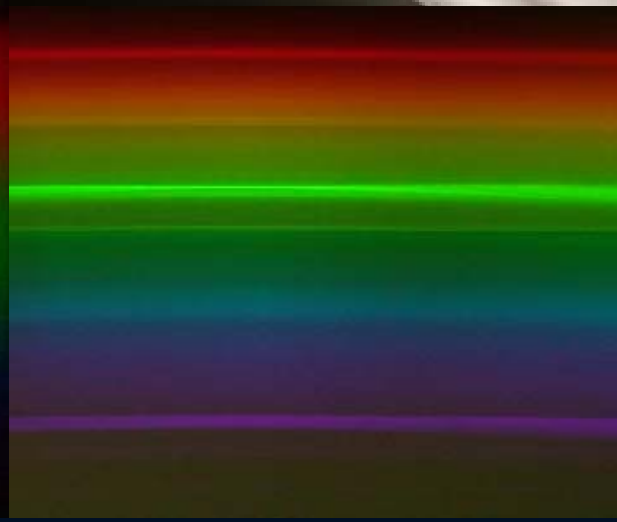




Color Rendition

Incandescent spectrum is continuous with an emphasis at the red end

Fluorescent spectrum is dominated by the phosphors used as the coating on the tube. Some fluorescent lamps have three or four phosphors, creating different results when viewing an object



Color Temperature

Color Temperature

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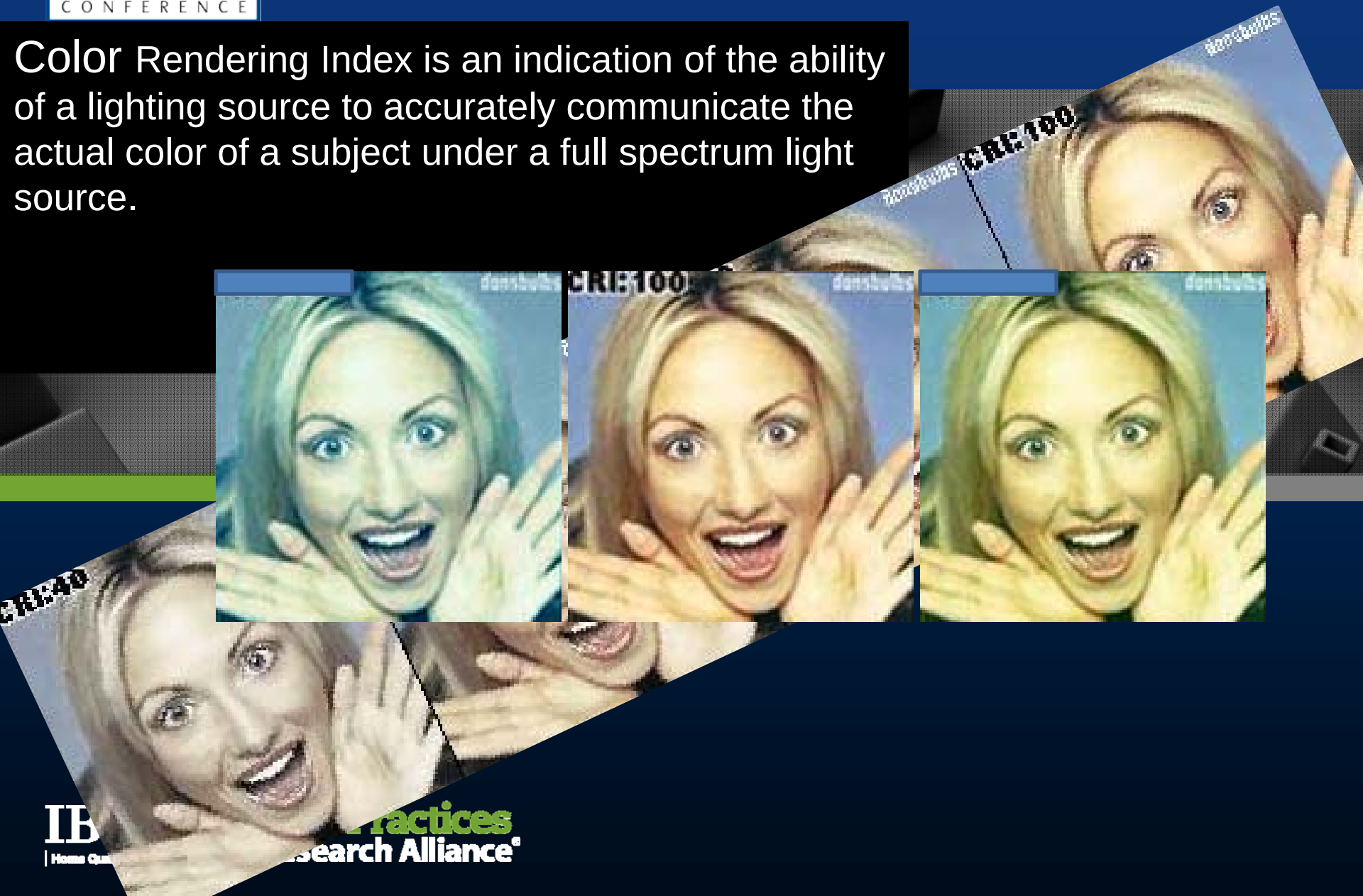
Color Rendering Index is an indication of the ability of a lighting source to accurately communicate the actual color of a subject under a full spectrum light source.



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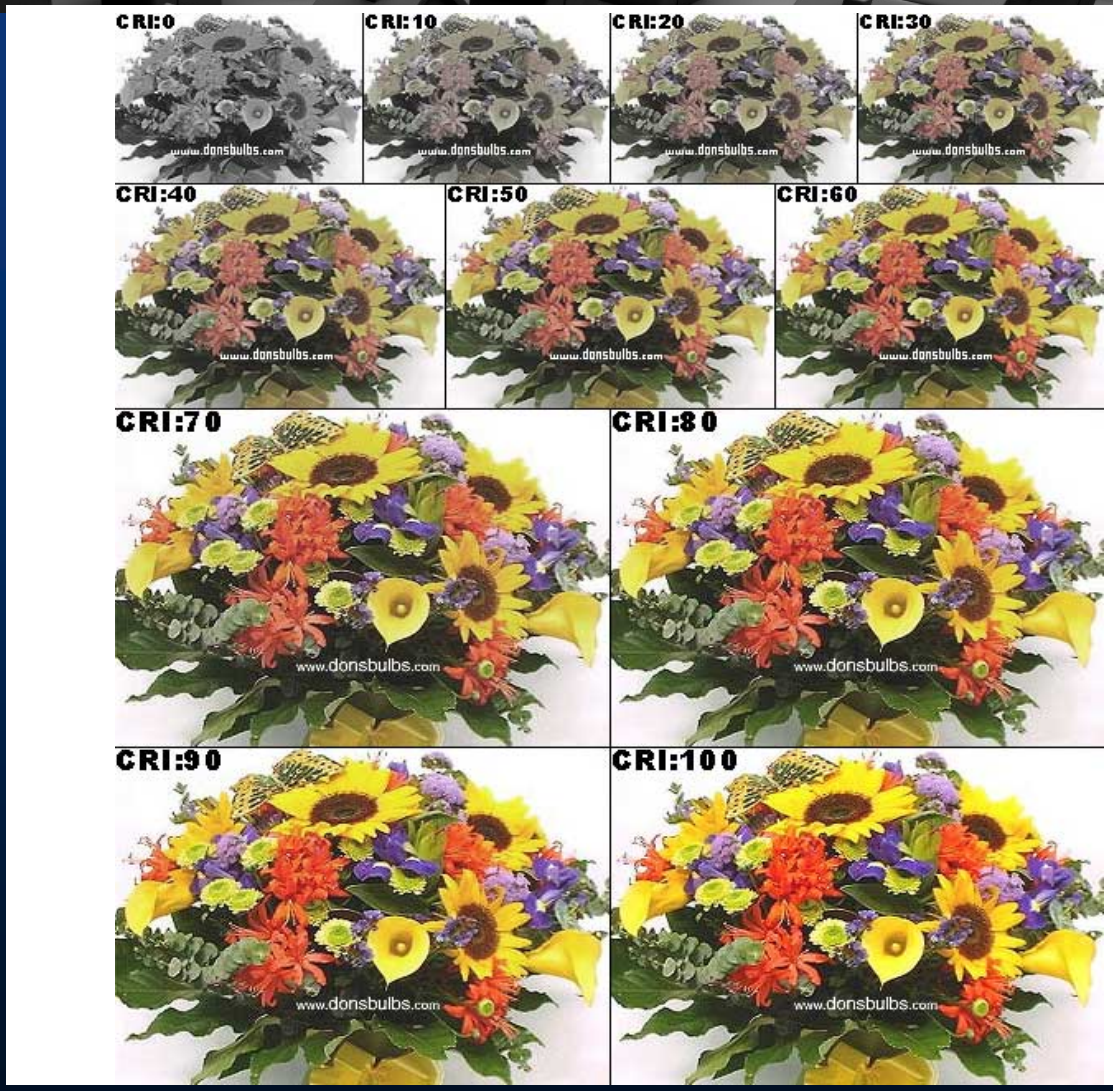
This image of Color Rendition Index is inaccurate in that the image is uniformly de-saturated.

Alternative lighting sources more correctly are of non-uniform saturation, emphasizing only a few colors

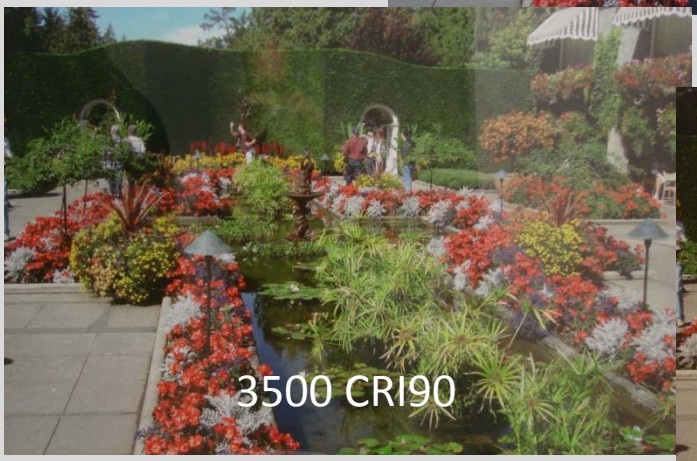


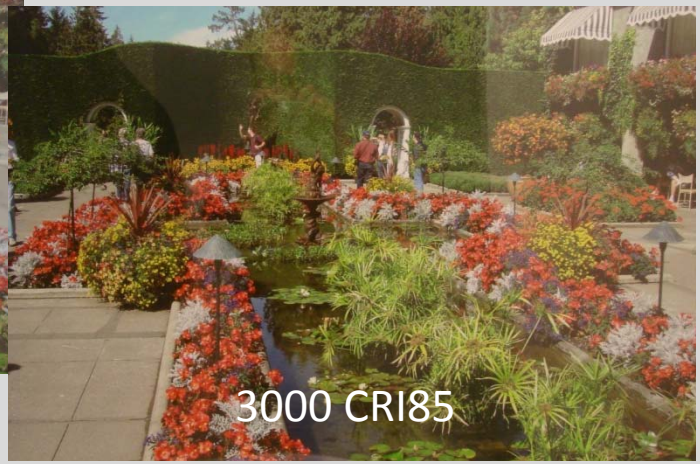
Change in primary color saturation

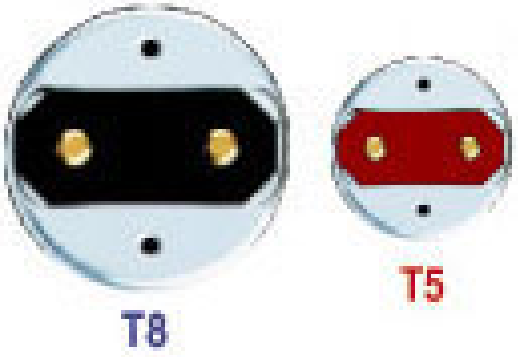
6500 CRI85

5000 CRI85

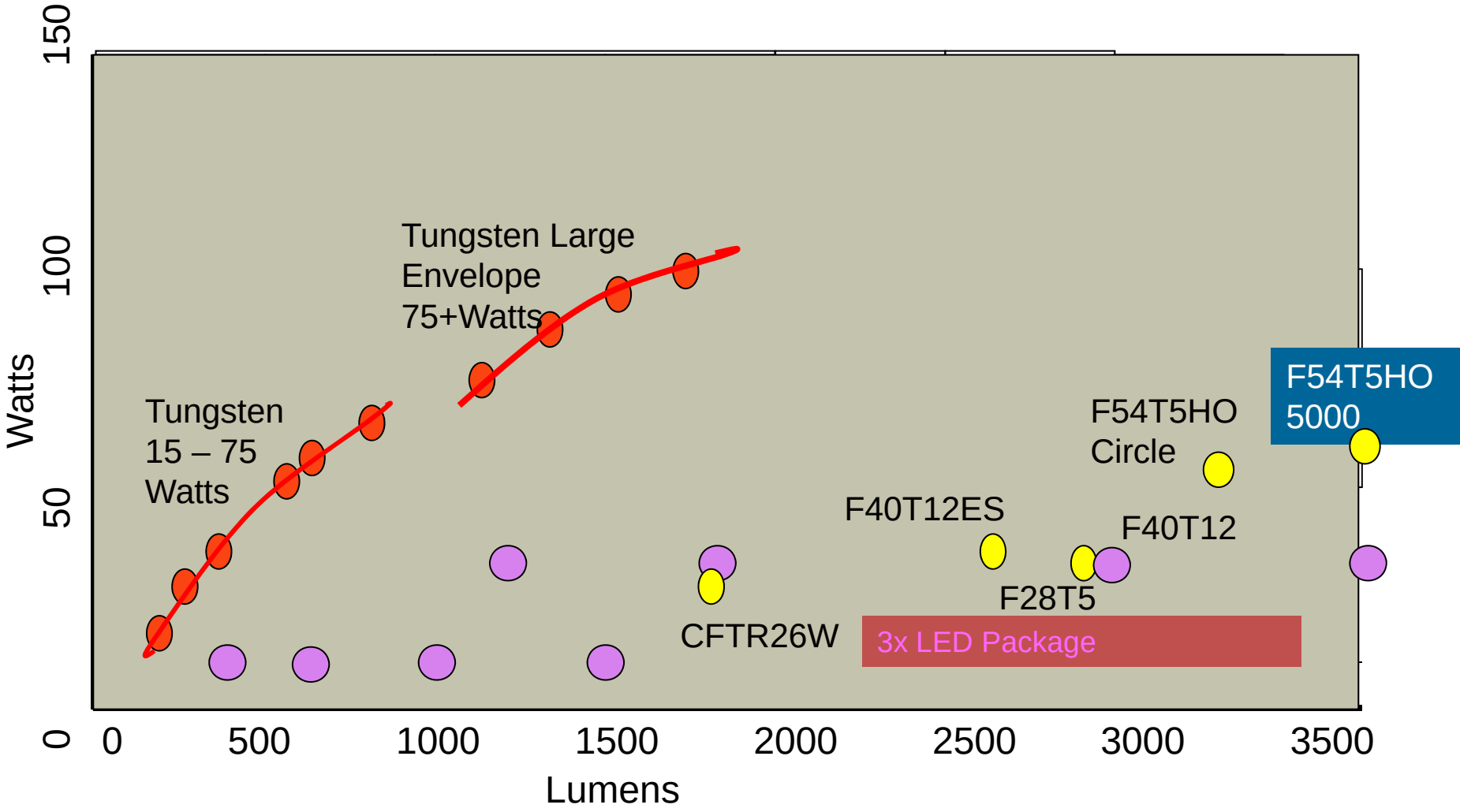
4100 CRI78


3500 CRI90

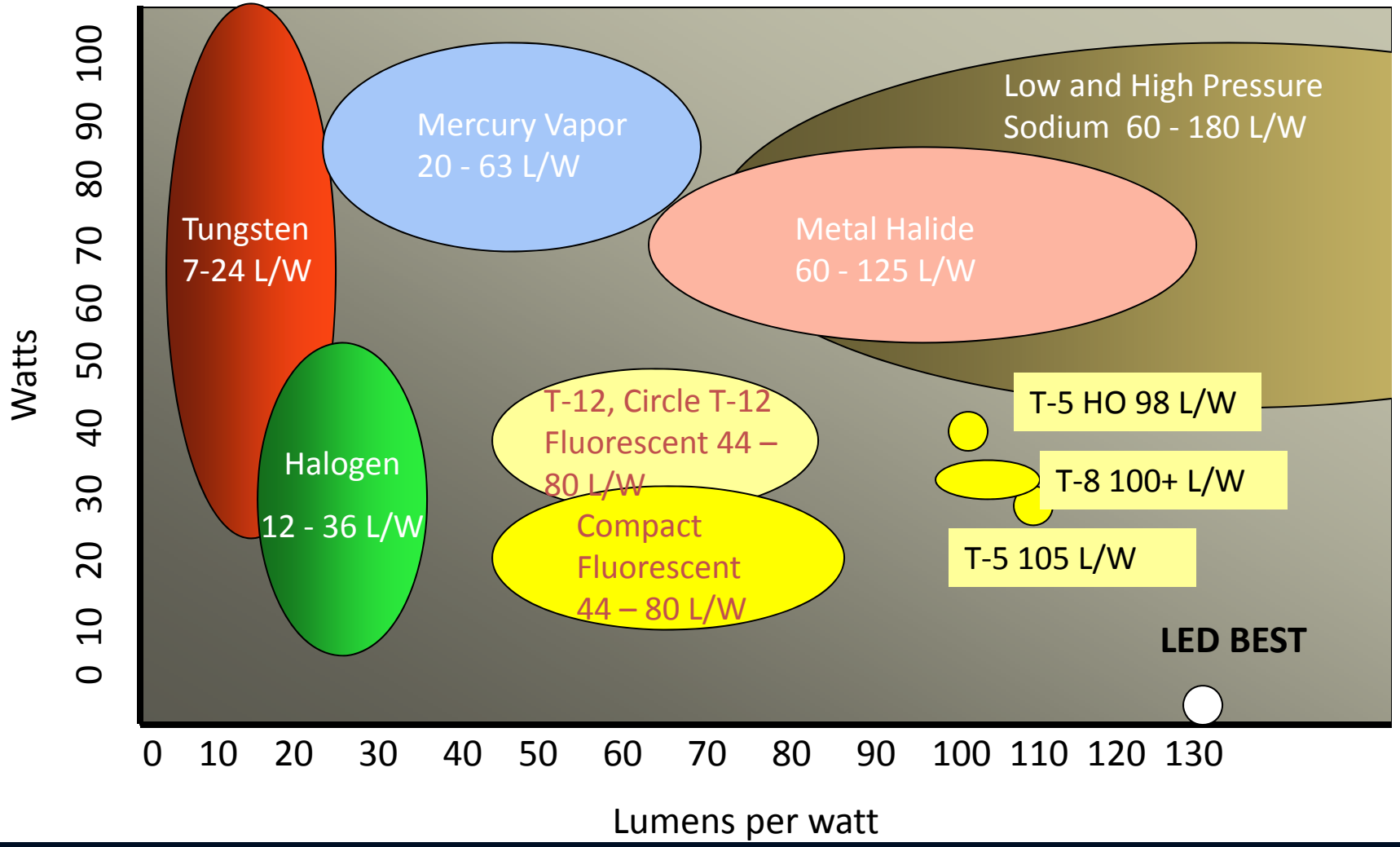

3000 CRI85


T8
T5

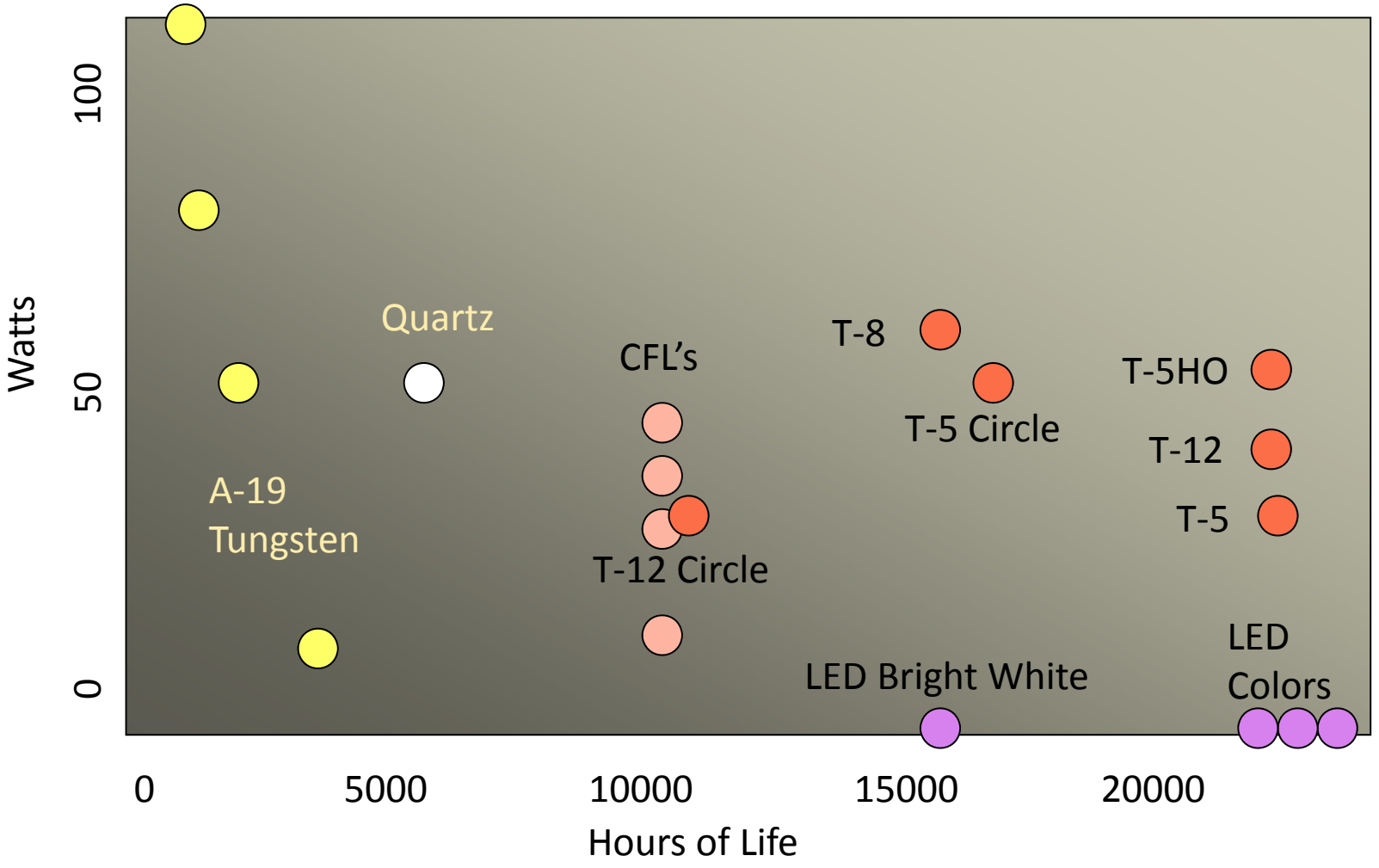
Light Output



Efficiency


Watts
0 10 20 30 40 50 60 70 80 90 100
Tungsten
7-24 L/W
Mercury Vapor
20 - 63 L/W
Low and High Pressure
Sodium 60 - 180 L/W
Metal Halide
60 - 125 L/W
Halogen
12 - 36 L/W
T-12, Circle T-12
Fluorescent 44 –
80 L/W
Compact
Fluorescent
44 – 80 L/W
T-5 HO 98 L/W
T-8 100+ L/W
T-5 105 L/W
LED BEST
0 10 20 30 40 50 60 70 80 90 100 110 120 130
Lumens per watt

Service Life



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Lighting Examples

Let’s look at some real examples

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Best Practices Research Alliance®

But first,
The Top Ten Barriers

1. The lead time to get fixtures is unreasonable
2. My show room is not knowledgeable
3. The cost is too high
4. Heat has been and always will be a major contributor to short life
5. Design of fixtures don’t match my décor
6. Adapted light fixtures don’t use new light sources optimally
7. Light output is not the same level
8. Light output is not the same character
9. Light output is not the same color
10. My electrician doesn’t do/know about/care to install

Build in Test Homes

- Hedgewood - GA
- Tindall - NJ
- Kacin (Malky) - PA
- TNAH 05 - FL
- Aspen - CO
- Summerset Green - PA
- Southern Living Home - GA

Harvard Leading a market of voluntary standards

Stapleton Community:

All voluntary energy standards

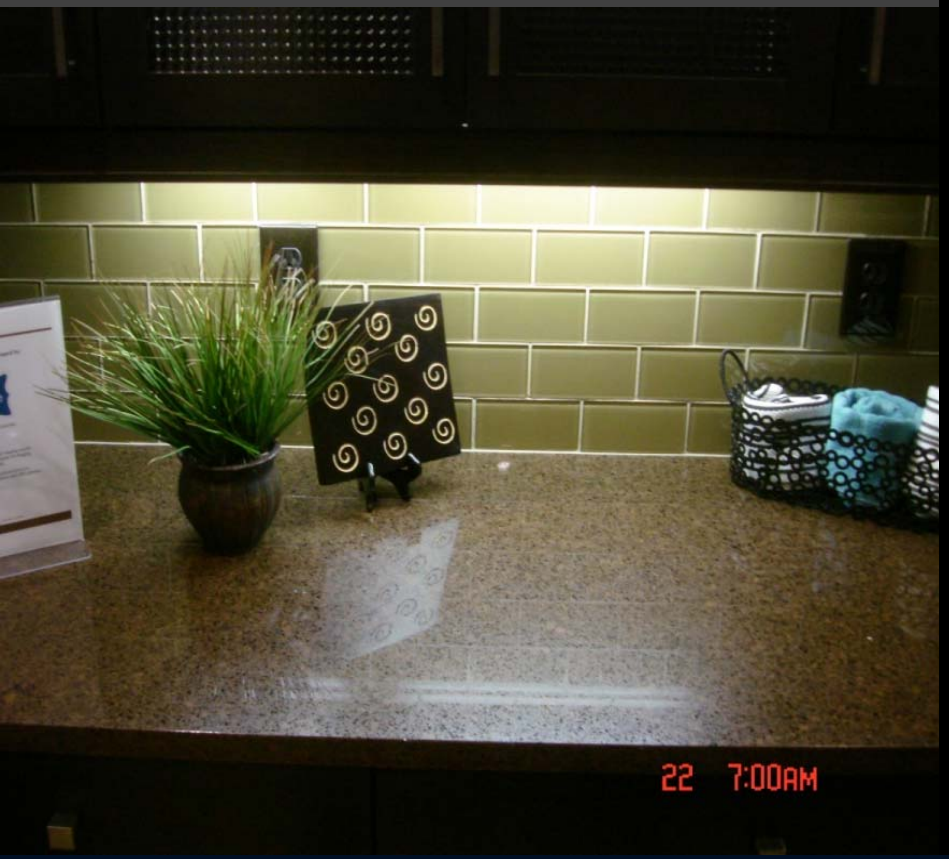
Progression from Code plus to many builders building at 50% better than code

Harvard Communities

Builder is building high efficiency and experimenting with specifications that approach Zero Energy

Harvard Communities

Under Cabinet



Surfaces

Harvard Communities

Living Room Toward Deck

Living Room

Living Room Accents

Harvard Communities

Master Bedroom

Learning about Valences

Harvard Communities

Master Closet

Toilet Room

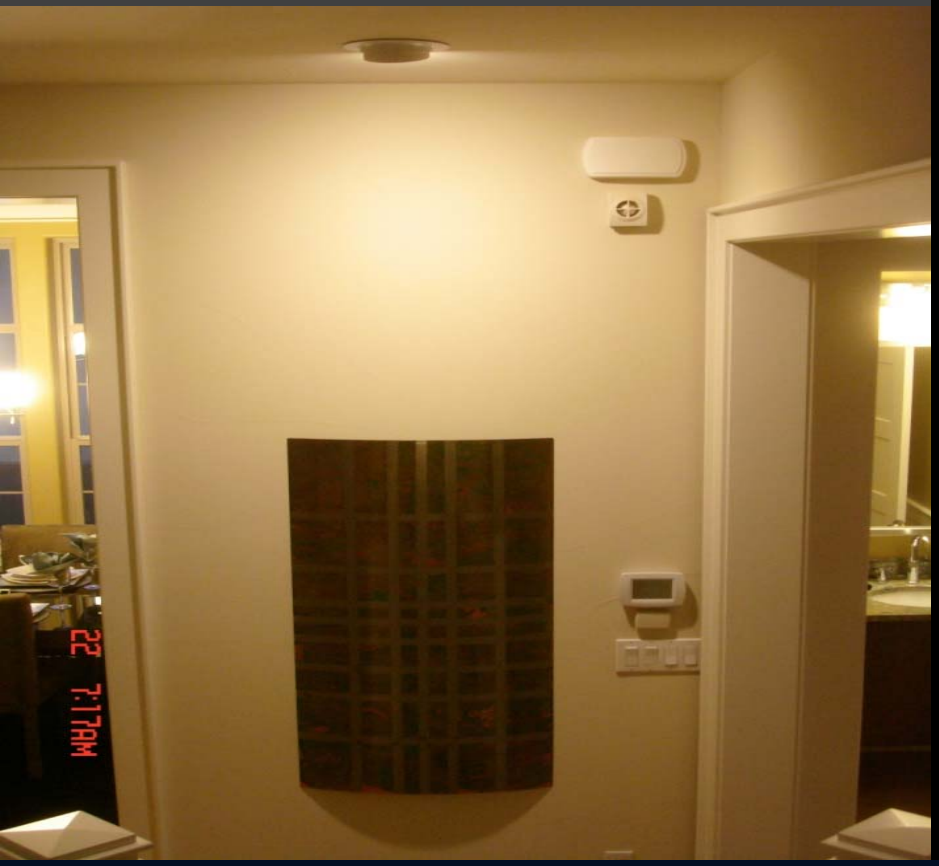
Harvard Communities

Vanity Lights

Master Bath Chandelier

Harvard Communities

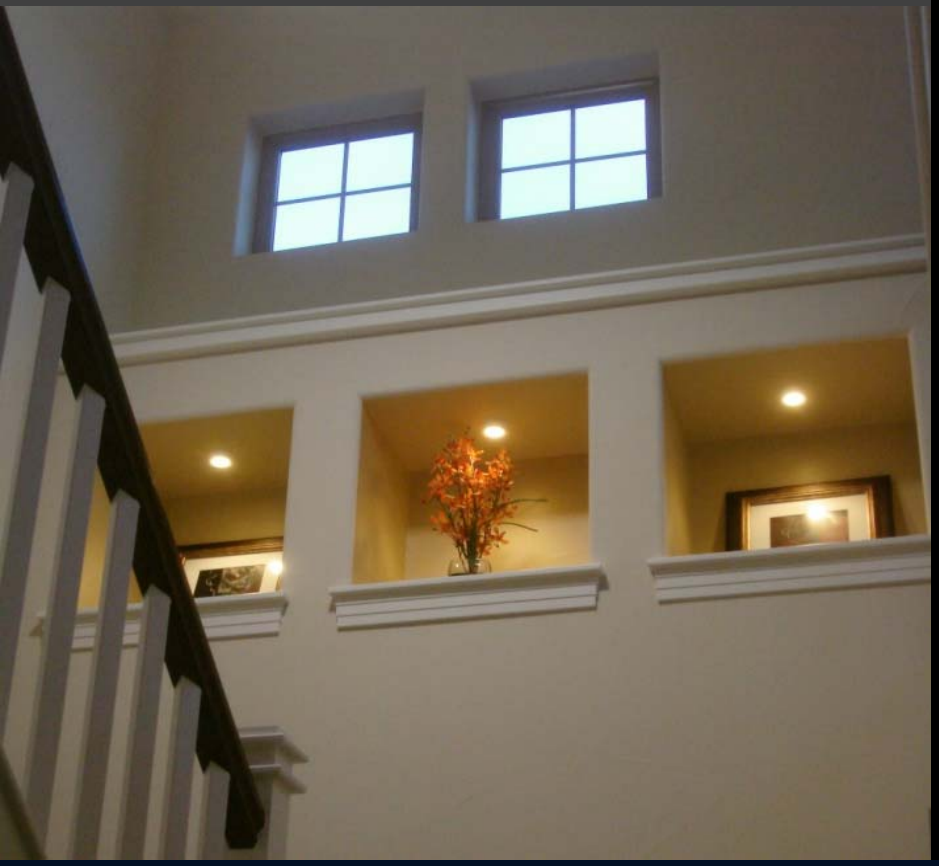
Dual Purpose



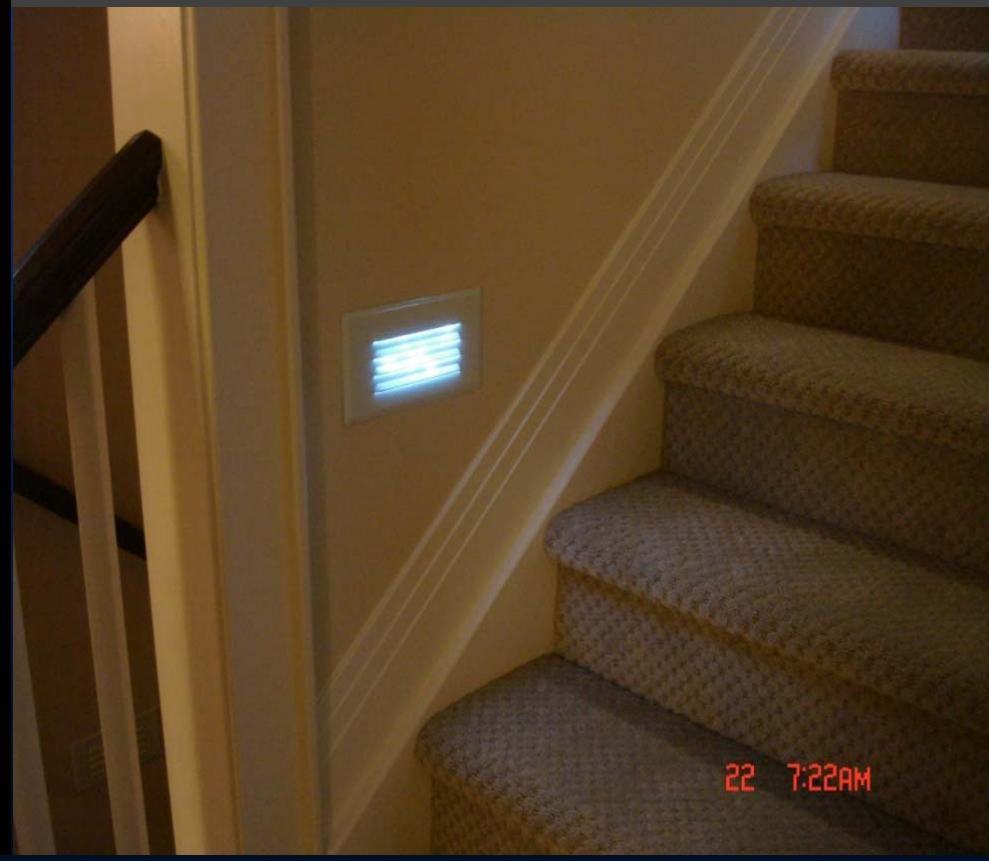
Office Loft

Harvard Communities

Stairway Accents



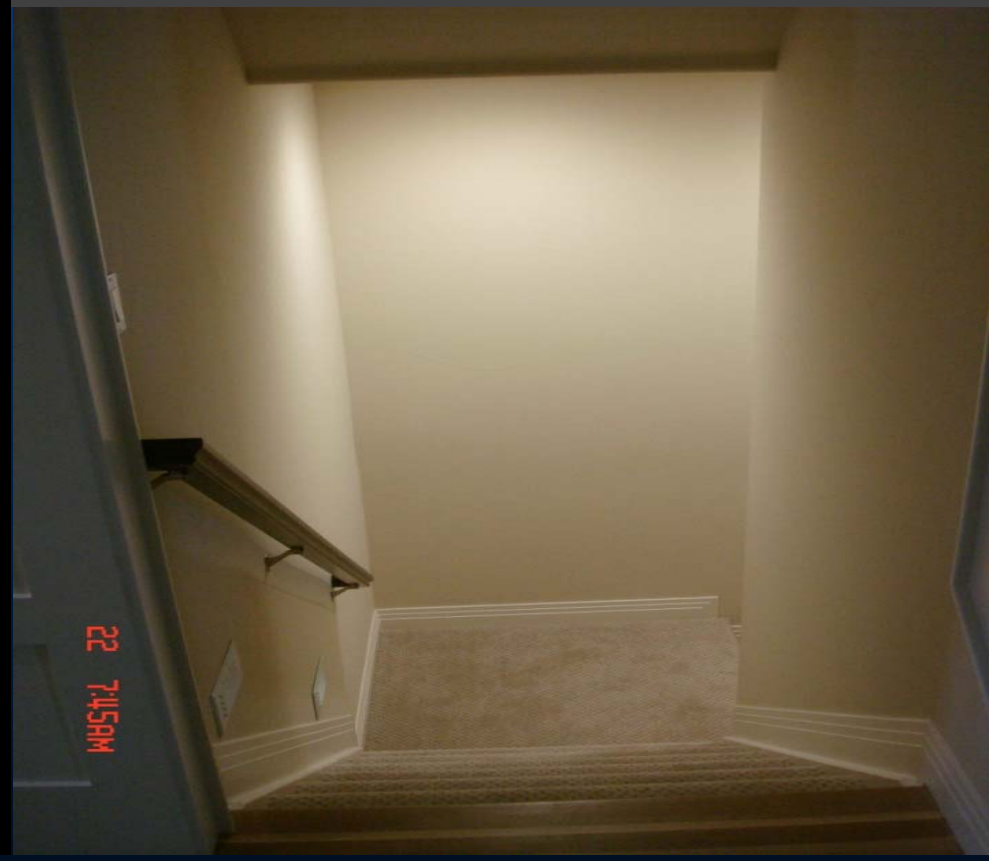
Stairway Way-finding



Harvard Communities

Hallways

Stairs



Harvard Communities

CFL - Acceptable

LED - Unacceptable

studio26 homes

Small custom builder leading through energy efficiency and style

studio26 homes

All lighting energy efficient sources

CFL and Linear as well as some LED

studio26 homes

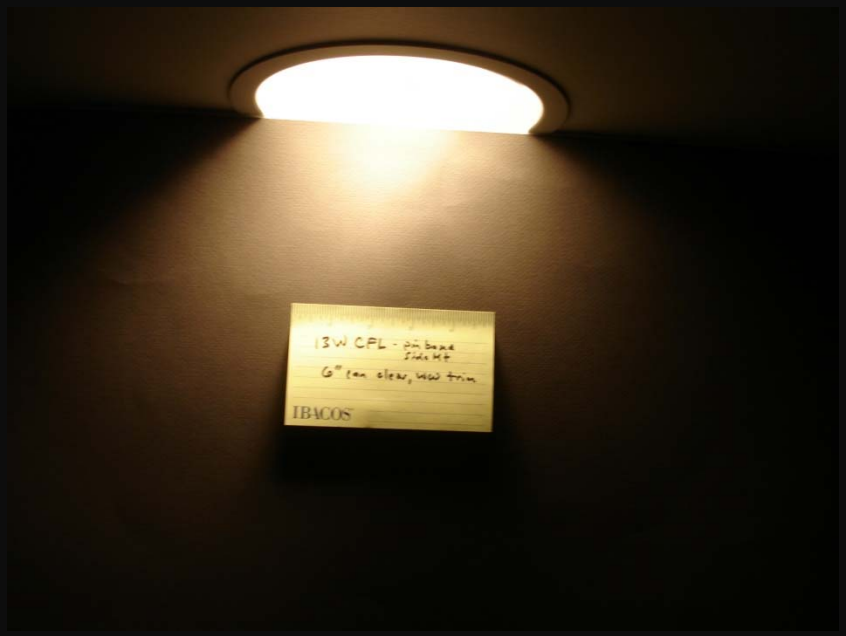
studio26 homes

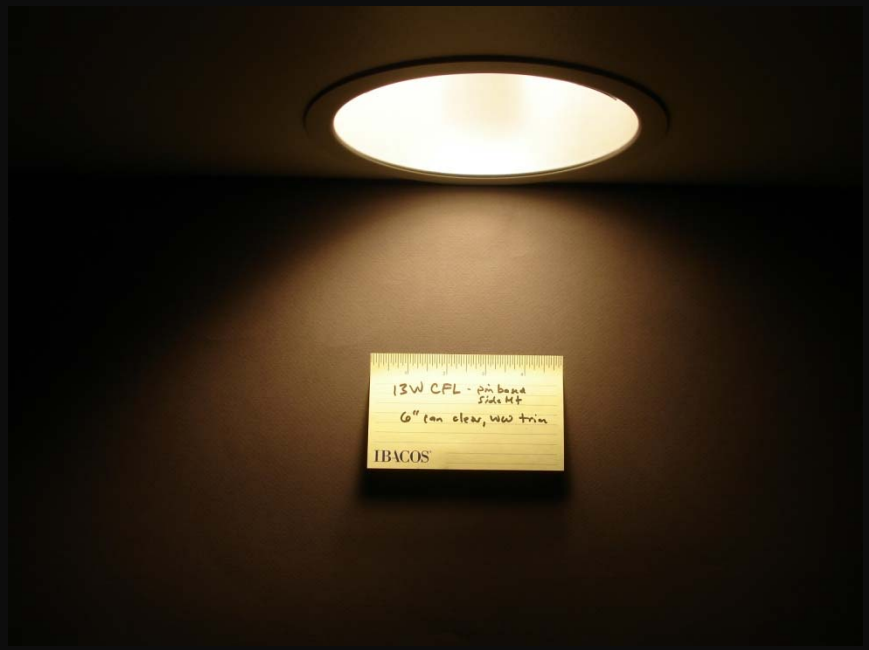
Lighting Demonstration Area

Learning how to communicate the character and differences of lighting options to a builder

Making the need to make lighting choices more evident

Visualize the shape of the light





Create context settings

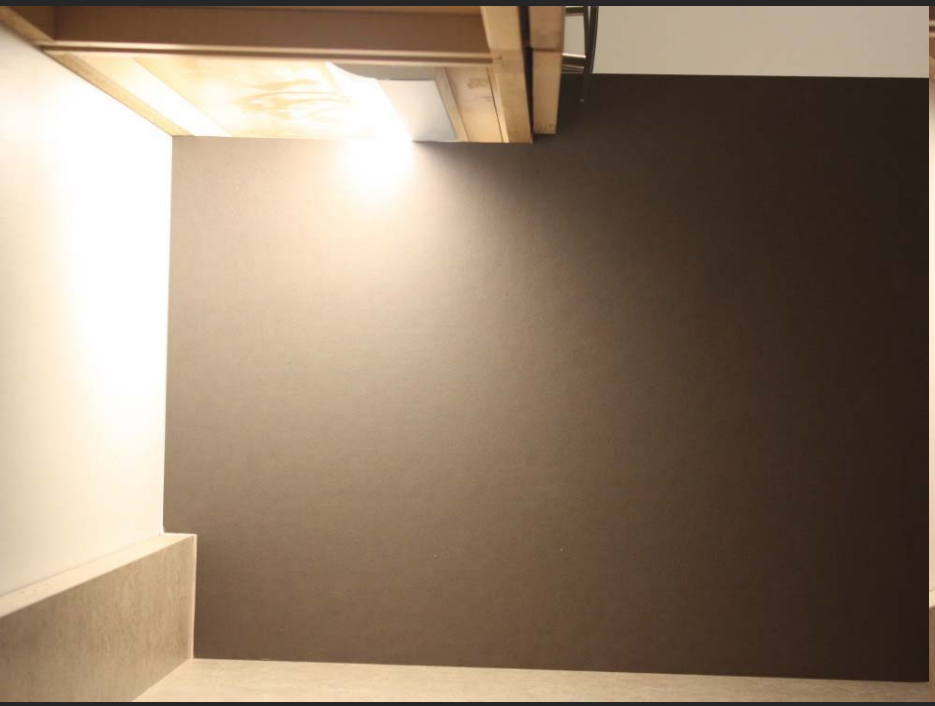
Compare various solutions

Kitchen and under cabinet lights generate a lot of interest

Measured Performance

Kitchen and under cabinet lights generate a lot of interest

Fixture Position



Lighting Inventory

Fixture Selection / Cost

Is performance related to what you pay?

T-2 vs T-5 ?

LED ?

LED High end fixture

- Good light color
- Less light
- High cost

On IBACOS.com

Lighting Design Guide

Energy Efficient Lighting Strategies

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Selecting the Ideal Windows for a High Performance Home in a Cold Climate

Presenter: John Broniek

Author: Ari Rapport

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Best Practices Research Alliance®

Session Overview

- To look at results of evaluation of window performance for a net zero energy production house in a cold climate
- Key evaluation criteria:
  - Market availability
  - Constructability & Durability
  - Cost vs. Energy performance
  - Comfort
- Summary of results and next steps

Our Challenge - A Net Zero Energy House that is Mainstream, Production

Specifications of Net Zero House Design

- R-60 attic
- R-26 basement foundation
- R-10 under-slab
- R-31 wall cavity with R-10 exterior sheathing (R-41 total)
- Air infiltration 0.00003 SLA (0.6 ACH50)
- GSHP with de-superheater for domestic hot water
- Ductwork within conditioned space, 0% leakage to outdoors
- Energy recovery ventilation system
- 100% high efficacy lighting
- All Energy Star appliances
- PV system – approx. 9 kW system needed for net zero
- Windows?

Evaluation Criteria – Must Meet

- Minimum Energy Performance Specification
- Code Acceptance
- Market Availability of the Technical Solution(s)
- Constructability
- Trade skill set change
- Functionality
- Architectural Flexibility
- Scalability Potential
- Durability: Moisture Management
- Cost vs. Energy Savings Ratio

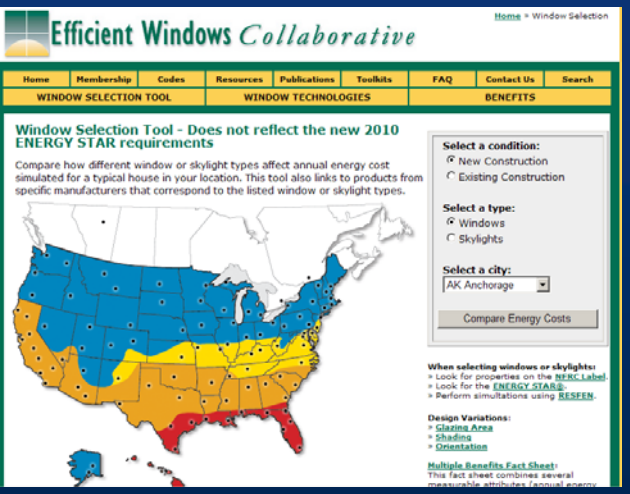
Evaluation Criteria – Should Meet

- Homeowner Impact
- Systems Integration and Elimination Potential
- Environmental Responsibility
- Cycle Time
- Durability and Maintenance
- Comfort

Evaluation Process

- Technical solution is given a ranking depending on how well it meets the criteria requirements
- Each criterion is assigned a weight value based on its importance
- The rank of each technical solution is multiplied by this weight, resulting in a weighted ranking
- The weighted rankings are totaled for each technical solution with the highest total score becoming the first system choice

Define Target Performance



- Efficient Windows Collaborative (www.efficientwindows.org)
  - Window Selection Tool: Pittsburgh, PA, USA
  - Total Unit U-value of 0.18 BTU/hr· F·ft^2 (3.7 kJ/hr·m^2·K)
  - Total Unit Solar Heat Gain Coefficient (SHGC) of 0.40

Market Availability– Must Meet

- Many favorable high performance window products were marketed as replacement window products only
- Supply chain well-defined for replacement market, but still undefined for new home market
- Options available for new construction (snap on nailing fins, integral J-channel, etc.), but not standard
- Some window products only available factory-direct for new construction

Constructability & Durability – Must Meet

- Varying availability of details, components, instructions, and installers for each product.
- Builder input:
  - Make sure installation of windows is not complicated and product is readily available
  - Ensure windows integrate well with cladding materials

Constructability & Durability – Must Meet

- Lack of adequate manufacturer details
  - Installing window in wall with thickened layers of exterior foam sheathing (2 – 4”)
  - In general, U.S. manufacturers had little knowledge of installation with exterior foam sheathing
  - In general, Canadian manufacturers had experience with this type of installation, but had no documented details to share

Constructability & Durability – Experimental mock-up

- Look at installation details in thickened wall assemblies
- How to best integrate window with drainage plane
  - In plane with exterior sheathing
  - Inset in wall cavity

Constructability & Durability – Structural Considerations of Window Installation

- Minimum of half the width of the window frame must bear upon solid wood framing
- With 2” XPS sheathing a ½” OSB buck needs to be installed at the sill of the framed opening. Rough opening size needs to be adjusted

Constructability & Durability – Window Installation

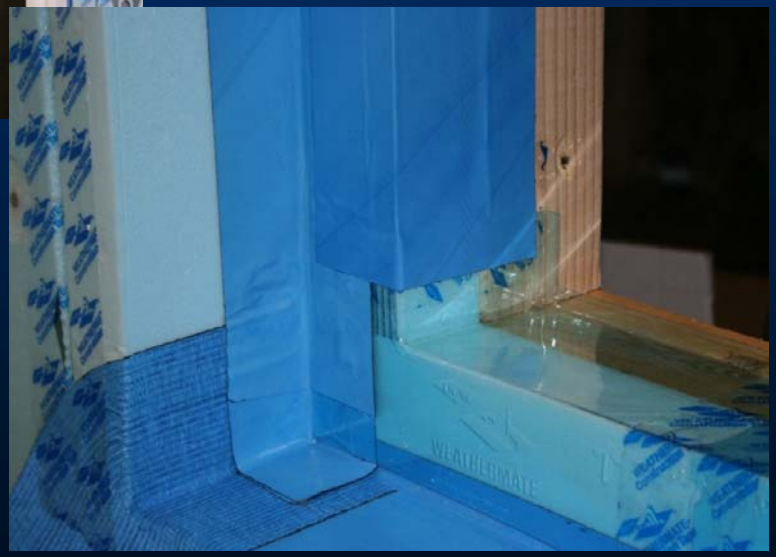
- Window nailing flanges need to be secured through foam sheathing directly to wood framing with minimum 1 ½” penetration into solid wood base
- Integral nailing flanges and J-channel very important in production building

Constructability & Durability – Window Placement and Flashing

- Examine window placement within the wall assembly
- Manufacturers suggest recessed/interior placement to keep them warmer
- Flashing details for exterior mounted window similar to typical sheathing case

Constructability & Durability – Window Placement and Flashing

- Window placement within center/interior mount requires recessing XPS & more flashing detailing, materials
- Exterior placement of window favored for constructability



Cost vs. Energy Performance – Must Meet

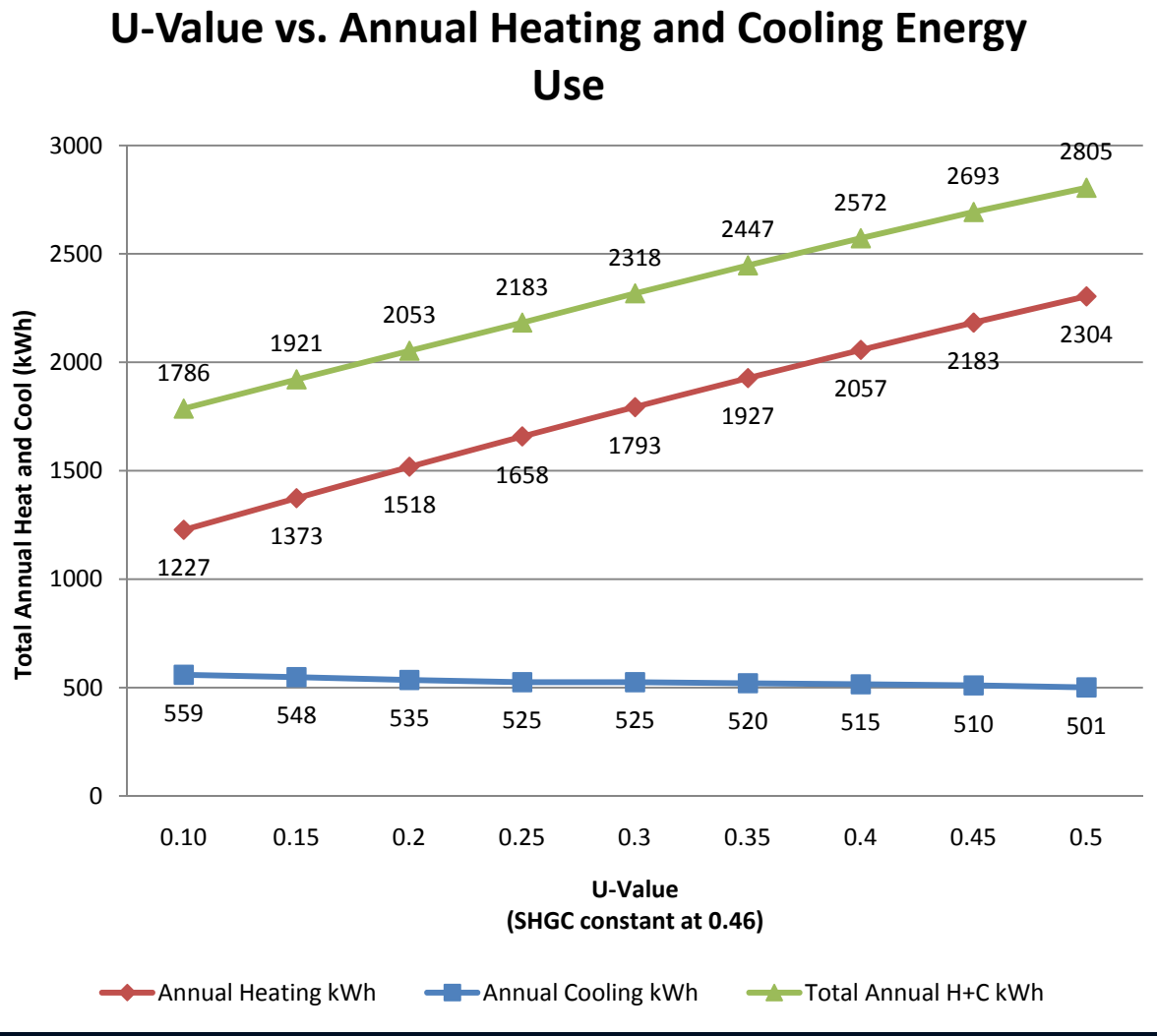
- Initially conducted U-value and SHGC optimization modeling
  - EnergyGauge® USA (version 2.8.01)
  - 2722 ft² house, Northwest orientation, two-story
  - Assumed same window performance on all orientations
  - Prominent Southwest (long axis) exposure, no Northeast exposure

Cost vs. Energy Performance – Must Meet

U-value Optimization

- Pittsburgh, PA weather data
- U-values between 0.10 and 0.50
- SHGC held constant

- Lower U-value = Lower annual heating energy use
- Total annual heating/cooling energy use mirrors total annual heating energy

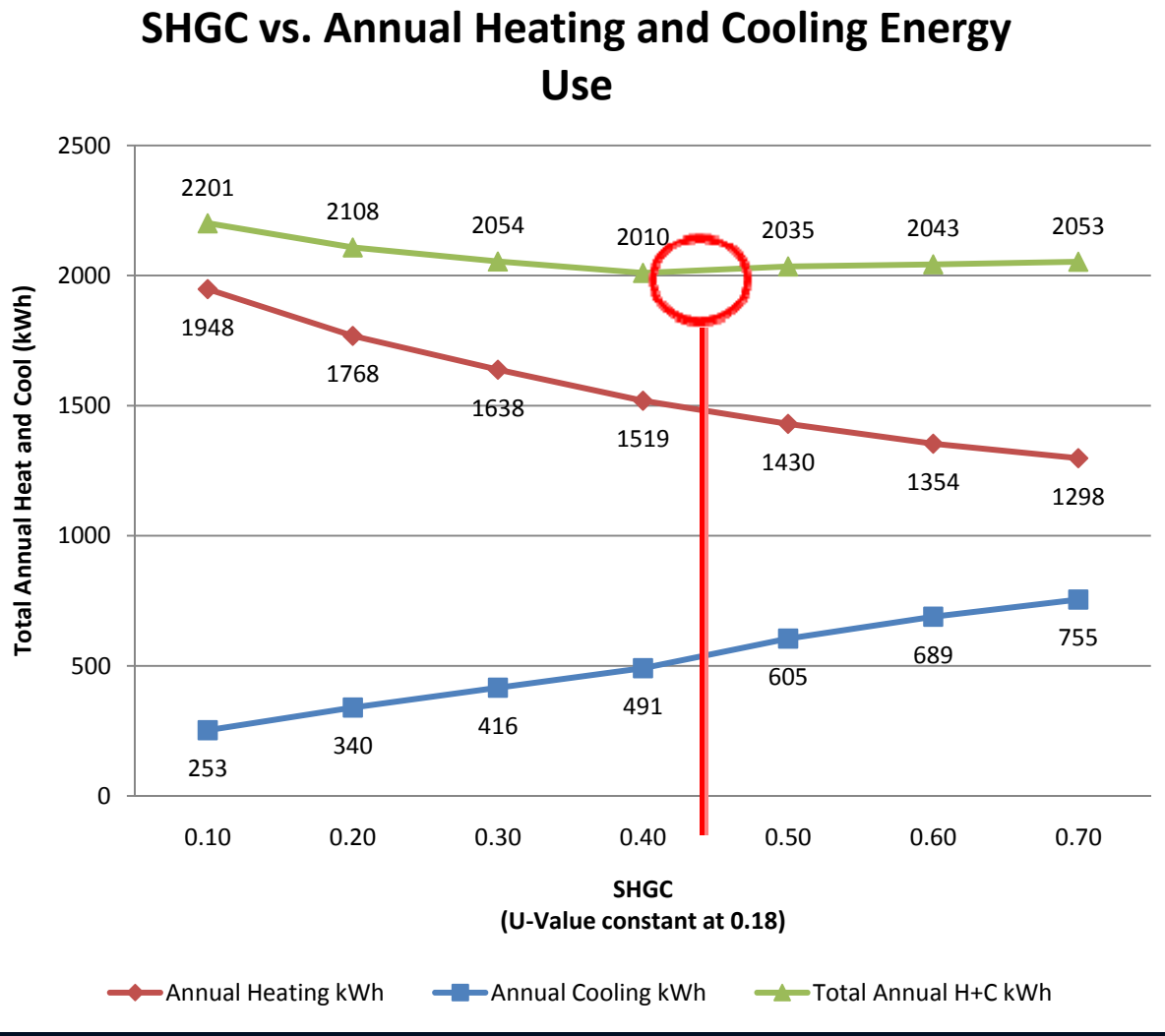


Cost vs. Energy Performance – Must Meet

SHGC Optimization

- Pittsburgh, PA weather data
- SHGC between 0.10 and 0.70
- U-value held constant (0.18)

- Heating energy decreases as SHGC increases (passive heating)
- Cooling energy increases as SHGC increases (greater solar gain)
- Total heating/cooling energy optimizes between 0.40 and 0.50 SHGC, settling at 0.46



Cost vs. Energy Performance – Must Meet

- U-value performance is more significant than SHGC in determining potential energy savings in a cold climate
- Ideal window for cold climate (Pittsburgh, PA) should have low U-value (<0.20) and SHGC around 0.46
  - Survey of window manufacturers revealed limited availability of windows with these performance values
  - Existing window products that met these specifications were more expensive (i.e. fiberglass frames, triple-pane glazing, Krypton or Xenon gas fills)
  - Most existing window products with these specifications were manufactured in Canada, with very few domestic U.S. products being produced

Cost vs. Energy Performance – Must Meet

- In general, window products with U-values below 0.20 are uncommon
- More common are windows with U-values between 0.20 and 0.30
  - However, the majority of windows with these U-values also had SHGC ratings between 0.20 and 0.30
  - Both U.S. and Canadian window products available
  - Cost more reasonable in comparison to builder's standard window product (lower incremental cost)

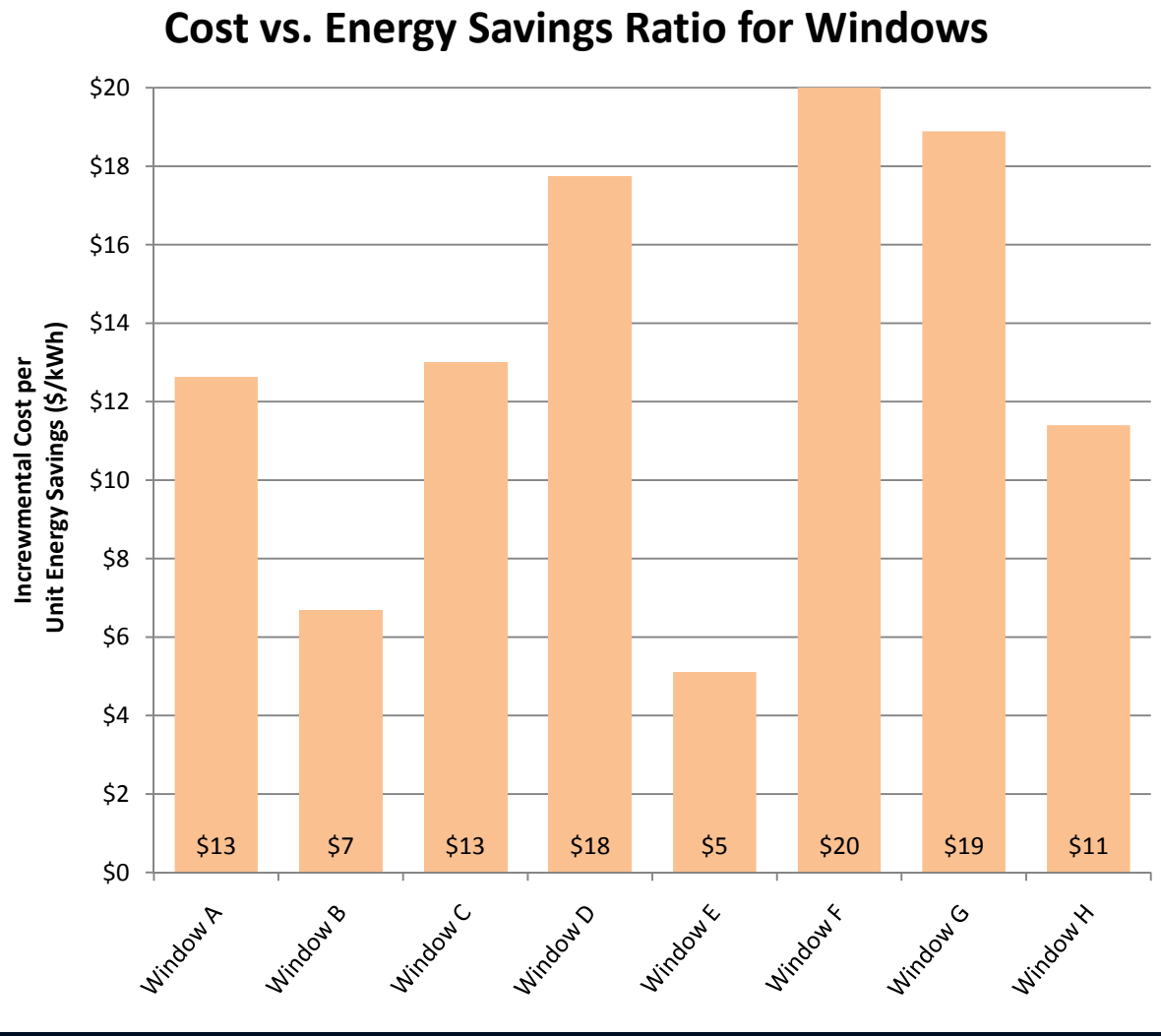
Cost vs. Energy Performance – Must Meet

- Since U-value has more influence on annual heating/cooling energy use than SHGC, window products with SHGC ratings between 0.20 and 0.30 were focused on.

- Selection of windows for detailed analysis included products with 2- and 3-pane glazing (either glass or suspended-film third pane); vinyl, fiberglass and composite framing; insulated and un-insulated frames
  - U-values between 0.17 and 0.28
  - SHGC ratings between 0.16 and 0.47
  - Visible Transmittance (VT) ratings between 0.36 – 0.50

Cost vs. Energy Performance – Must Meet

- TRNSYS (6 min time step) for energy and comfort determination
- Best Cost vs Energy Savings Ratio:
- Window E – Double-glazed with suspended film, krypton gas fill; vinyl frame; U=0.22; SHGC=0.33
- Window B – Triple-glazed with suspended film; krypton gas fill; fiberglass-reinforced vinyl frame; U=0.17; SHGC=0.16

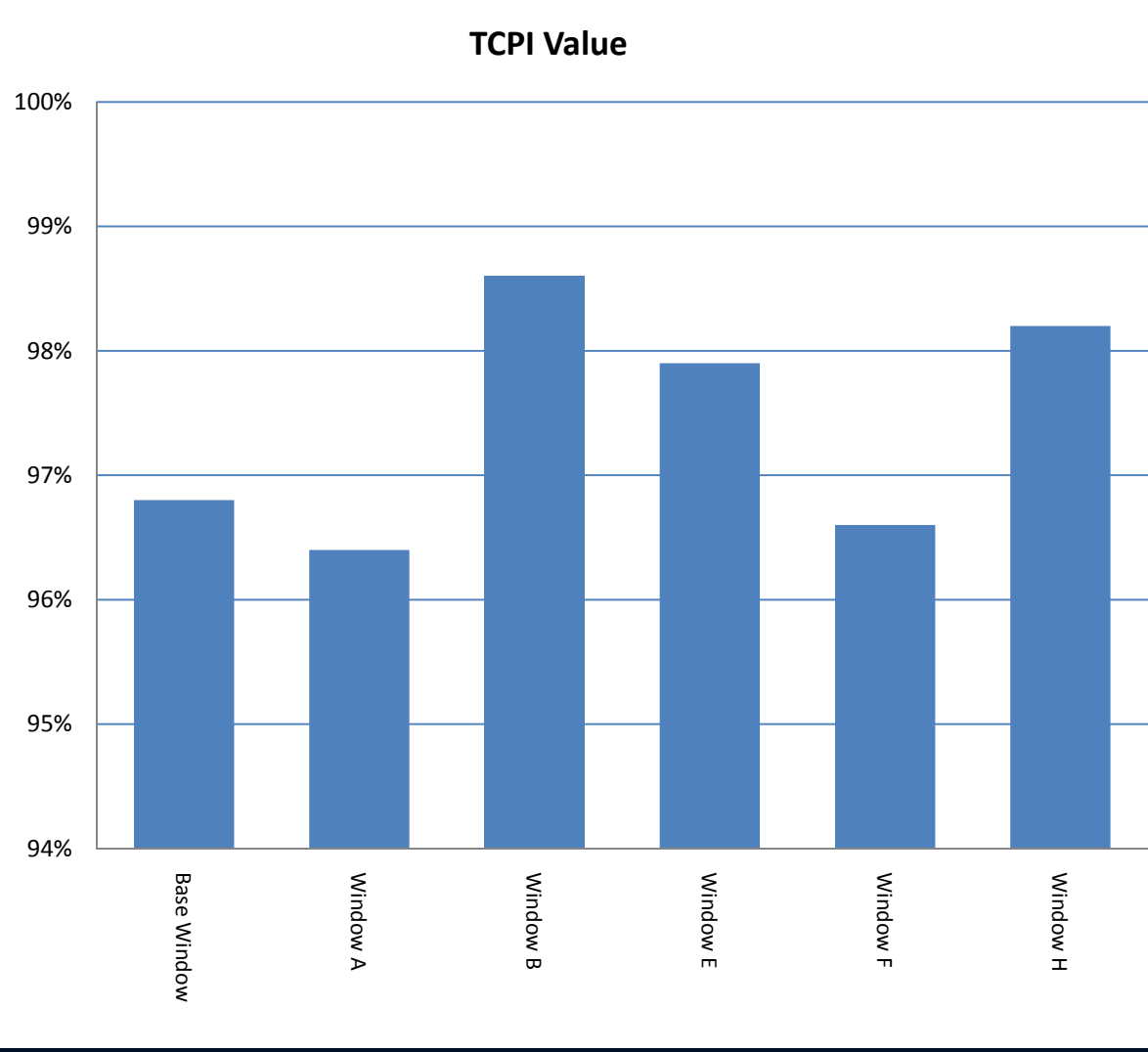


Comfort – Should Meet

- Considered “Should Meet” but is highly important to building occupants
- Top five window options evaluated more closely with respect to:
  1. Thermal Comfort Performance Index (TCPI)
  2. Visible Transmittance (VT)

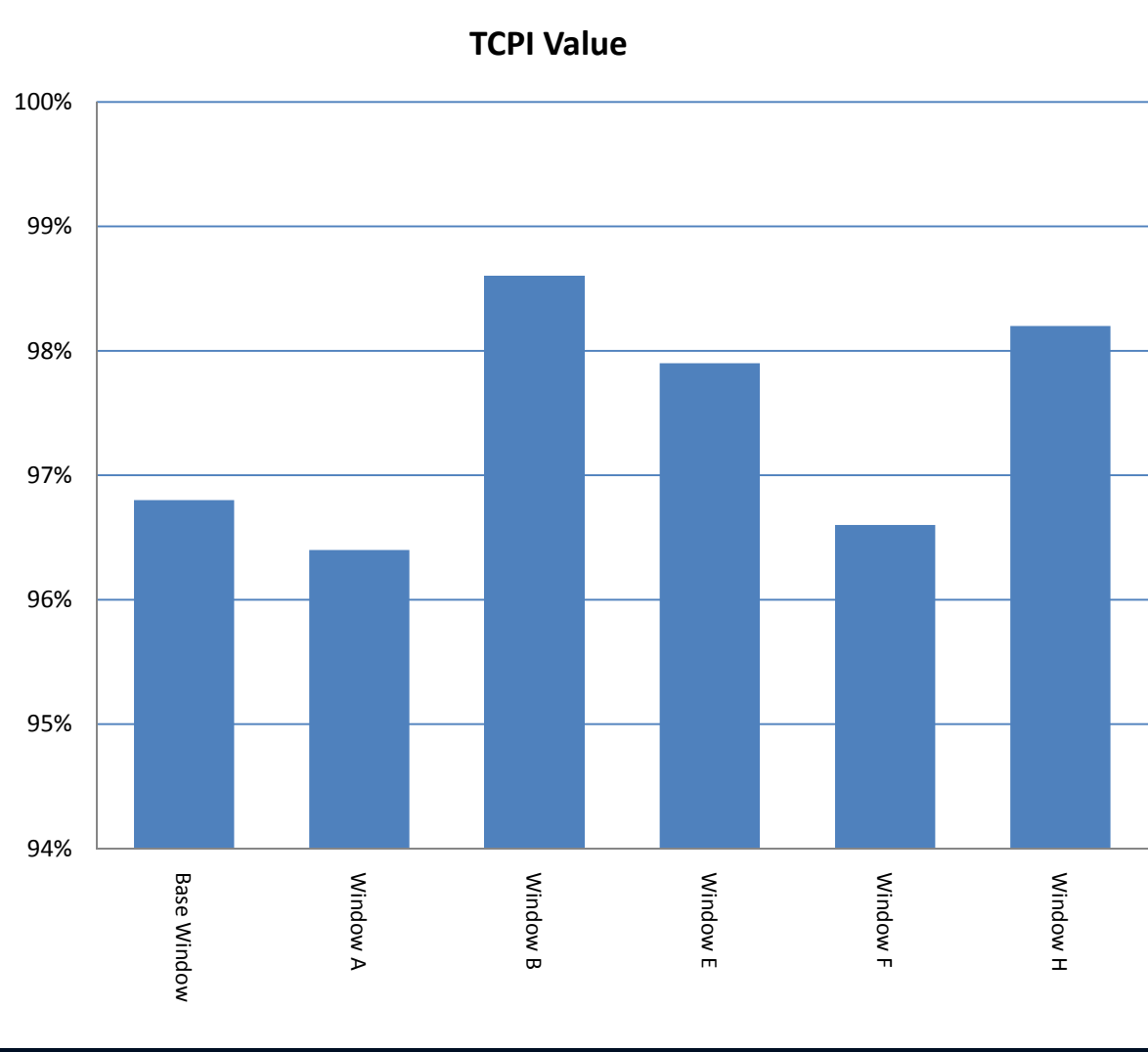
Comfort – Should Meet

- Indicates thermal comfort conditions in each zone of house
- TRNSYS simulations to calculate average whole house TCPI value per window system
- Value between 98% and 100% is preferable



Comfort – Should Meet

- Highest TCPI:
- Window B – Triple-glazed with suspended film; krypton gas fill; fiberglass-reinforced vinyl frame; U-0.17; SHGC-0.16; VT-0.36
- Window H – Double-glazed; krypton gas fill; vinyl frame; U-0.25; SHGC-0.27; VT-0.44



Comfort – Should Meet

- **Visible Transmittance**
  - Percentage of light from visible spectrum passing through window
  - Higher VT = greater visibility = higher visible comfort for occupants
  - VT ≥ 0.50 is ideal for cold climate
  - VT < 0.40 is restrictive to vision

  - Window B has VT of 0.36 and is likely too dark for a cold climate (based on visual inspection) & unacceptable to homeowners
  - Window H has VT of 0.44 and is acceptable for a cold climate

Conclusion

- Window H was selected as the ideal window for our cold climate net zero energy house because:
  - Superior comfort-related performance, good VT level
  - Affordable, available, and scored highest for constructability due to standard installation features of integral nailing flanges and J-channel

- Window H has:
  - U-value is average for windows evaluated (0.25)
  - SHGC was also average (0.27)

Conclusion

- In summary, the ideal window selection for a net zero energy, cold climate house:
  - Balances thermal performance with affordability (U-value more important than SHGC)
  - Is available with typical installation features for new construction production housing like integral nailing flanges and J-channel
  - Provides VT levels that homeowners should find acceptable

Next Steps

- Expand modeling evaluation to include greater number of high performance windows particularly energy efficiency leaders
- Perform evaluation for other climate zones
- Spread the word that there is a strong need for high performance windows in the cold climate that are suitable for the new construction production market.

Thank You

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Any Questions?

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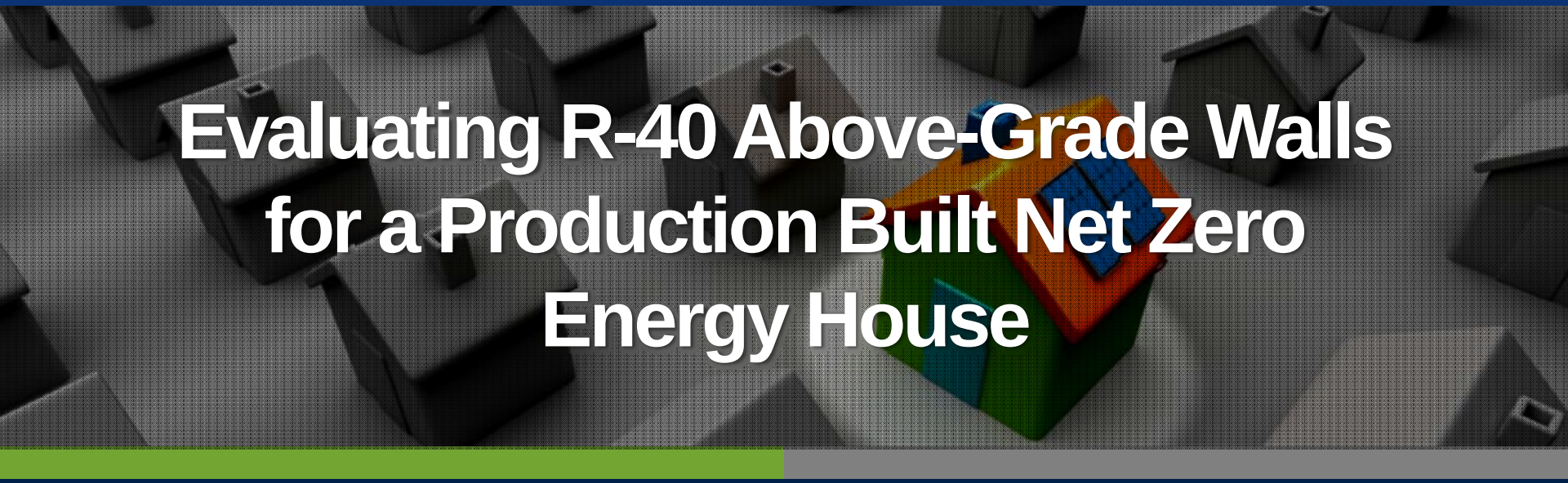

Evaluating R-40 Above-Grade Walls for a Production Built Net Zero Energy House

Co-Author/Presenter: John Broniek

Co-Authors: Kevin Brozyna and Dave Stecher

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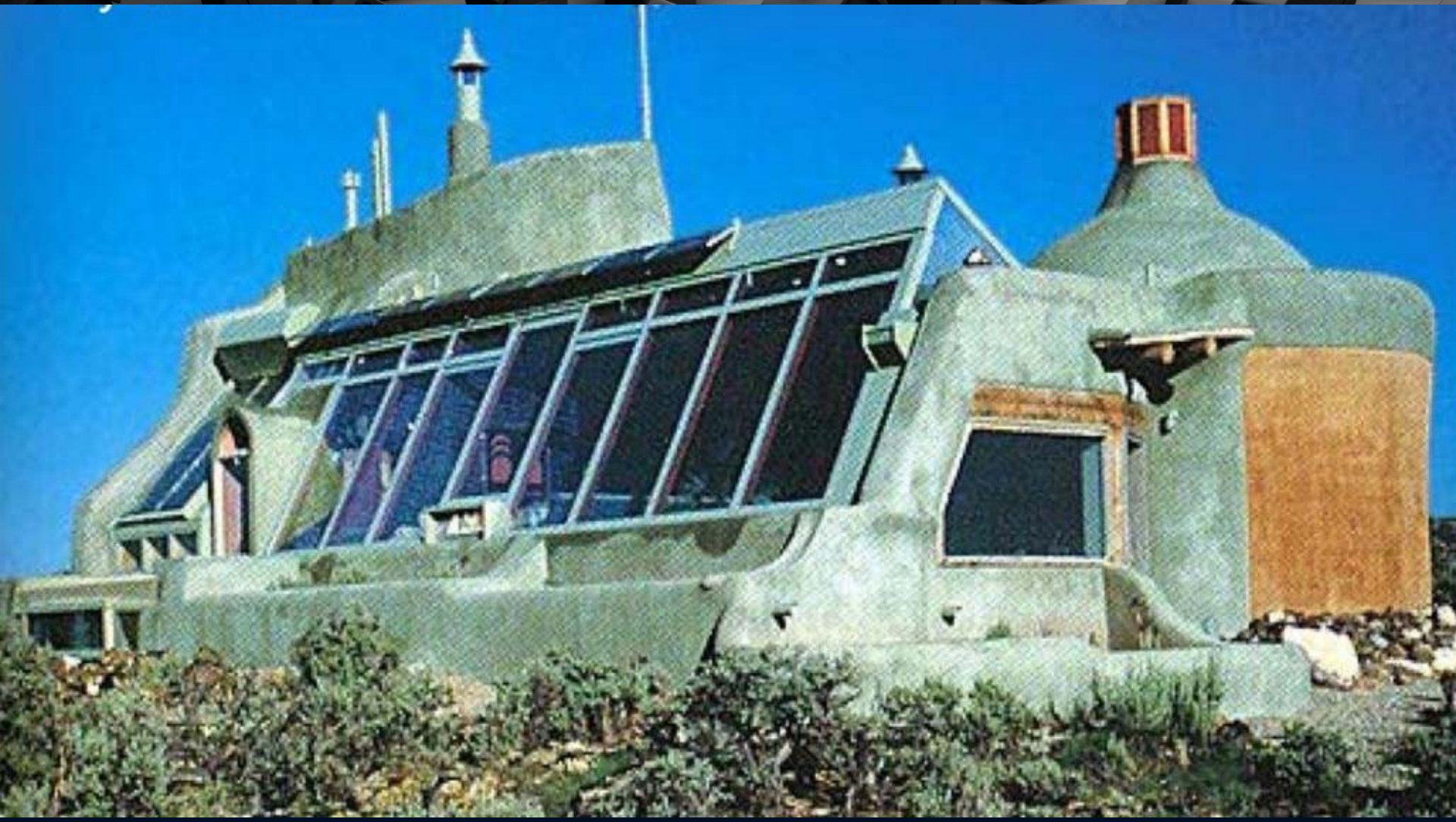
Session Overview

- Findings, challenges, and lessons learned during research in above-grade walls for a net zero energy house
- Cold climate solutions for production homebuilding
- Evaluation process used in our research
- Key evaluation criteria:
  - Constructability
  - Cost effectiveness
  - Durability
  - Comfort
- Evaluation results

Plenty of Custom Built Net Zero Energy Houses Around



Our Challenge - A Net Zero Energy House that is Mainstream, Production

Specification of a Net Zero House Design in Pittsburgh

- R-60 attic
- R-26 basement foundation
- R-10 under slab
- Vinyl windows with U=0.25, SHGC=0.27; krypton gas fill
- Air infiltration 0.00003 SLA (0.6 ACH50)
- GSHP with desuperheater for domestic hot water production
- Ductwork within conditioned space, 0% leakage to outdoors
- Energy recovery ventilation system
- 100% high efficacy lighting
- All ENERGY STAR® appliances
- PV system: Approx. 9 kW system needed for net zero
- Above Grade Walls?

Evaluation Criteria: Must Meet

- Minimum energy performance specification
- Code acceptance
- Market availability of the technical solution(s)
- Constructability
- Trade skill set change
- Functionality
- Architectural flexibility
- Scalability potential
- Cost vs. energy savings ratio
- Durability: moisture management

Evaluation Criteria: Should Meet

- Homeowner impact
- Systems integration and elimination potential
- Environmental responsibility
- Cycle time
- Durability and maintenance
- Comfort

Evaluation Criteria Process

- Technical solution is given a ranking depending on how well it meets the criteria requirements
- Each criterion is assigned a weight value based on its importance
- The rank of each technical solution is multiplied by this weight, resulting in a weighted ranking
- The weighted rankings are totaled for each technical solution with the highest total score becoming the first system choice

Initial Wall Design Considerations

- Initial modeling found R-40 plus or minus R-10 nominal thermal performance required to achieve goals

- For wood framed wall systems, the exterior insulating sheathing considered most suitable was un-faced extruded (XPS) polystyrene:
  - Compatible with different siding systems, durable
  - Cost effective, lower cost per R-value than polyisocyanurate
  - High R-value per thickness (compared to EPS)
  - Higher vapor permeability for 1” and 2” un-faced XPS compared to polyisocyanurate gives wall greater drying potential

Focus on These Wall Systems

- A production homebuilder could potentially use all of them

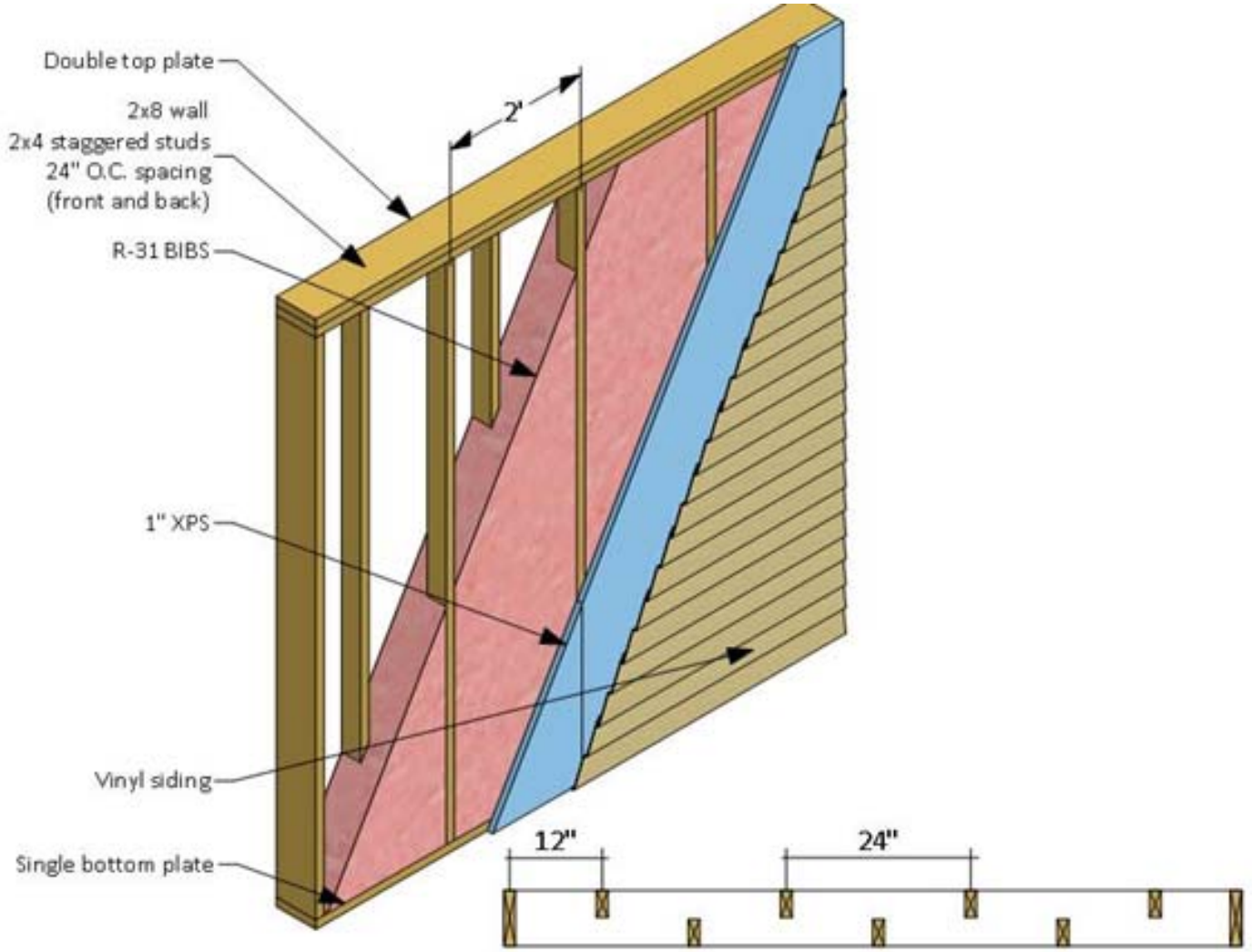
- Staggered stud 2x8 and 2x6 framing limit thermal bridging
- Double wall with two rows of 2x4 studs for a lot of cavity insulation
- 2x6 stud with 1” plus of insulating sheathing to limit thermal bridging
- SIPS (Structural Insulated Panel System) as “emerging” option

Cavity Insulation Choices

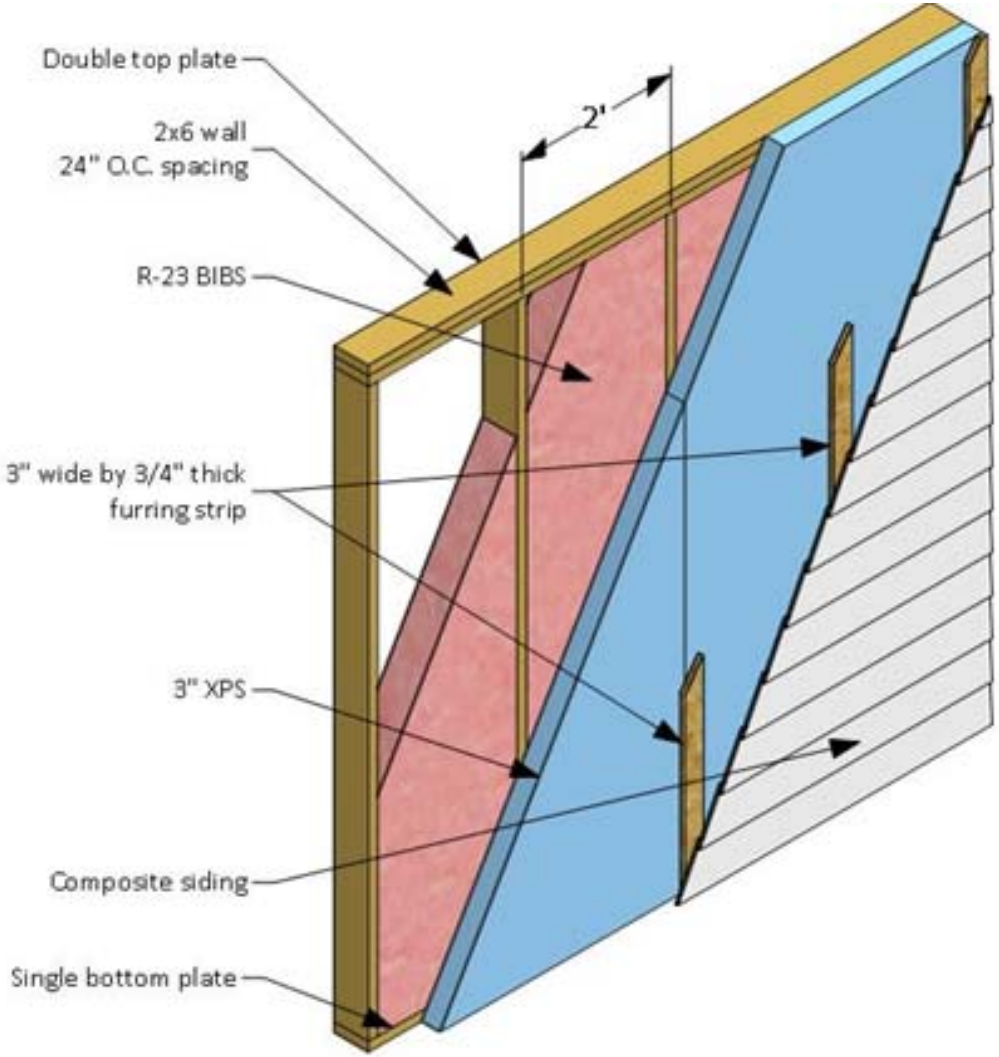
- Choices have variable cost, airtightness, and permeability and are readily available

- Blown fiberglass, R-23 to R-33 depending on thickness
- Closed cell polyurethane spray foam, R-6.6 to R-33 depending on thickness
- Expanded polystyrene core in SIPS, R-32 to R-43 nominal for total system

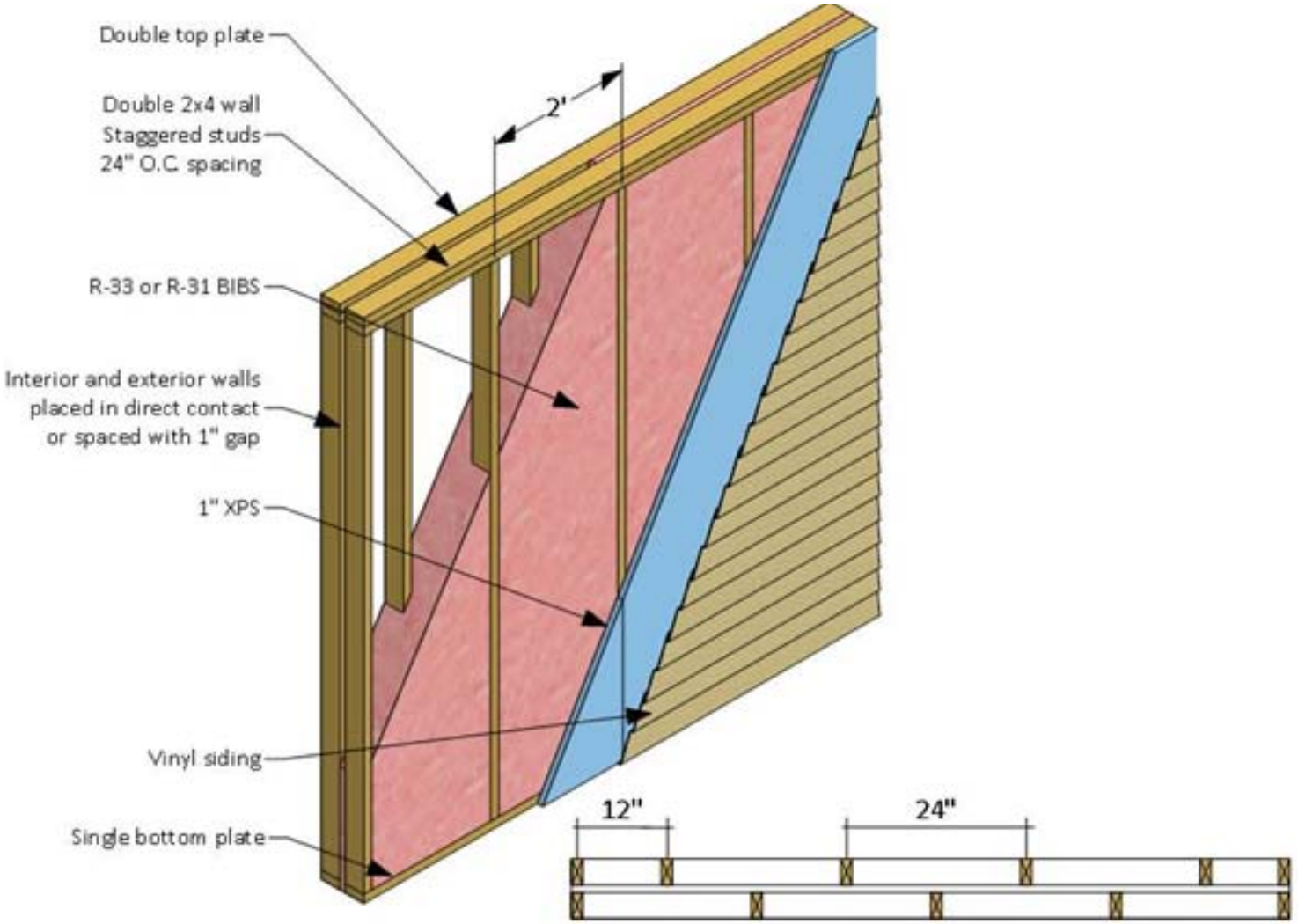
2x8 Staggered Stud Wall with XPS Sheathing



2x6 Stud Wall with XPS Sheathing



Double Stud Wall (2x4s)



List of 17 Wall Systems Studied

Staggered stud 2x8, blown fiberglass with…	1. R-5 insulating sheathing 2. R-10 insulating sheathing 3. R-10 insulating sheathing and layer of SPF
Double walls, blown fiberglass with…	4. R-5 insulating sheathing 5. 1-inch spacing; R-5 insulating sheathing
2x6, closed cell spray polyurethane with…	6. R-5 insulating sheathing 7. R-10 insulating sheathing 8. Staggered stud; R-10 insulating sheathing
2x6, layer of closed cell spray polyurethane with…	9. R-5 insulating sheathing 10. R-10 insulating sheathing 11. R-15 insulating sheathing
2x6, blown fiberglass with…	12. R-5 insulating sheathing 13. R-10 insulating sheathing 14. R-15 insulating sheathing 15. R-20 insulating sheathing
SIPS	16. 8 ¼ in. thick 17. 10 ¼ in. thick

Constructability Research

- 1½-story mock-up structure in IBACOS facility
- Split mock-up into 2x8 staggered stud wall and 2x6 wall with high levels of insulating sheathing
- Evaluate:
  - Framing approaches and requirements, particularly for studs, top plates, and wall bracing
  - Attachment of varying thicknesses (1”-4”) of exterior insulating sheathing
  - Fastening of cladding over the sheathing
  - Water management strategies for the wall system

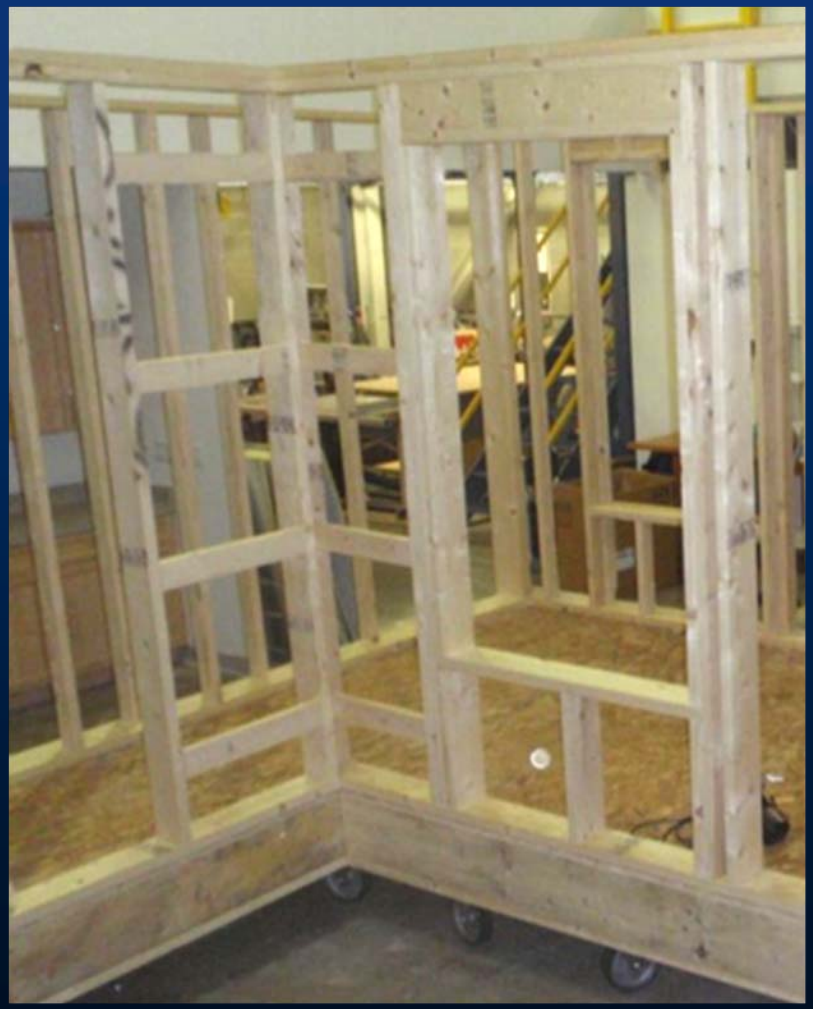
Mock-up for Wall Research

2x8 Staggered Stud Approach

- Gain practical experience with different approach
- Only need one flush face for 2x8 system
- 2x8 members used at rough openings
- Some more initial layout required than 2x6 full stud system
- Overall, 2x8 staggered stud easier to build than first thought

Wall Framing Approach

- Examine framing details for windows and inside corners with 24” o/c studs
- Double top plates simplified load bearing preferred for production building; only 10 kWh/yr energy penalty vs single top plate when R-10 insulating sheathing used



Wall Sheathing Issues

- Providing shear capacity is only one issue; OSB is preferred
- How many layers of XPS insulating sheathing are needed to achieve required thickness?
- What fasteners are needed?
- Do long fasteners drift and miss the framing?
- How is siding applied? To what?

Insulating Wall Sheathing

- For 2” XPS and greater, cap screws and washer head screws used
- When using multiple layers of XPS, only outer layer needs to satisfy manufacturer’s attachment requirements
- More sheathing = greater drift from longer screws

Alternative Insulating Sheathing

- Typically used in basements has recessed channels
- Application transferred to walls
- Flush surface good for backing of cladding, especially vinyl siding
- More expensive than typical XPS

Alternative Insulating Sheathing

- OSB furring strips at 24” o.c. fastened to studs
- For 2” XPS, 3¼” nail with pneumatic gun used, eliminating need for screws, reducing cost, and simplifying installation
- Hot knife cutter for furring channels allowed for trim and siding nail base

Wall Durability

- Housewrap for bulk water management
- Attached to furring strips

Cladding Considerations

- Cement fiber, vinyl and wood siding installed to recessed furring strips
- 24” o.c. attachments stable

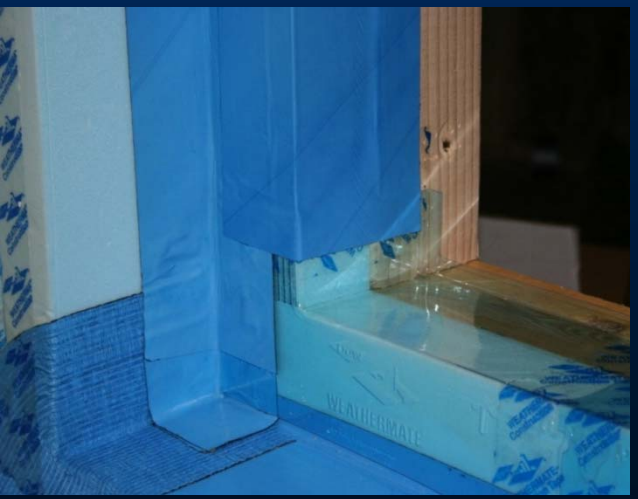
Ventilated Cavity Strategy

- Taped joints and surface-applied furring provide excellent drying
- Horizontal tape joint quality and insect screen critical to success
- Screws needed to install furring strips (nails not long enough) for 2” XPS or greater

Cladding Considerations

- Ventilated claddings need to be stiffer to span air space
- Vinyl siding installation OK at 24” o.c.

Window Durability



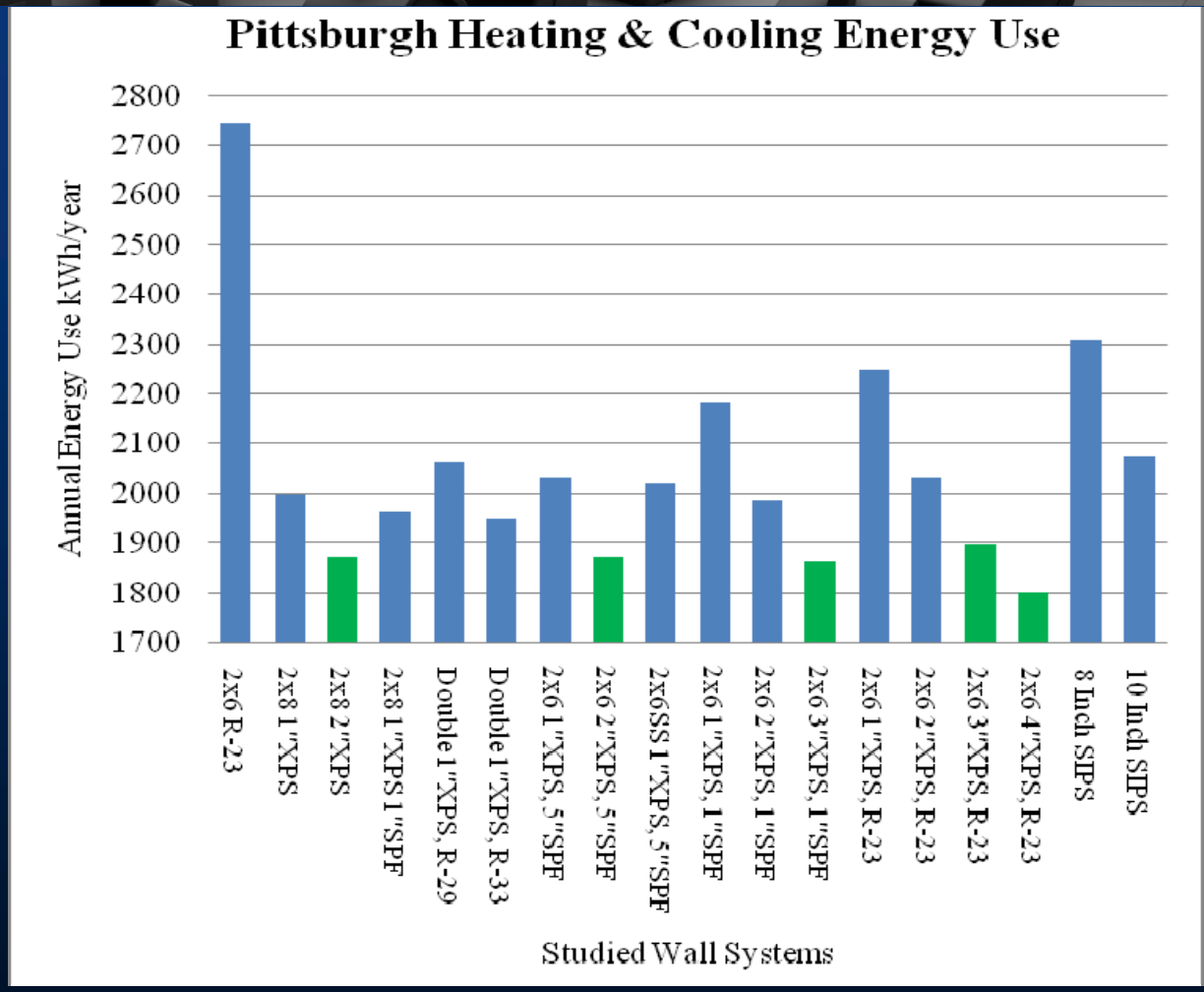
- Flashing details for exterior mounted window similar to typical sheathing case were preferred
- With 2” XPS insulating sheathing, a ½” OSB buck needs to be installed at the sill of the framed opening and the rough opening size needs to be adjusted
- Recessing windows made flashing and insulation details onerous

Door Durability

- Door positioned to the exterior and had jamb and threshold extensions
- Sill pan adapted for thick wall

Cost Effectiveness Research

- TRNSYS used for energy use
- #1: 2x6 wall, R-20 sheathing
- #2: 2x6 wall, 1” spray polyurethane, R-15 sheathing
- #3: 2x6 wall, polyurethane foam, R-10 sheathing
- #4: Staggered stud 2x8 wall, R-10 sheathing
- #5: 2x6 wall, R-15 sheathing

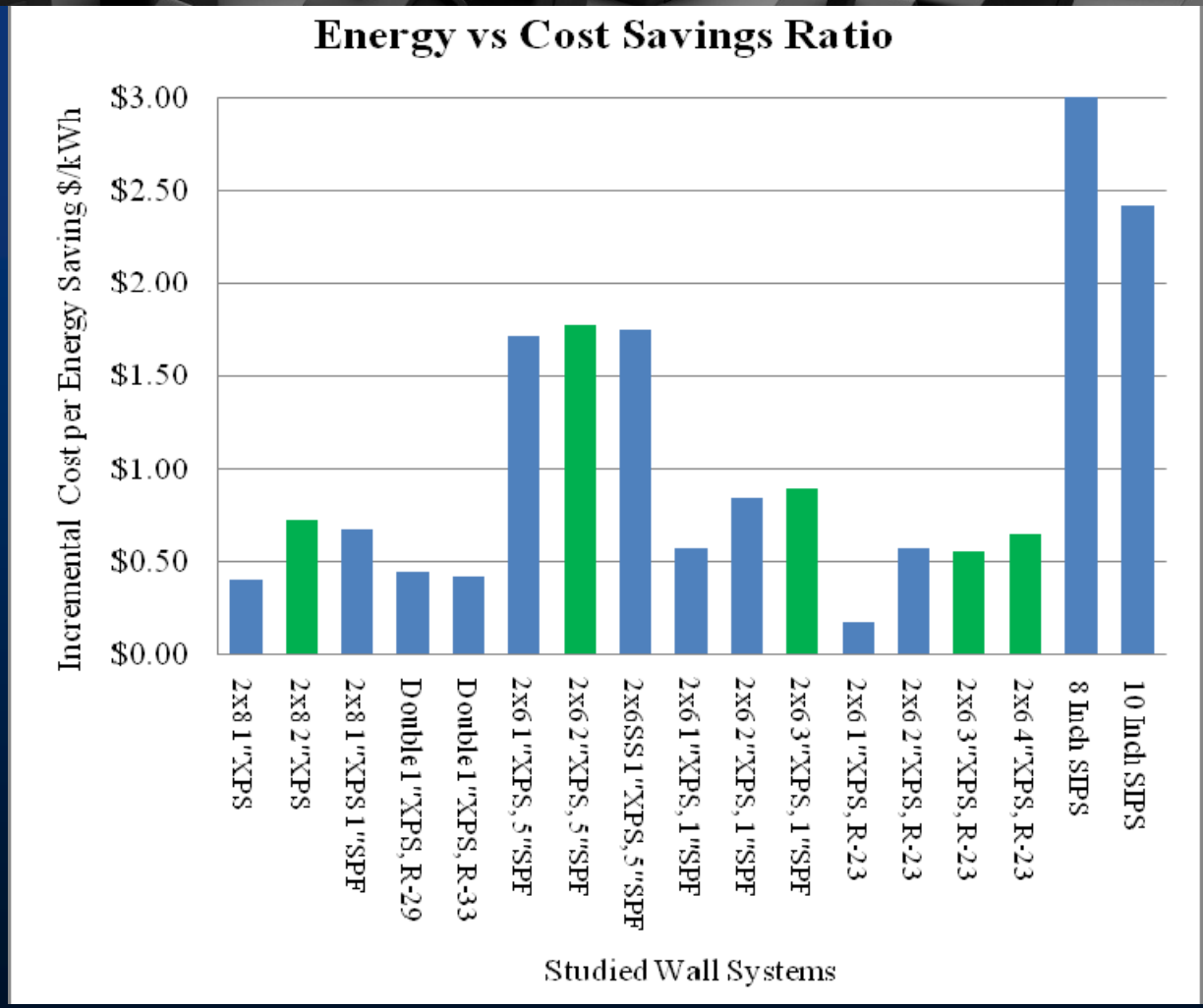


Cost Effectiveness Research

- Ratio with respect to 2x6 R-23 wall
- #1: 2x6 wall, R-5 sheathing
- #2: Staggered stud 2x8 wall, R-5 sheathing

Also:

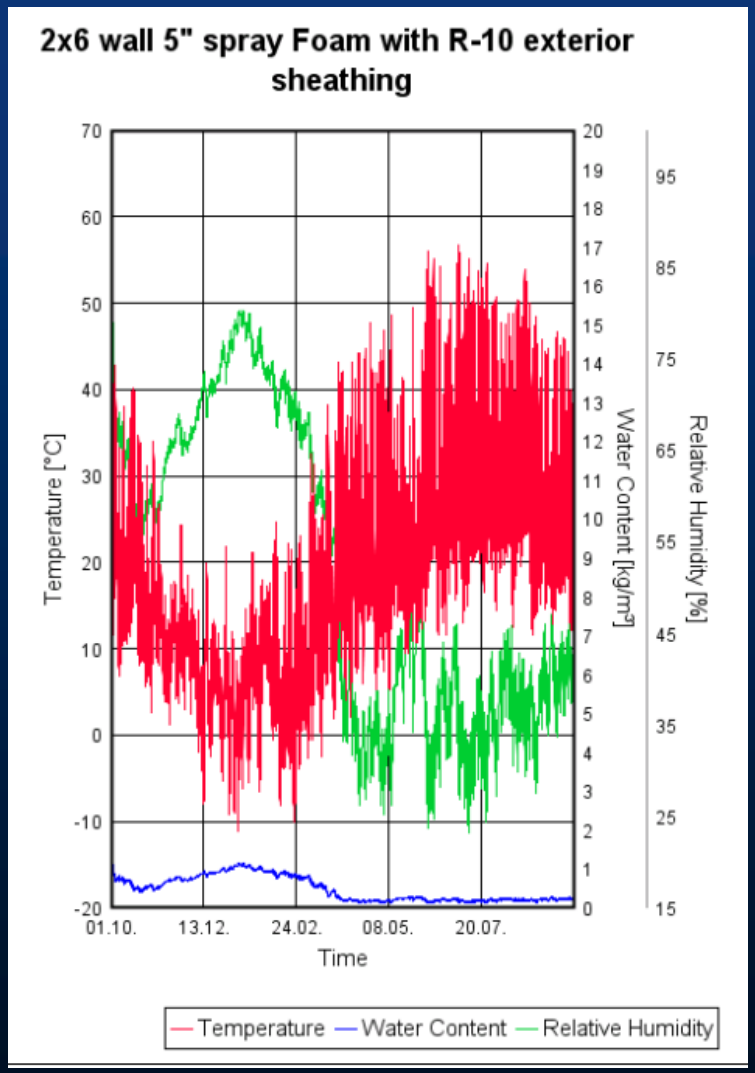
- Double wall, R-5 sheathing
- 2x6 wall, R-10 sheathing
- 2x6 wall, R-5 sheathing, 1” SPF



Durability Research

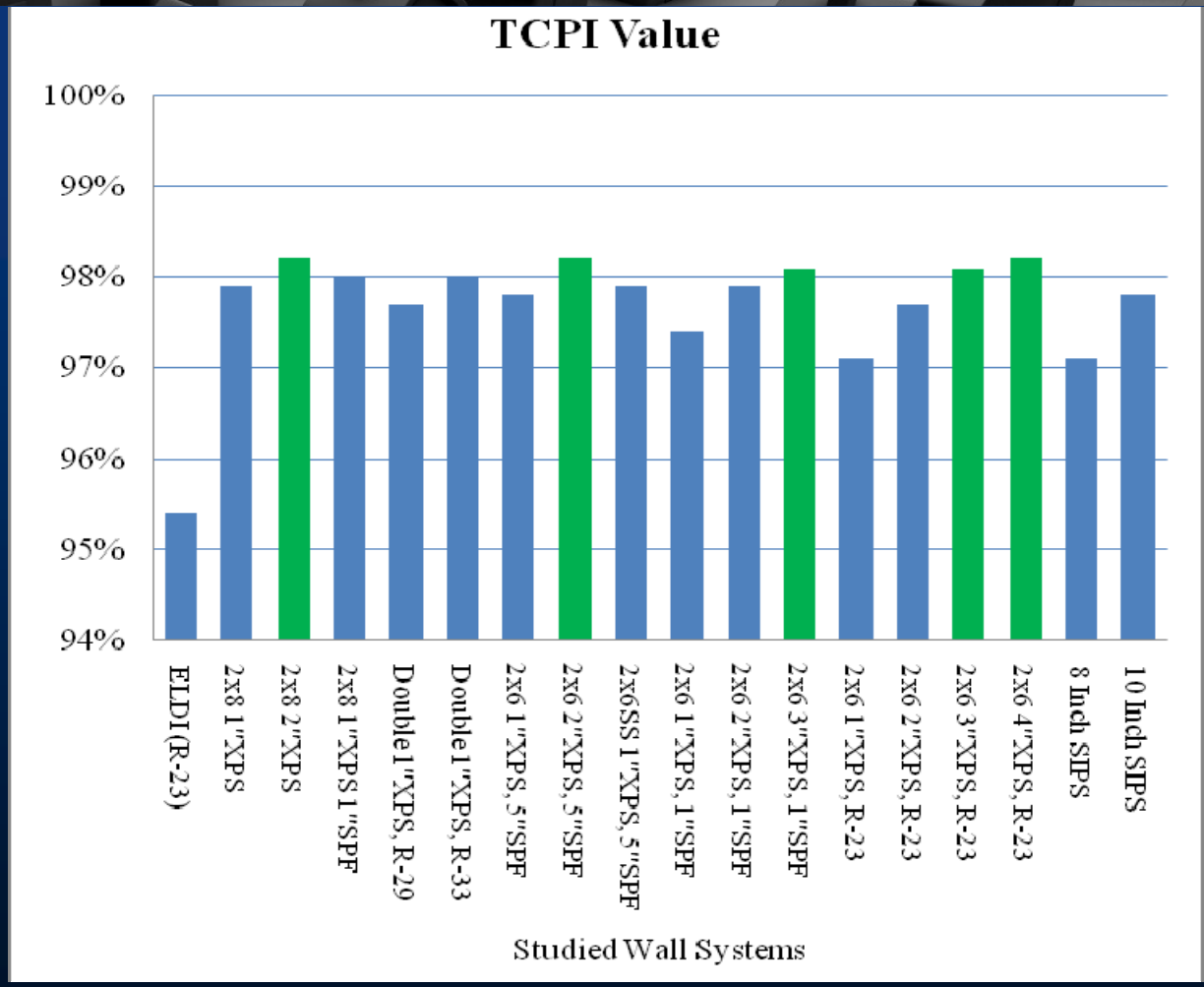
- Bulk water durability findings came in constructability research.

- WUFI and Therm modeling showed that systems with XPS insulating sheathing and spray polyurethane in wall cavities should have the fewest moisture problems due to lower condensation potential



Comfort Research

- Indoor comfort conditions for each house design zone
- The five leaders in energy efficiency were also leaders in comfort, having the highest Thermal Comfort Performance Index (TCPI) values
- TCPI value of 100% indicates perfect comfort at all times



Final Evaluation Results

- Best score: 2x6 wall system with R-5 insulating sheathing
- Second best score: 2x6 wall system with a layer of closed cell spray polyurethane foam and R-5 insulating sheathing
- Third best score: Staggered stud 2x8 wall with R-10 insulating sheathing (then 2x6 walls with R-10 and R-15)
- Of the top three, the staggered stud 2x8 wall with R-10 insulating sheathing offers the greatest amount of heating and cooling energy savings for the whole house, saving an additional 379 kWh/yr (17%) in energy use than the first wall and 313 kWh/yr (14%) more than the second wall

Final Evaluation Results

- The staggered stud 2x8 wall with R-10 insulating sheathing did not have the lowest evaluation score
- It has merit as a wall system for a net zero energy house
- It was leading energy efficiency; constructability issues resolved during mock-up research
- We will use 2x8 wall with R-10 insulating sheathing (recessed channels) design in the field
- Overall energy usage is important for net zero energy house construction and must be considered

Thank You

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Any Questions?

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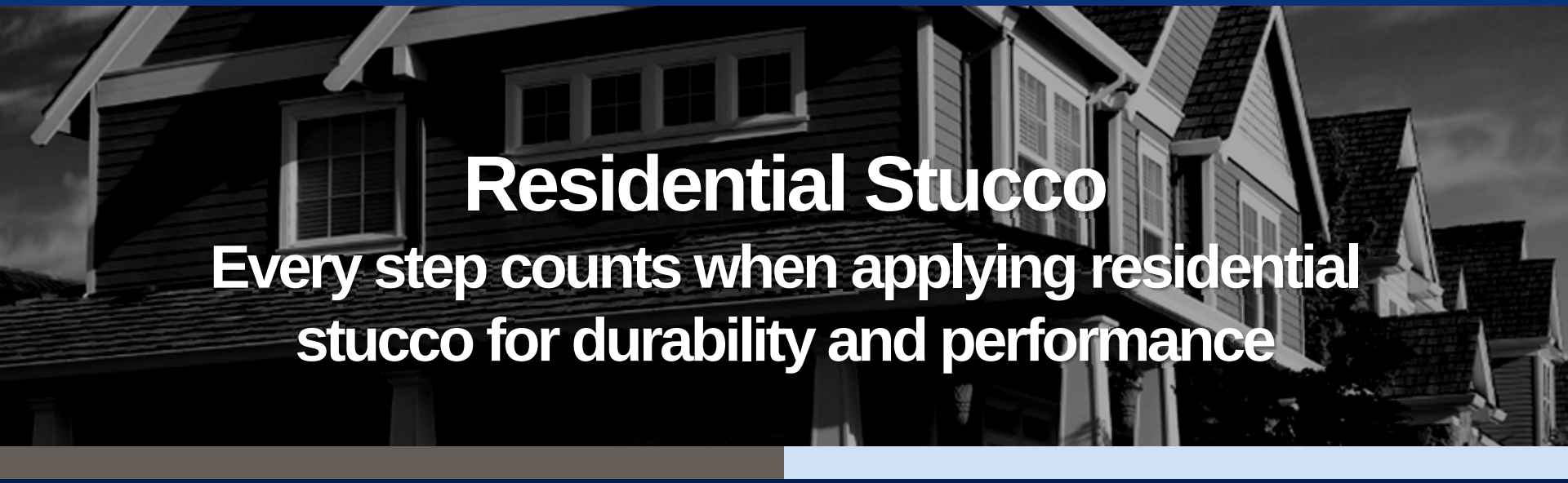

Residential Stucco

Every step counts when applying residential stucco for durability and performance

Brad Oberg, Chief Technology Officer

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Topics

- Installing the drainage plane, bond break, and lath
- Selecting and storing raw materials
- Mixing and applying cementitious stucco
- Applying the scratch coat or base coat
  - Differences between one coat and three coat
- Executing wetting and testing for hydration
- Applying the finish coat

Residential Stucco: Builder View

Stucco is a cementitious mix

Delivered to the surface for application

Finished to uniform surface

Enhanced with texture and details

Finished with color

Residential Stucco: Quality View

Stucco is a cementitious mix

Of carefully proportioned clean materials

Delivered to the surface for application

Which includes pumping or hand application

Finished to accurate thicknesses

Over a stable, level base layer with tooling to achieve a specified uniform thickness and texture

Enhanced with texture and details

Finished with color

Basic Stucco Practice

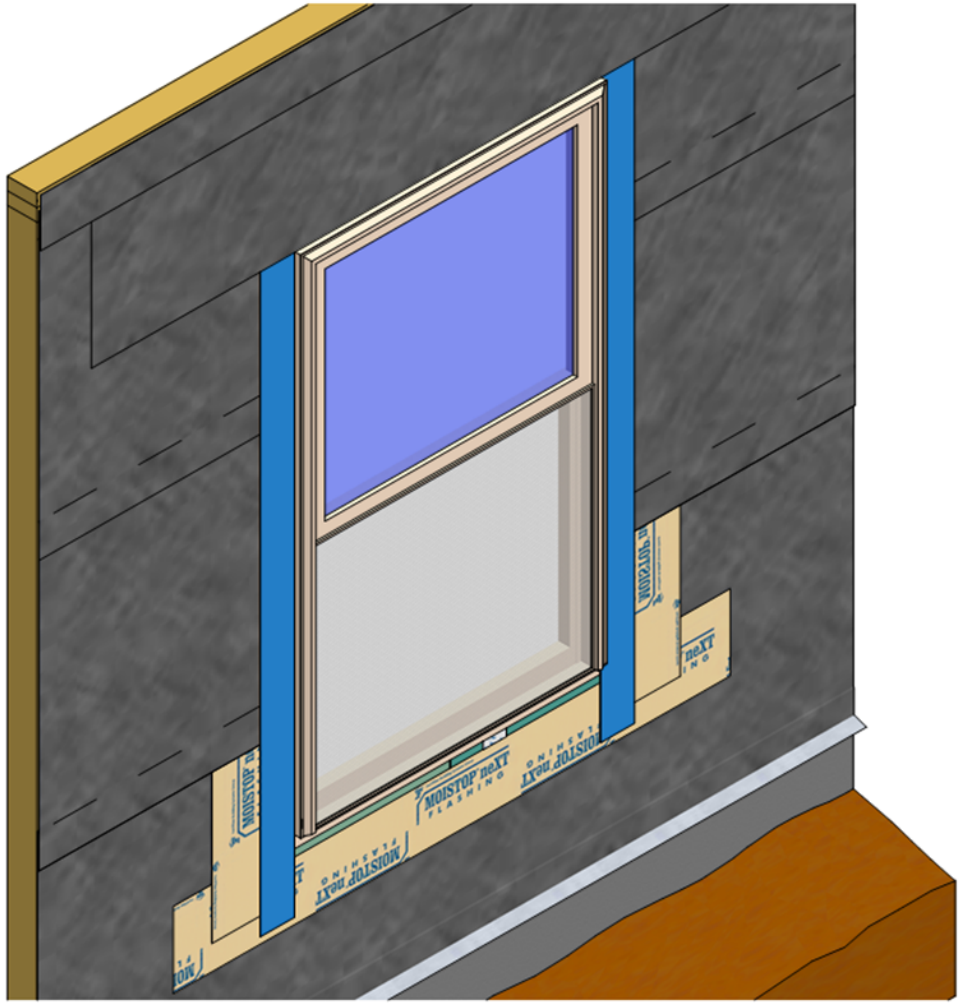
Stucco is a cementitious mix of carefully proportioned materials

- Cement, preferably low alkali
- Additives including workability modifiers and lime
- Sand, clean and graded
- Water, potable

Typical Three-Coat Stucco System

Drainage Plane and Bond Break

- Apply drainage plane integrated with penetration and opening flashings
- For one coat systems the paper is the drainage plane behind the foam
- For two coat systems the first layer of paper is the drainage plane, the second layer is a bond break



Drainage Plane and Bond Break

All stucco systems need two layers of paper, except direct application to masonry backer.

Double layer on one roll looks like a productivity tool, but can create major cracking in the finish.

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Drainage Plane and Bond Break

Back layer of paper is the drainage plane.

Front layer is the bond break.

Drainage plane water is reintroduced to the stucco and causes a water concentration, which changes the hydration and shrinkage rates .

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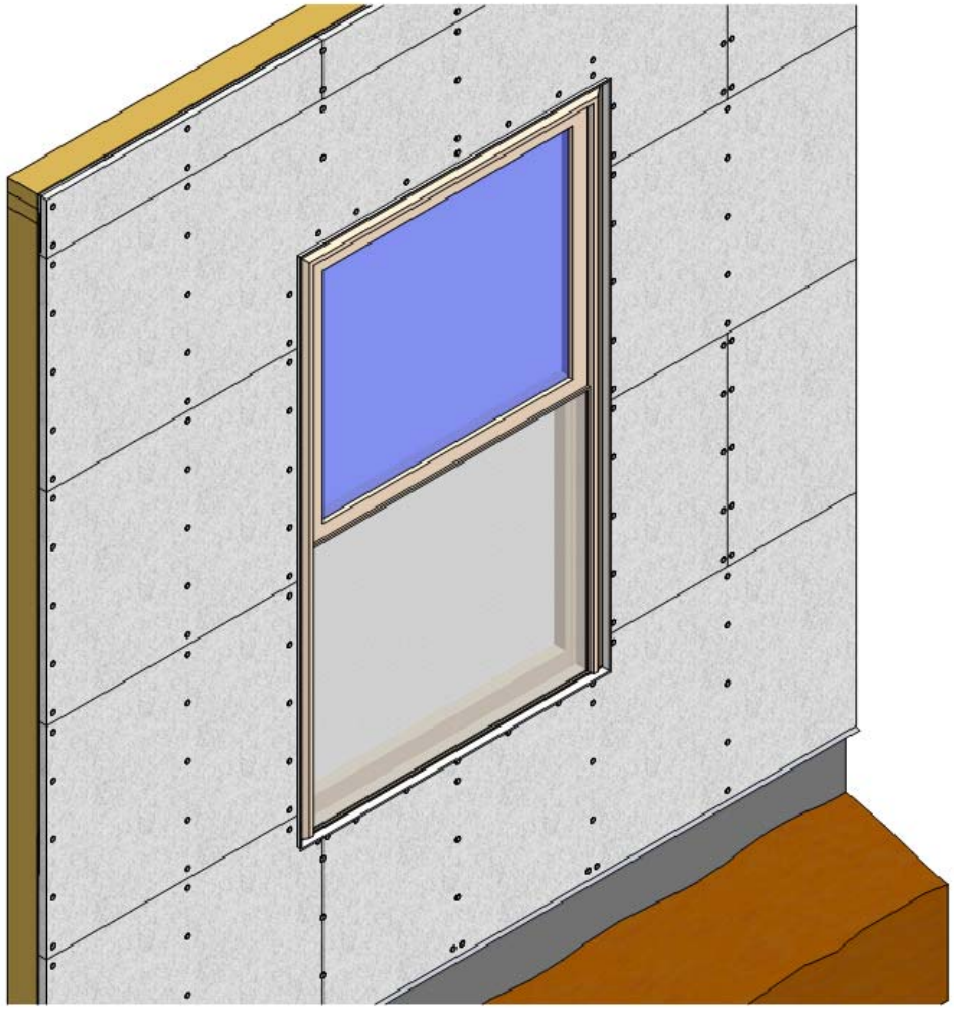
Wall Preparation

One inch expanded foam board is applied over the base layer of paper.

Fasteners must be into framing members and not over-driven

Board should fit tightly and gaps should be filled with slivers of foam



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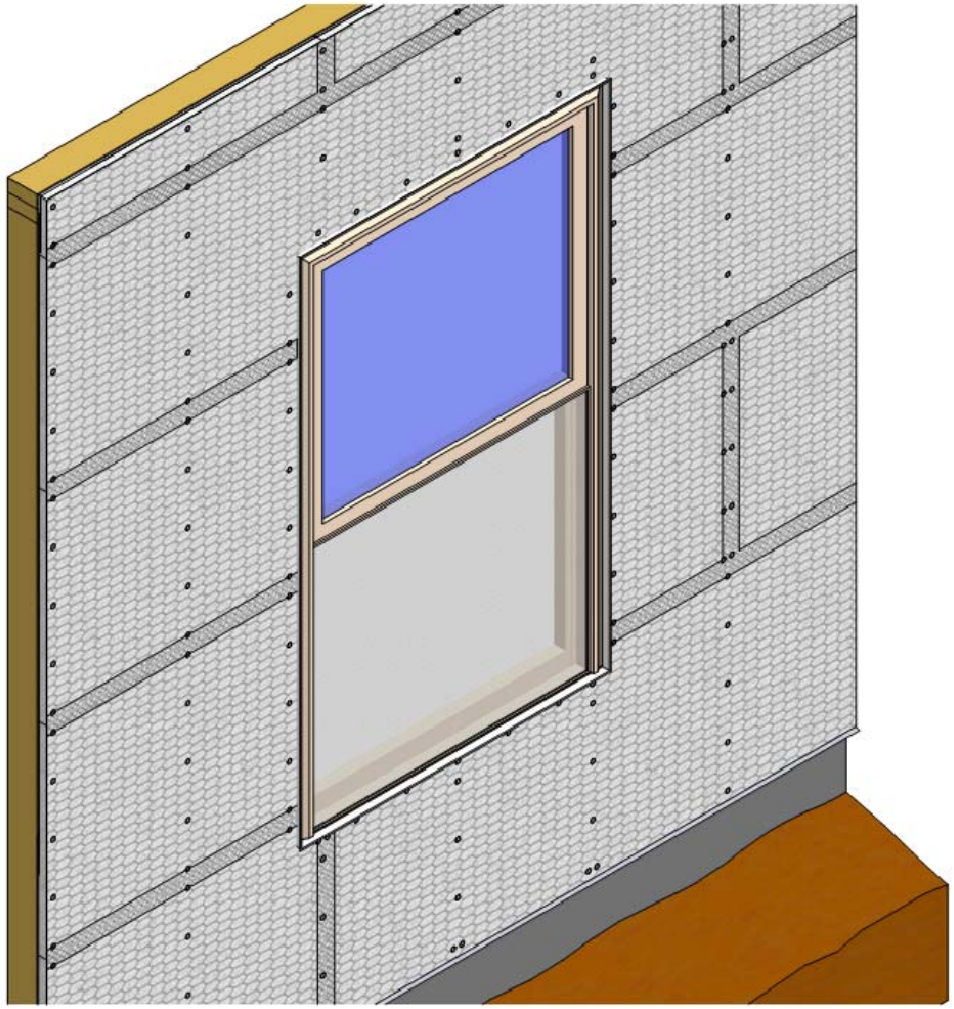
Lath Application

Metal lath is applied to engage the base layer of stucco.

Over expanded foam, the lath may be pulled tightly and not furred out, since the foam deforms under the application of the base.

All other conditions require self furred lath or furring nails



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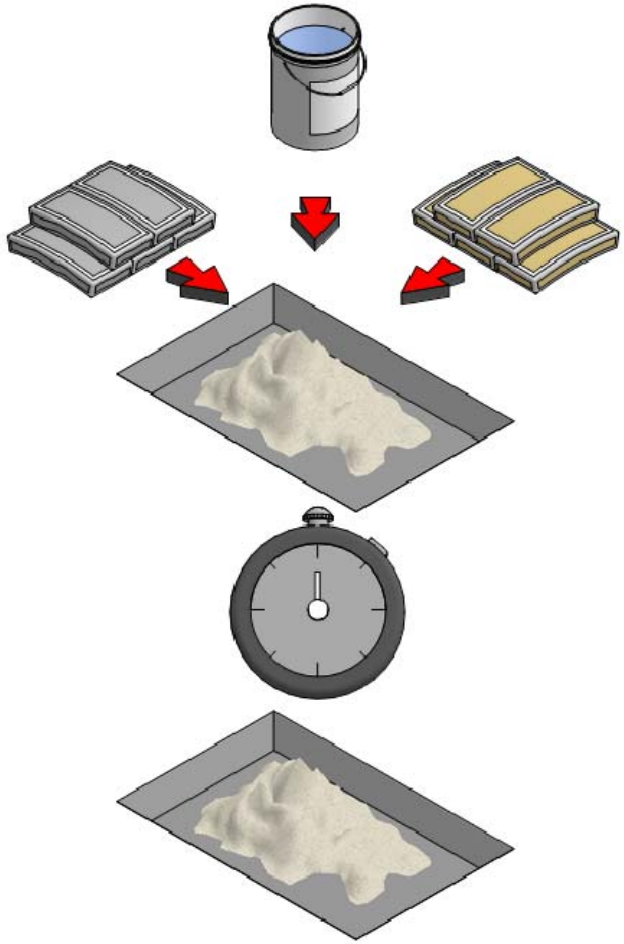
Stucco Mix

Each stucco layer is mixed specifically for the function of that layer.

The base layer is always stronger than the next layer.

All must be mixed for application consistency within certain proportions to control strength and shrinkage.



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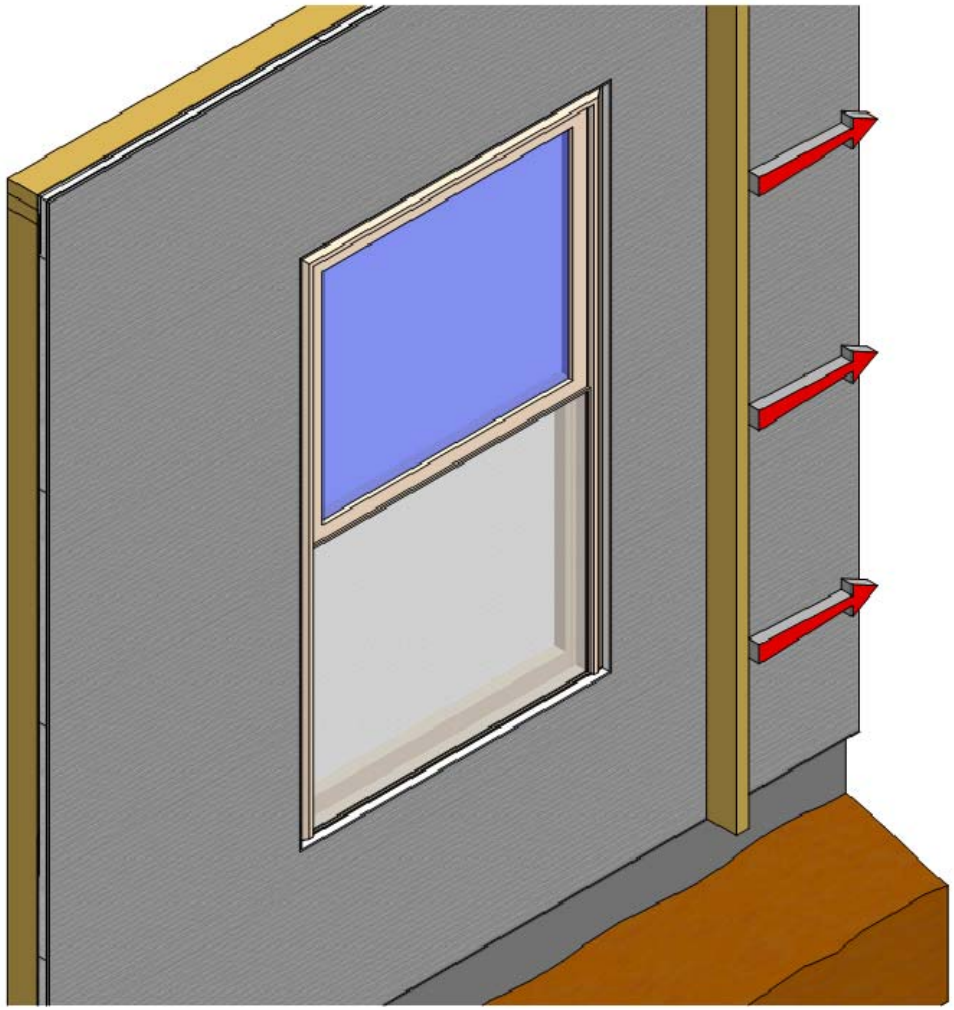
Base Coat or Scratch Coat

The first coat engages the lath and forms a stable base for the next one or two layers.

Thickness control is critical and often overlooked .

Uniform thickness allows small uniform shrinkage crack to form and uniform thickness allows consistent hydration



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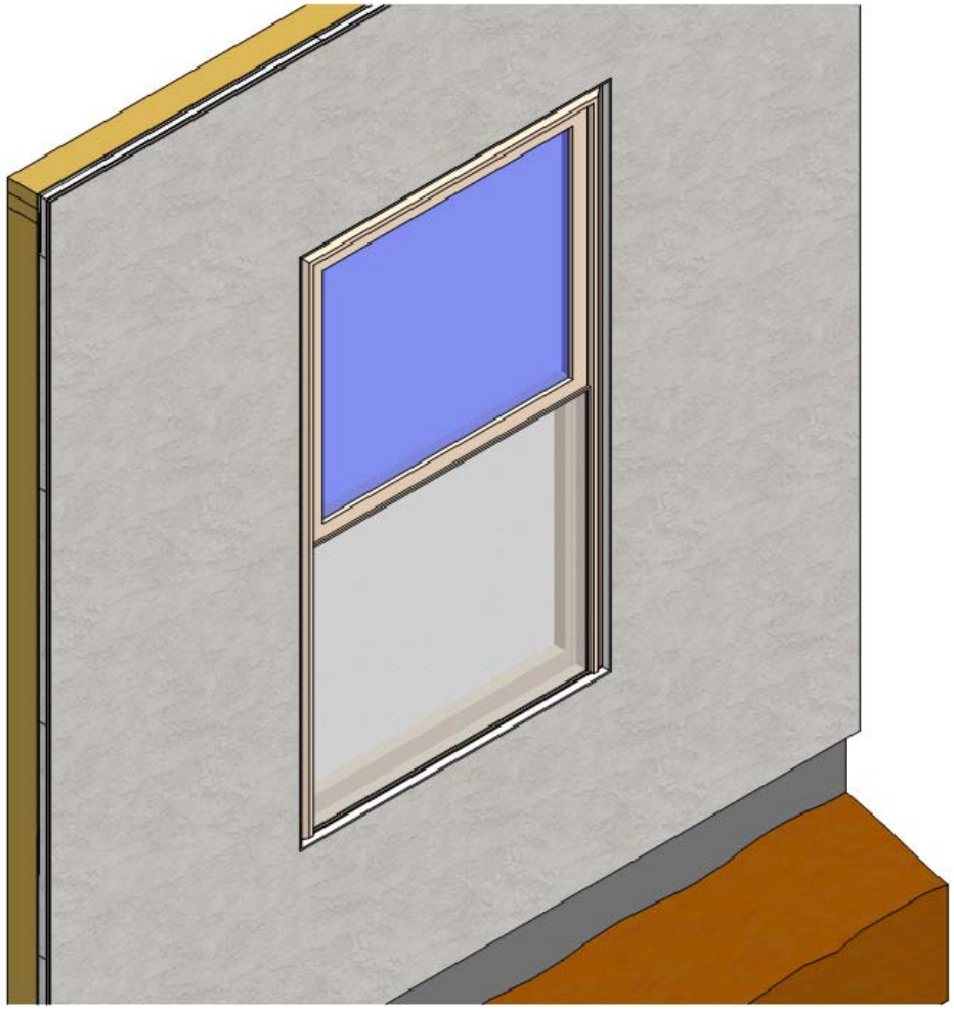
Brown Coat, Texture Coat, or Color Coat

The next layers are slightly weaker but again uniform in thickness.

The prior coat must be wet prior to application of the next coat for both suction and for maintenance of moisture for hydration.



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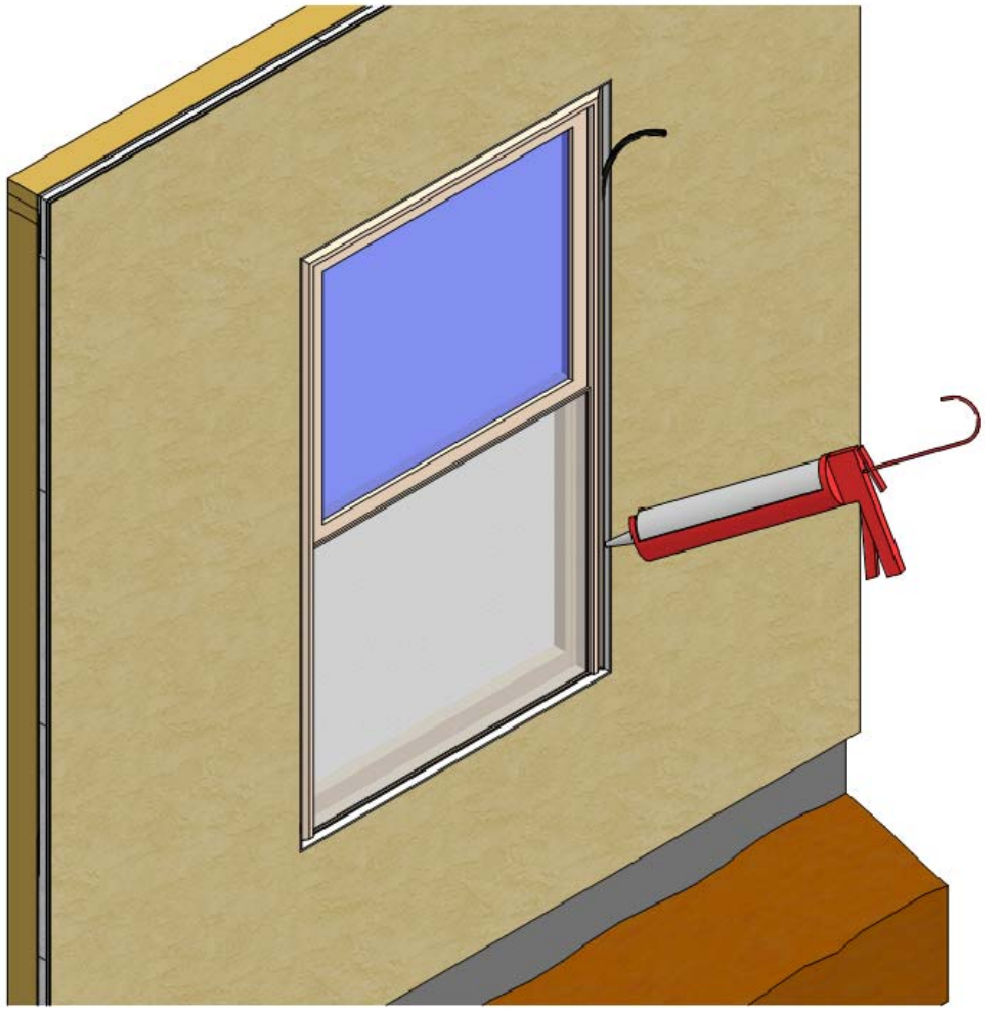
Finishing

The top coat provides texture and can either be integrally colored or can be painted to provide a variety of colors.

All systems should be completed with appropriate sealants to provide weather resistance.



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Many Substrates

Continuous OSB

- sheathing and block are two difficult substrates

OSB

- Proper gapping is critical. 1/8” or more may be required and must be in both directions

Block

- Must respect control joints and changes in mass

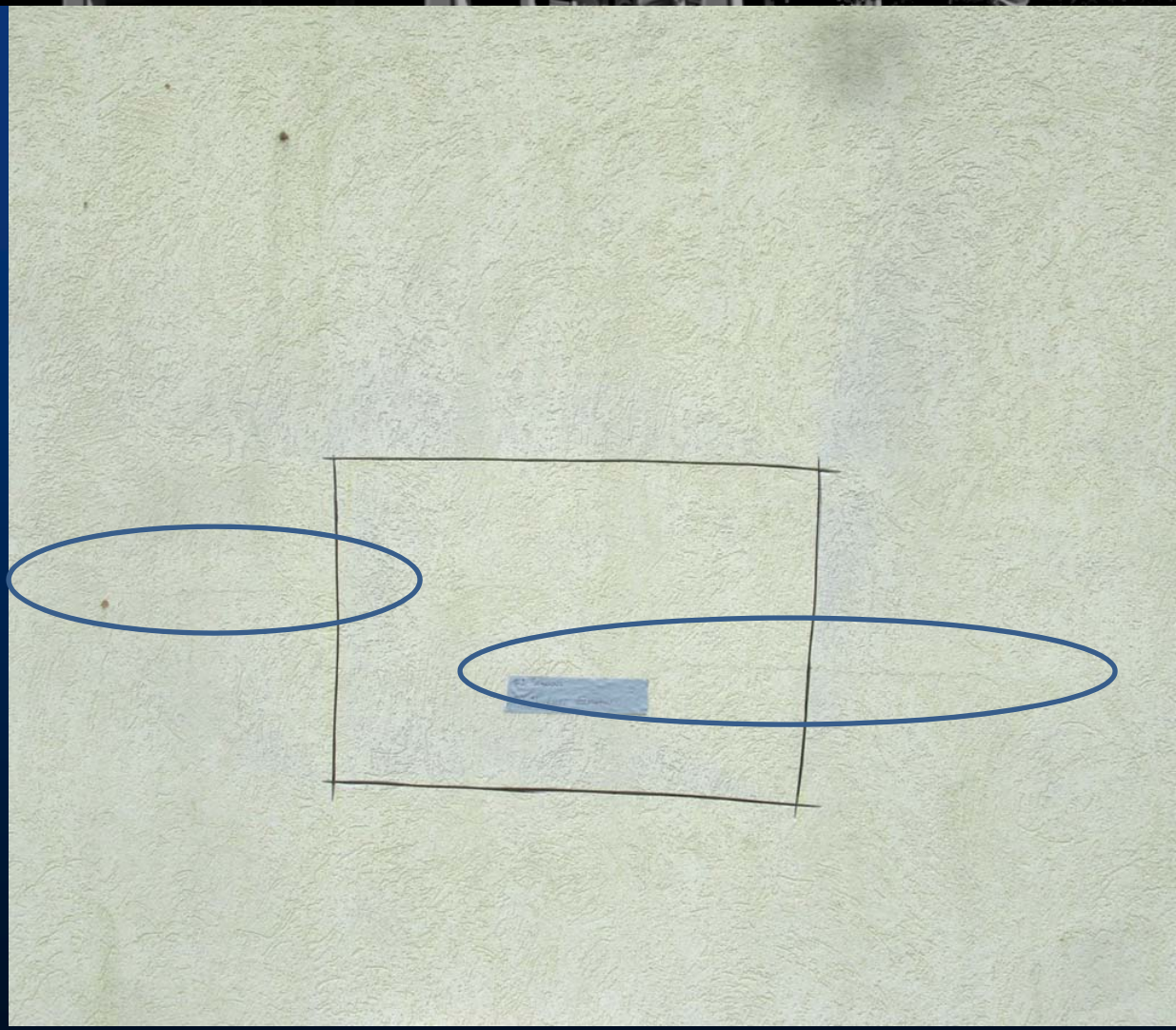
Stucco Over OSB

- Gap was not adequate
- Nailing was at half of shear schedule
- Lath was not furred or on furred nails
- Scratch coat not engaged with lath

Cracks due to OSB

Horizontal cracks

- Expansion of OSB caused a belly in the stucco and the under-nailed OSB
- Second crack was caused by the poorly bedded lath causing a change is thickness of the stucco



Lapped Lath

Three impacts of lapped lath

1. Reduction in the cross section of the cement
2. Poor consolidation or fill of intermediate space
3. Top layer of lath extends to surface creating defect location

Diamond lath at window corners can cause as many issues as it solves

One Coat Stucco Preparation

- Electric panel is on plywood backer
- Drainage plane is not in the same plane and will collect water
- Expanded foam is not tightly applied and should be filled

Three Coat Preparation

- Self furred lath is applied uniformly
- Small defects are sealed with sealant to minimize water penetration
- Good use of flashing at penetrations
- Good position of weep screed

Flashing at Penetrations

Field built or pre-manufactured?

- Integrated in shingle style
- Rubber membrane stretched over penetrations, particularly pipes, works well
- Make sure pipes slope down with positive slope

Three Coat Detailing

- Furred with spacer nails. Each nail has a fiber disc to support the lath off the paper
- Window sill flashing should integrate between two layers of paper

One Coat Detailing

Good detail at wood interface

- Ground at interface controls thickness
- Ground separates the stucco from the wood
- Ground allows space for sealant application

One Coat Detailing

Comments

- Insulation should be square at corner, not held back
- Corner bead would help in definition of corner and help control stucco thickness
- Water runs of surface of sloped weep, not really through holes

Detailing of Inset Window

Substrate must be sloped to start

- A continuous membrane is needed to carry window sill flashing to outer wall
- Do not build slope with base layer of stucco
- Corner bed will define stucco thickness
- Repair foam before lathing

One Coat Stucco

Excellent preparation

- Minimum and controlled lapping of lath
- Open end of lath tight to wall
- Staples in framing members
- Staples not over driven
- Adequate reveal at window
- Adequate space to grade

Stucco to Grade

- Stucco is a porous material with strong capacity for capillary draw of moisture
- Depending on the coating quality of the paint, water can rise as much as two feet
- Lime plaster parging was a sacrificial layer to control
- Use weep and texture coat below to create sacrificial layer

Drainage Layer Integration

- Membrane should continue behind roof framing
- Typically done with second piece of drainage plane
- Should have stucco ground at stucco return to fascia
- All wood to stucco should be primed

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Drainage Layer Integration

Flashing integration issues

- Kick out is not tall enough, this is a tile roof
- Massive sealant mess results in thin base coat and a point of water intrusion
- Poorly aligned foam at upper roof results in thin base or projection beyond roof overhang

Drainage Layer Integration

Flashing integration solutions

- Taller kick-out flashing
- Counter flashing integrated with drainage plane

- Still have issue with wood in stucco

Control Joints

- Dissimilar masses
- Dissimilar materials
- Areas over 150 square feet
- Lengths over sixteen feet
- Control joints accommodate movement in the structure and provide preferred locations for the shrinkage to be released

Design appropriate solutions

Learn from past experience.

- Cracks appear at window corners
- Two pieces now is less than a field repair latter
- Lath is continuous
- Make sure to fully work in base coat or edge of control joint could be the crack location

Design appropriate solutions

- Stucco above and lumpy stucco below
- Horizontal control joint separates three coat stucco system from direct application of manufactured stone
- Too many fasteners
- Drainage plane not continuous at bottom
- Window sill flashing draining on bond break

Stucco Mixing

- Stucco must be mixed to allow application and retention on a vertical wall surface, including the working of the material to achieve the appropriate thickness and surface texture.
- The base coat relies on adhesion and embedment in the lath, while the additional coats can benefit from suction and bond to the base coat.
- There is no standard for slump, but workability is judged by the applicator. Most production stucco companies use a proprietary mix such as Omega brand products, which include proprietary additives to help with workability and to control shrinkage.

Specific strength and thickness

- Scratch coat is to be stringer than the brown coat.
- Nominal sand
- Thickness no less than brown coat

- The same or greater sand proportion shall be used in the second coat than is used in the first coat

Base Coats[1]

Plaster mix symbols	Parts by volume[2]							
	Cementitious materials					Volume of aggregate per sum of separate volumes of cementitious materials		
	Portland cement or blended cement	Plastic cement	Masonry cement[4]		Lime	Scratch coat	Brown coat 2nd[3] coat	Finish coat[5]
			N	M or S				
C	1	—	—	—	0 – 3/4	2-1/2–4	3–5	—
CL	1	—	—	—	3/4–1-1/2	2-1/2–4	3–5	—
M	—	—	1	—	—	2-1/2–4	3–5	—
CM	1	—	1	—	—	2 -1/2–4	3–5	—
MS	—	—	—	1	—	2-1/2–4	3–5	—
P	—	1	—	—	—	2-1/2–4	3–5	—
CP	1	1	—	—	—	2-1/2–4	3–5	—

Finish Coat[1]

F	1	—	—	—	3/4–1-1/2	—	—	1-1/2–3
FL	1	—	—	—	1-1/2–2	—	—	1-1/2–3
FM	—	—	1	—	—	—	—	1-1/2–3
FCM	1	—	1	—	—	—	—	1-1/2–3
FMS	—	—	—	1	—	—	—	1-1/2–3
FP	—	1	—	—	—	—	—	1-1/2–3

[1]The mix proportions for plaster coats to receive ceramic tile shall be in accordance with the applicable requirements of ANSI A108.1 series applicable to specified method of setting time.

[2]Variations in lime, sand, and perlite contents are allowed due to variation in local sands and insulation and weight requirements. A higher lime content will generally support a higher aggregate content without loss of workability. The workability of the plaster mix will govern the amounts of lime, sand, or perlite.

[3]The same or greater sand proportion shall be used in the second coat than is used in the first coat.

[4]Additional portland cement is not required when Type S or M masonry cement is used.

[5]In areas not subject to impact, perlite aggregate shall be permitted to be used over base-coat plaster containing perlite aggregate.

Stucco Sand

The gaps between sand grains is filled by cement paste and water

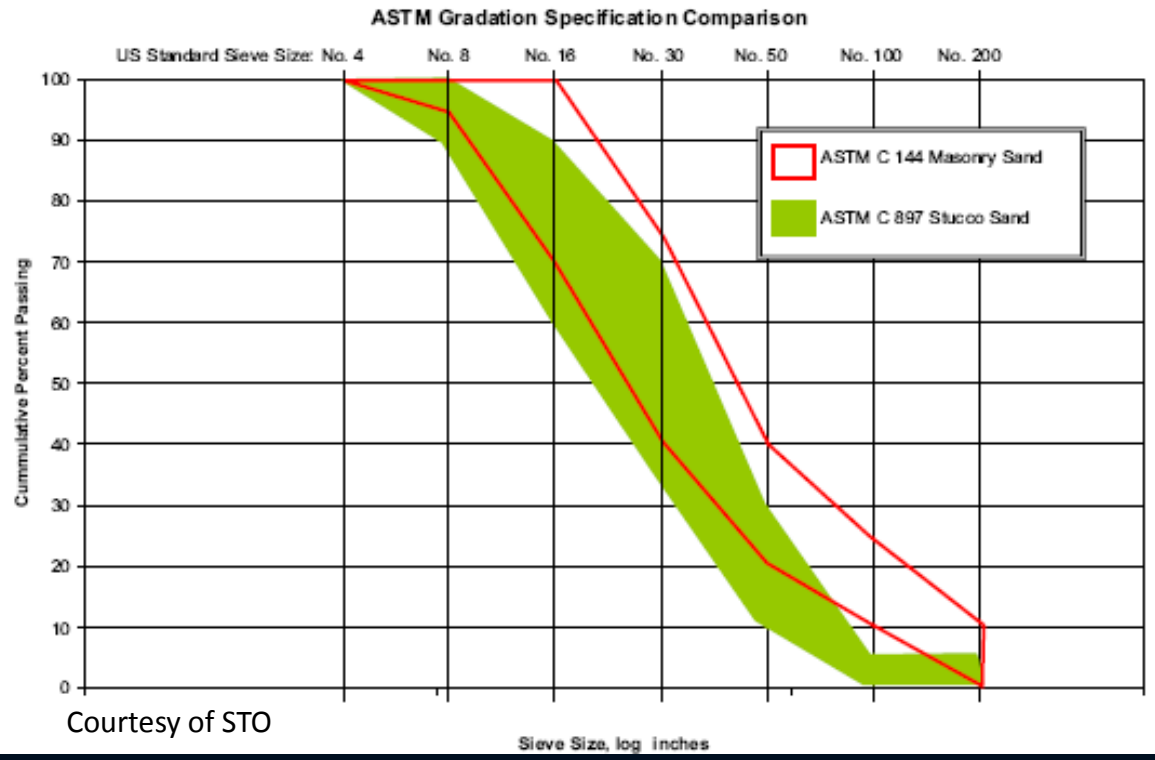
- Sand that is too course will require too much cement and water to make a workable mix
- Sand that has too many fines will require too much water because of high surface area of the sand
- Clean general purpose sand is a good choice
- Mason sand is too course

Stucco Sand

- ASTM C- 897 Stucco
- ASTM C 144 Masonry
- Masonry Sand is much more common but contains more fines and therefore has a higher water demand
- Translate higher water demand as higher shrinkage

Sand - Percent Passing

Sieve Size Inches	3/8"	#4	#8	#16	#30	#50	#100
Sieve Size Millimeters	9.51 mm	4.76 mm	2.38 mm	1.19 mm	595 µ	297 µ	149 µ
Masonry Sand	100	95-100	70-100	40-75		10-35	0-10
Stucco Sand	100	95-100	70-100	40-75			
Concrete Sand	100	95-100	80-100		30-60	5-40	0-5
Grit Sand	100	90-100	50-70	30-50	10-25	0-10	0-5



Courtesy of STO

Stucco Sand

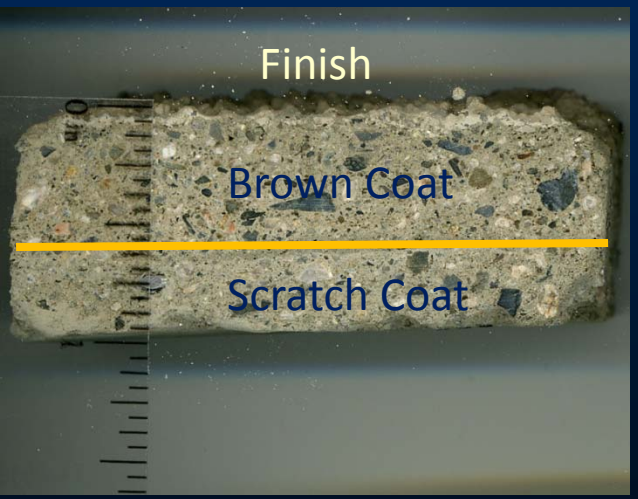
- Sand is the aggregate of stucco
- Sand must be clean and free of deleterious materials
- Sand determines workability of the stucco mix
- Sand also determines the amount of water needed to reach a good workability

Sand Storage

These are not equal sands

- Sand on the ground will have native soils mixed in
- Can require 200% more water to reach workable consistency
- The loss of water creates shrinkage
- It also reduces the paste's ability to form a consistent gel stage

Looking at Thickness



Cracking is controlled by assuring that the scratch coat is stronger than the brown coat

- Scratch coat should be thicker, marginally
- Scratch coat should be more cement rich
- Scratch coat must be hydrated to advance the cure and the shrinkage

Thickness Control

- One coat stucco is designed to be optimally applied between 3/8” and 1/2” in thickness
- Thicker brown coats will develop cracks farther apart
- Controlled cracking in a properly hydrated base coat will minimize cracking in the texture coat

Three Coat Stucco

What's wrong

1. Non uniform thickness
2. Poorly Hydrated
3. Too much water for this gun application
4. Bond break layer is visible and not patched as part of the Scratch Coat step
5. Oh yeah, it also isn't scratched horizontally

Three Coat Stucco

Diamond lath

- Staple applied with no self furring
- Two layers must both be fully bedded in scratch coat
- Rust can bleed through the stucco and stain the finish
- Oh Yeah, it also isn't scratched horizontally

Three Coat Stucco

Brown coat

- Builds out the detail of the finish
- If the scratch is properly level, the brown is uniform and approximately 3/8” in thickness

- Notice roof is fully loaded with tile

Three Coat Stucco

- Details are built over foam with Lath and full thickness stucco

Or

- Foam plant-ons can be applied and finished with just a thin finish layer

Hydration

All cement based construction must be maintained in a wet condition in order for the cement to build strength

- Depending on conditions, a stucco layer must be wet at least once a day
- Note dark edges vs. light field, indicating poor thickness control and poor wetting

Ready for Paint?

Hydrated cement will become more neutral in pH

- Latex based paint is attacked by Alkali environments
- Acrylic paints are more resistant, but will not stop poorly hydrated stucco from showing efflorescence
- The only way to know is to test

Testing for pH

pH strips are most accurate but least convenient

- The goal is to be less than pH 9
- Early on pH will test at up to 12

- Testing must be done on fully wetted area
- The surface of the stucco will carbonate and show a false neutral

Paint Burning and Efflorescence

Areas of water concentration will activate uncured stucco.

This is not water from the ground, but infiltrating water from poor roof detailing

In some cases, poor paint allows water to enter through holidays

Detailing

- Projections of stucco can pick up concentrated flow off roofs
- Even well executed stucco can not survive concentrated wettings

Detailing

Foam plant on

- Adhered with adhesive mortar over a full base coat of 3/8” stucco
- Note: wall texture is a skip trowel, plant on finish is brush applied thin coat finish

Clearance to weeps

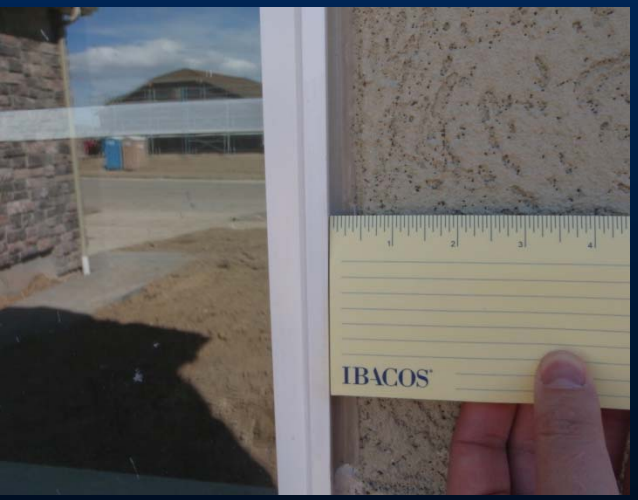
- Note 1” drop to trim and no stucco in weeps

Detailing

Many windows are not dimensioned for stucco

- Brown coat should be held back to allow finish to be flush
- This detail will allow water in through dissimilar materials
- Better detail is to use a ground and sealant

Detailing



Stucco ground is used to provide:

- Thickness control for brown coat
- Keying for edge of stucco
- Space for backer rod
- Clean edge for sealant

- Ideal dimension is 3/8” wide and 3/16” deep

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The Inherent Risk of Going Green

Graham Davis

IBACOS®
| Home Quality + Performance |

Graham Davis

- IBACOS
  - Building Performance Specialist
- John Laing Homes
  - Quality Assurance Manager
- Quality Built
  - Training Program Manager
- Habitat for Humanity International
  - Senior Technical Advisor
  - National Green Building Program Director

And…

- Who are you?

Preview

- Green building is entering a new era
- The history behind the challenges
  - What do builders really understand about green building?
- What are the risk in transitioning into becoming a green, high performance homebuilder?
- What are buyers expecting?
- How does this transition affect the trades who build the homes?
- 10 Steps a company must do to transition into being a high performance homebuilder?

A New Era of Green Building

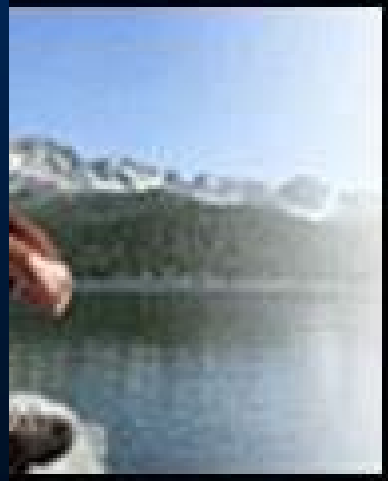
As a movement, green building began with a handful of tree huggers in the early 70's who felt the pressure to move the world to a more environmentally friendly place.

A New Era of Green Building

By the 80's a few visionaries were building test tube homes for the very brave.

A New Era of Green Building

In the 90's the EPA jumped on board and the Energy Star program was born.



A New Era of Green Building – The Production Builder

The new century has ushered in a maturing green building era where large scale production builders are coming on board.

Tackling the Challenge

The question we're addressing is:

What issues must a production (or any) builder be aware of when transitioning into becoming a green, high performance homebuilder?

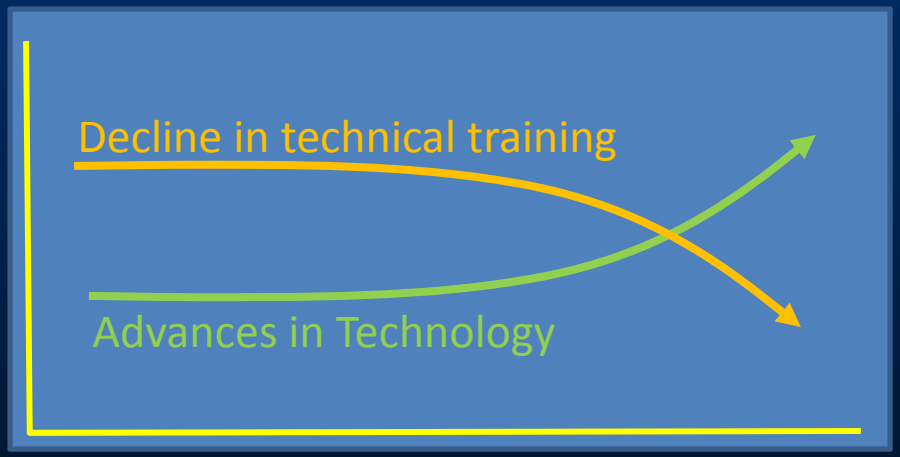
The History Behind the Challenge

- In the world of production manufacturing, home building is very unique.
- The top three driving forces in home construction:
  1. Location
  2. Floor plan
  3. Dollars per square foot

  4,5,6…Somewhere down the list you will finally come to building performance.
- For decades, the industry could get by with building fast, poor performing homes that were pretty and sold quickly.

The History Behind the Challenge

While there have been significant advances in residential components in the last decade or two the technical training level of residential construction mechanics has been on the decline.



Mind you, this is only this presenter's opinion as one who has been engaged in the industry in a "hands on" capacity for nearly 30 years.

Reality Check

"It is possible to be a high quality builder without being green builder, but you can't be green if you're not a high quality builder."

Author unknown…but we say it a lot around IBACOS!

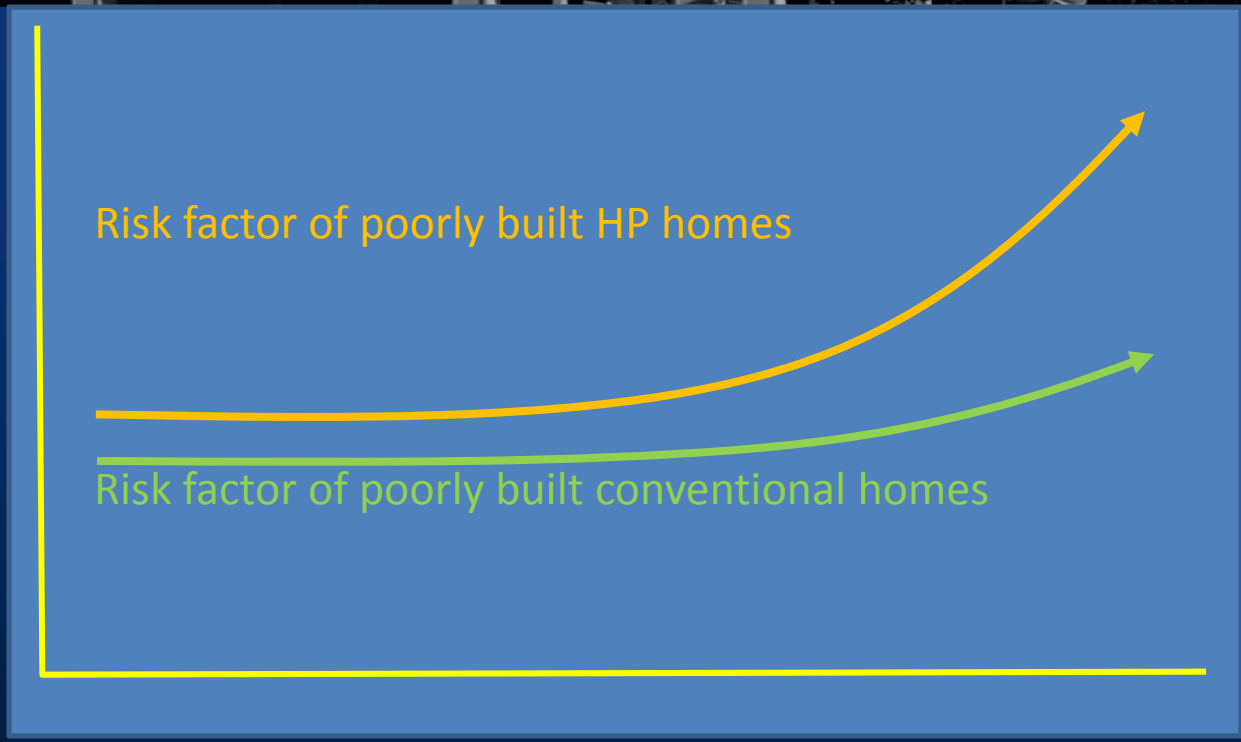
This Has Created a Wake Up Call!

As a result of the green building movement, production builders are waking up to the fact that the challenge to “go green” will require more than a simple technology swap.

Conventional Practice

One of the greatest risk of going green without first going high quality is

BUILDING PERFORMANCE TOLERANCE



Conventional Practice

Conventional Construction

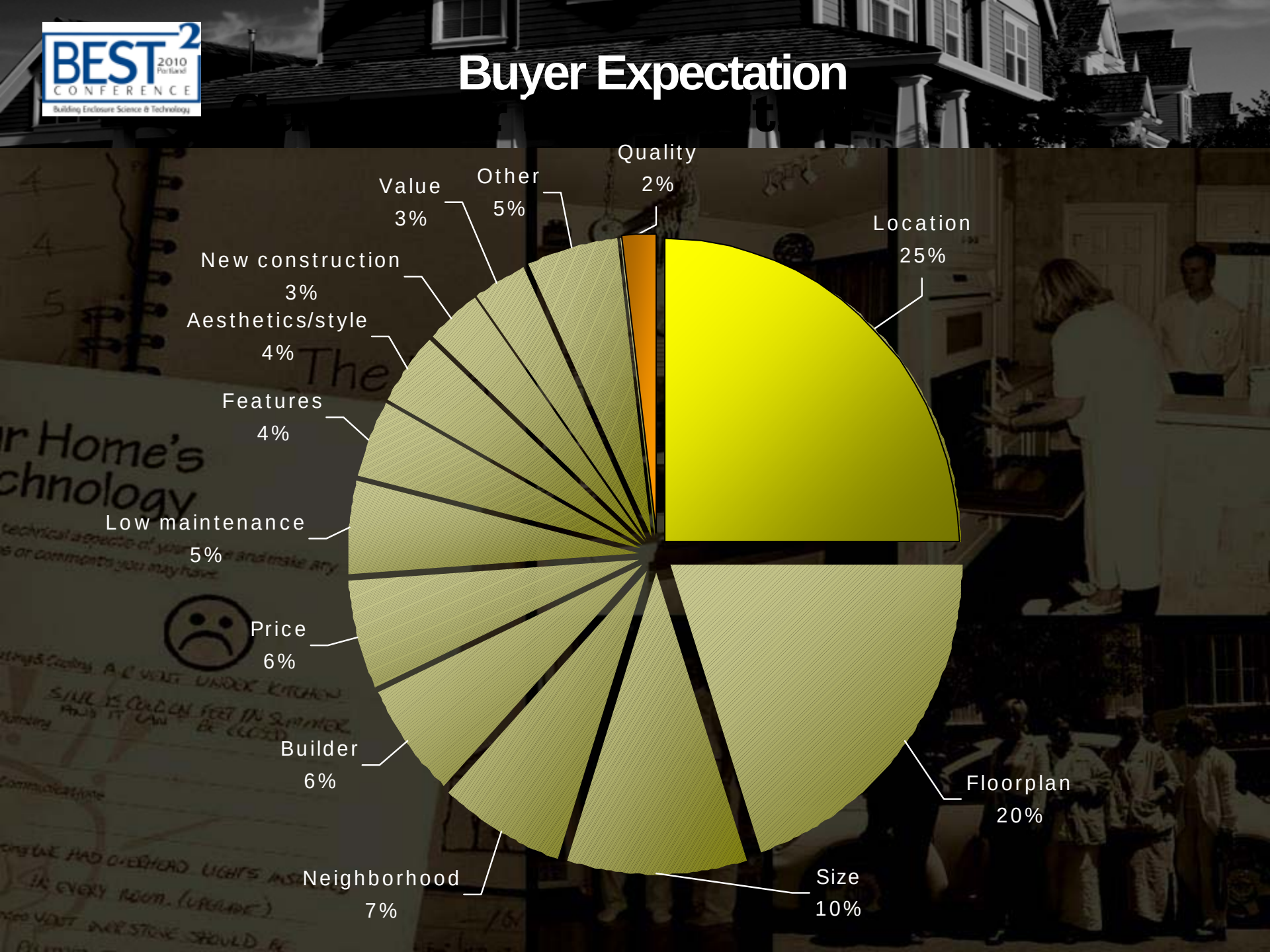
- Looser enclosures may:
  - Increase drying capacity of wall systems
  - Reduce potential for high concentrations of contaminants
- Lower owner expectation
  - Comfort levels
  - Utility consumption
  - Higher maintenance expectations

High Performance Building

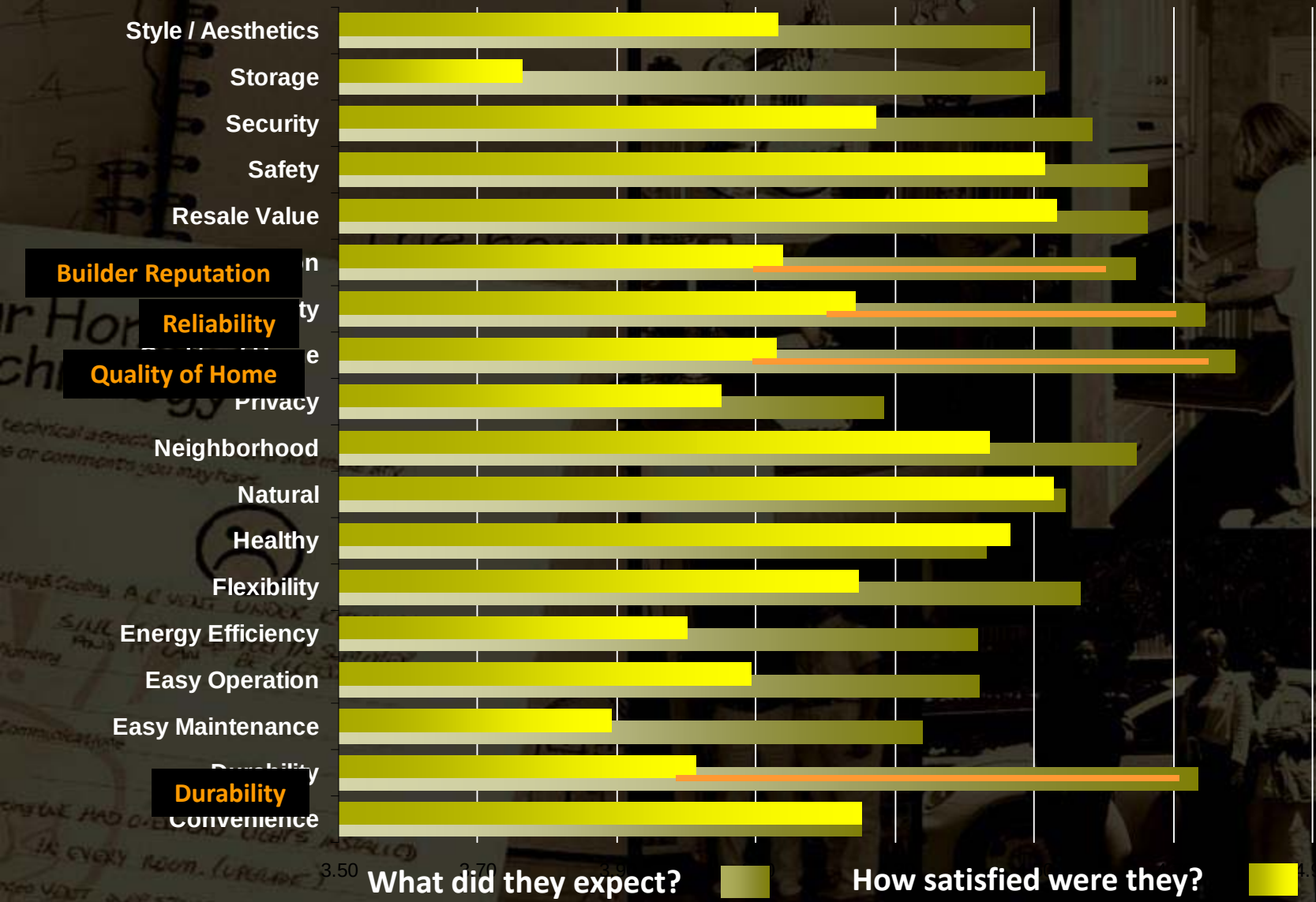
High Performance Construction

- Less room for error in wall systems performance
  - Reduced drying capacity of wall systems
  - Increased potential for high concentrations of contaminants
- High homeowner expectation
  - Stricter comfort levels
  - Lower utility consumption
  - Lower maintenance expectations

Buyer Expectation

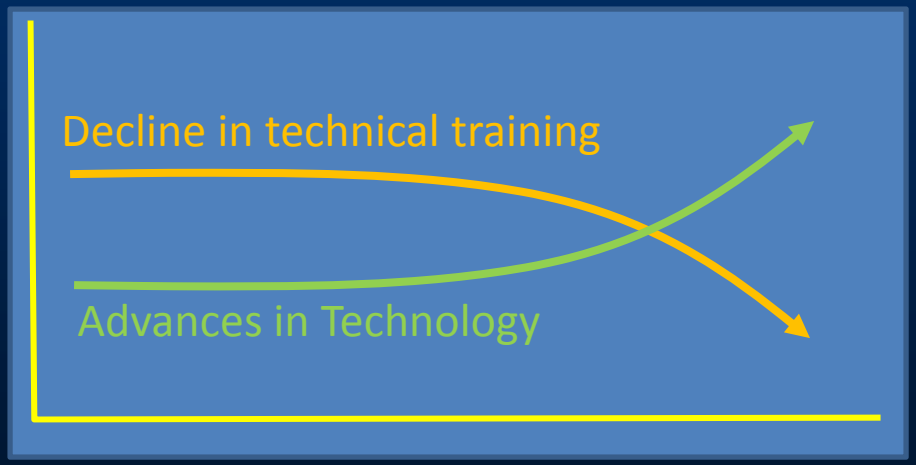


Homeowner Expectation



The History Behind the Challenge

It has been this order of market priority that has driven builders to allow for the decline in maintaining high **Quality Managed Systems** in the building process.



Traditional Operations vs. QMS

- When demand for high quality has been the driving force in any manufacturing process, there are tools and processes developed to ensure quality is being done.

- Since this demand has been low on the radar for residential builders, these tools and systems have been lacking.

Why?

- It’s so easy to hide our mistakes and poor workmanship!

Traditional Operations vs. QMS

- Processes to examine:
  - Initial design
  - Plan sets and details
  - Optimized value engineering
  - Purchasing
  - Construction
  - Trade training
  - Quality standards & quality control
  - Inspections

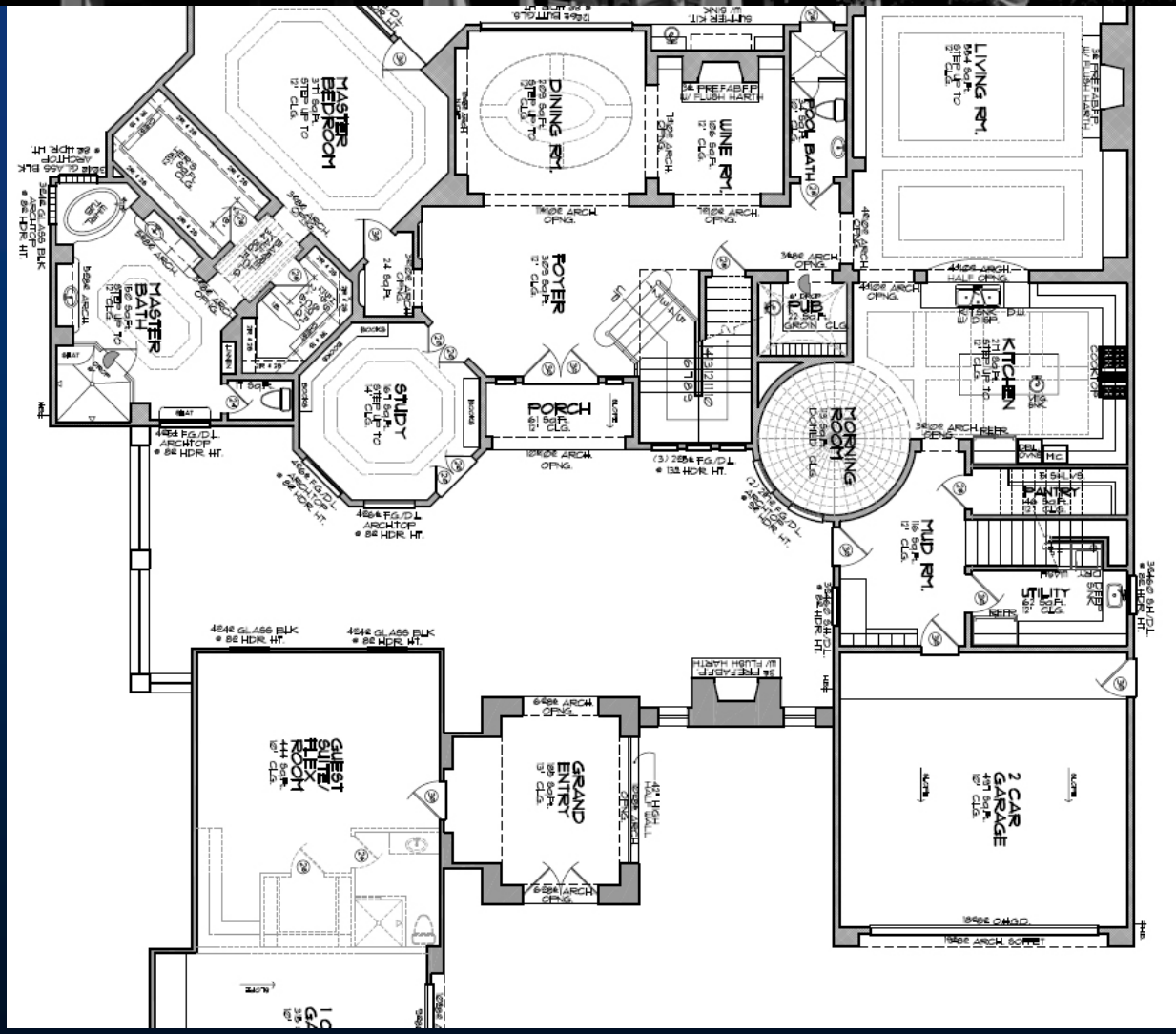
Design

Form Follows Function?

Systems Integration?

Optimized Value Engineering?

These terms have gone begging in residential home design.



Design

- Too often the design charette starts with the criteria:
  - What is the developer mandating?
  - What does market research say the buyer is looking for?
  - What “base” home features can we afford offer?
- A layout is then established followed by a variety of elevations.
- Somewhere around 50% plan completion, someone suggest they do a “value engineer” session.

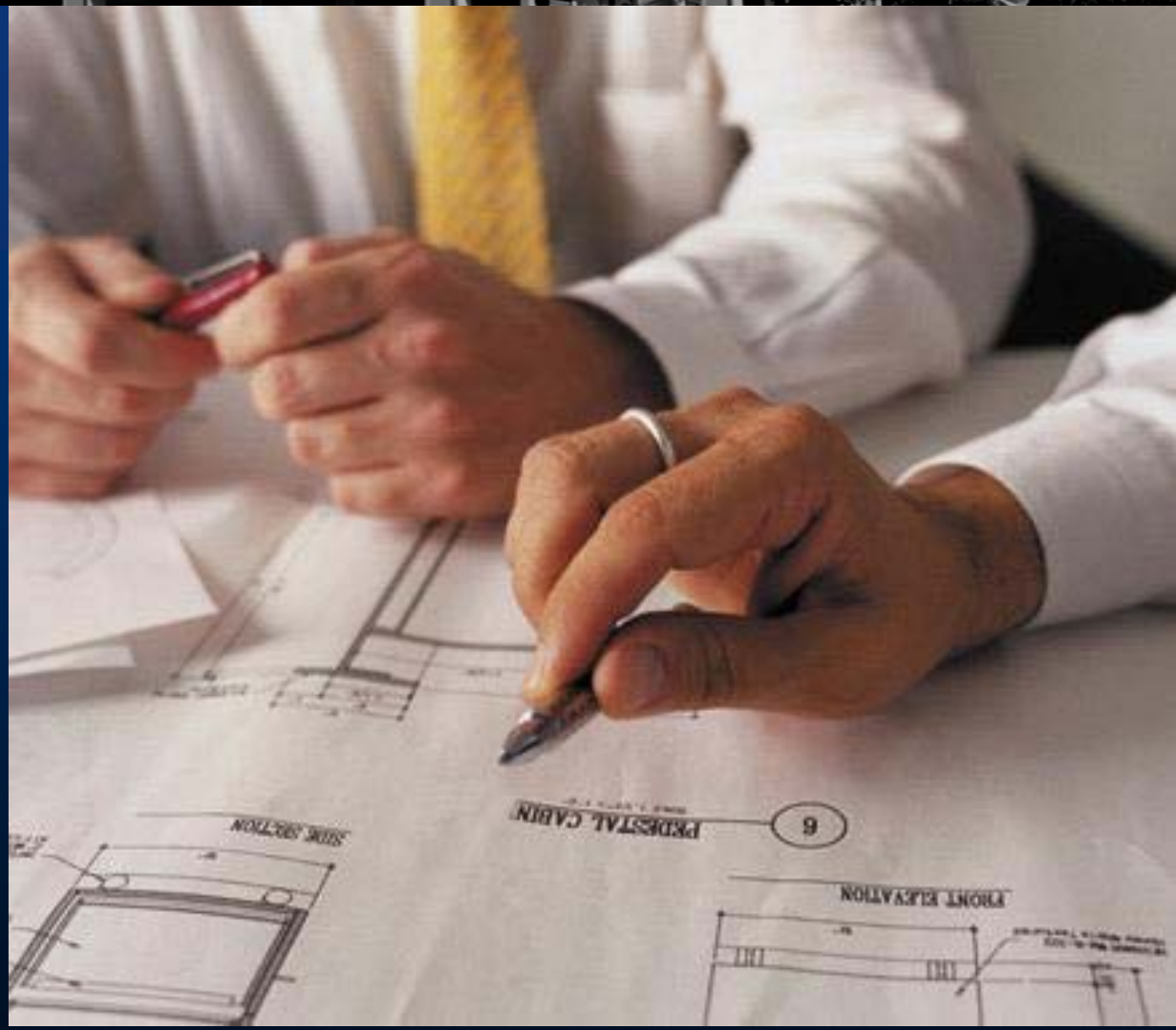
Design

- Before the design considerations on the previous slide, start with this criteria:
  - What are our performance objectives?
  - What is our personal “building code of ethics”?
    - The common construction practices that we know will fail.
    - The best practices that create a home we are confident in.
  - What performance systems do we believe in and what design considerations will ensure their proper operation?

Design

How early in the design process do the critical trades get to provide input?

Once the “Building Code of ethics” has been established, there is much less to fear.



Systems Integration

A building code of ethics could include things like “We will not install open combustion equipment inside the living space.

Especially when there will be an industrial range hood nearby!

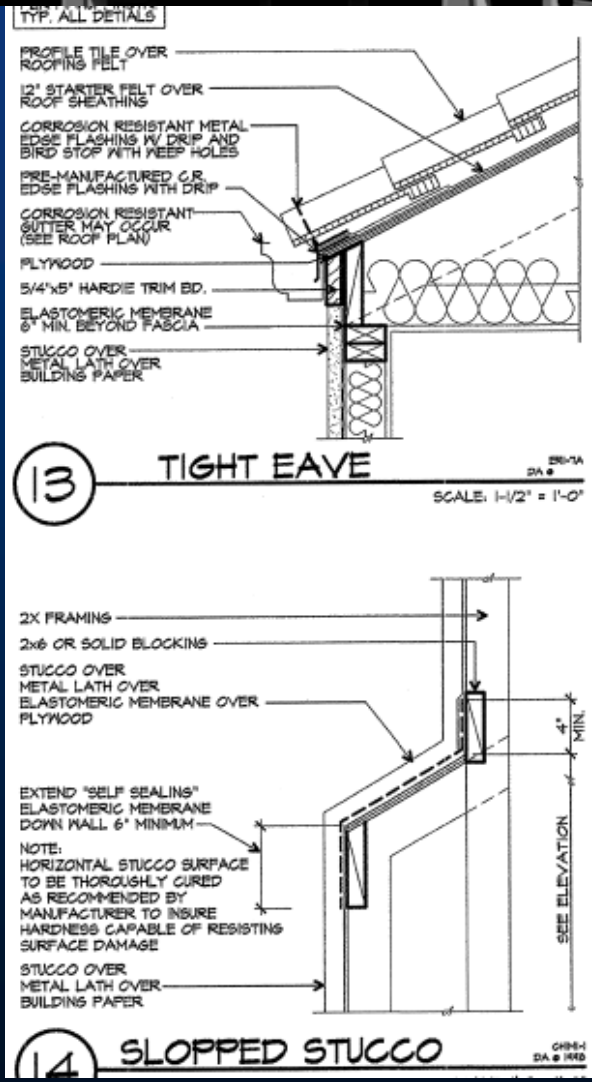
Plans

What is a “complete set of plans”?

How much information is left out?

Trades often simply follow “standard practice”.

But in many cases, a high performance home isn’t built according to “standard practice”



OVE

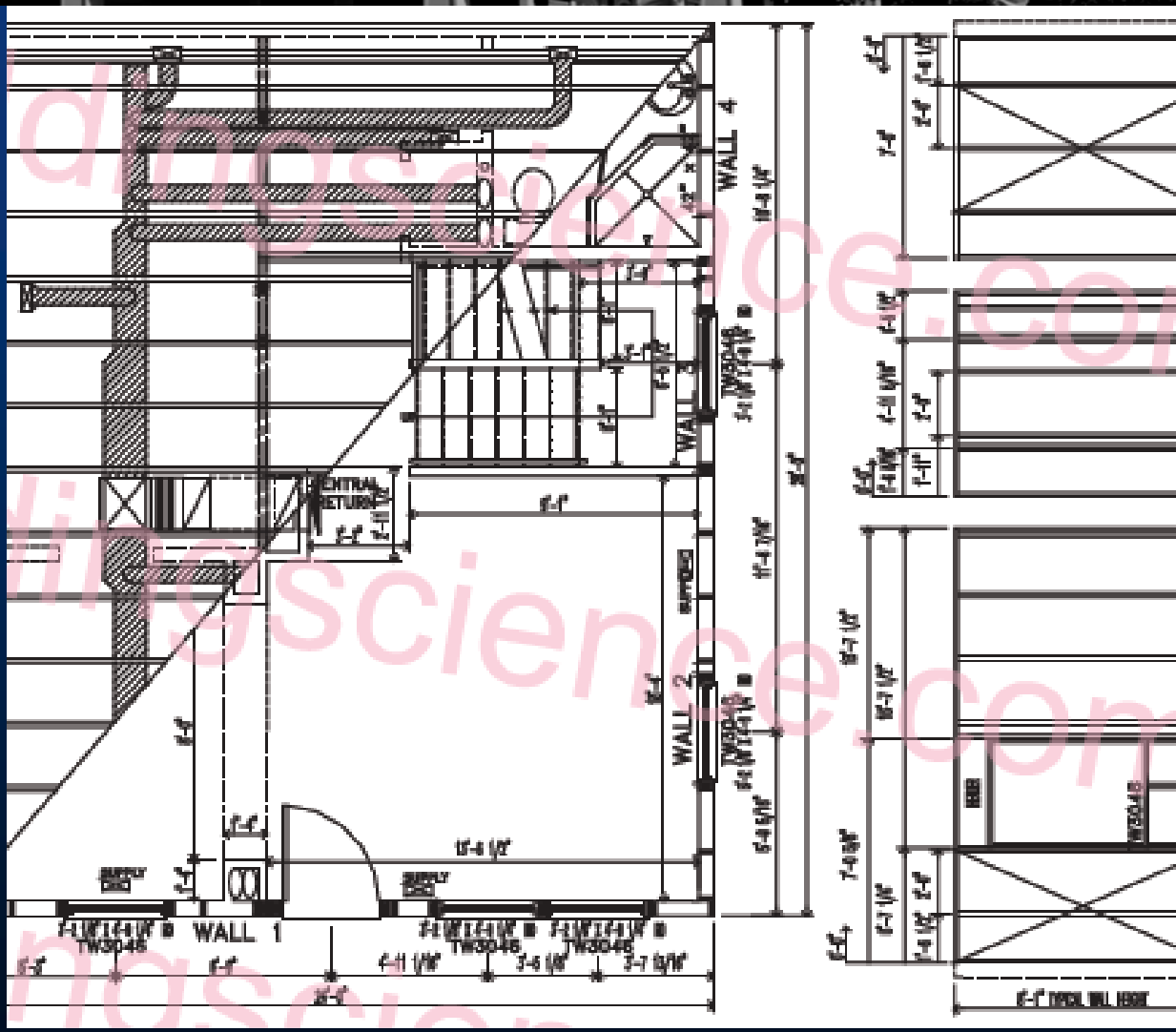
A green home is first and foremost an energy efficient home.

But it is also a material efficient home.

Homes must be designed with materials in mind.

OVE

Truth is that one of the risk in going green by applying OVE methodology is the builder may save a ton of money!



OVE

That and…

There won't be as many leftovers when the house is finished!

And we know how much builders love leftovers!

Purchasing

The demand for the most square footage for the least amount of money has played a huge role in the decline of quality.

Purchasing

- “Spec and purchase” design must fall to the wayside when transitioning to high performance building.
- It has contributed to such issues as:
  - Incomparability of materials that were bonded together.
  - Incompatibility of systems that share the conditioned space.
  - Installation of equipment that doesn’t perform the service it was intended to perform.
  - Early equipment failure and warranty issues.
  - General “jury rigging”

Purchasing

- In most cases, penny pinching simply replaces sound, well thought out design decisions with cheap materials and installation.
- Often, it isn't much of a challenge to find an extra $1000 laying around in poorly thought out residential design and construction process.

Construction

If we didn't get it right on paper, there is no logical reason to assume we will get it right in the field.

This reality becomes accentuated when building high performance homes.

Construction

Leaving detail decisions to the trades will often result in an attractive but dysfunctional product.

Construction

- Systems integration is not a concept that most component installation mechanics grasp.

Construction

Systems integration is often easier and definitely cheaper to work out on paper than in the field!

System Integration

This detail never appeared on any plans.

How will the framer incorporate this window buck?

Why did this installation happen in the first place?

Training

- Why has trade training suffered so much?
  - **Greed?** In pursuit of higher margins, builder's put the squeeze on labor cost.
  - **Foreign labor?** This adds a layer of cultural and communication barriers.
  - **Turnover?** Are the days of mentor and apprentice past?
  - **Highly specialized trades?** This adds to a lack of system integration understanding.
  - **Attitude?** As builders have become investors and trades become syndical have they lost their sense of craftsmanship?

Training

Whatever the case, the high performance, green home builder must be ready to tackle this issue.

Training the trades will have to begin with the builder's initiative.

Training

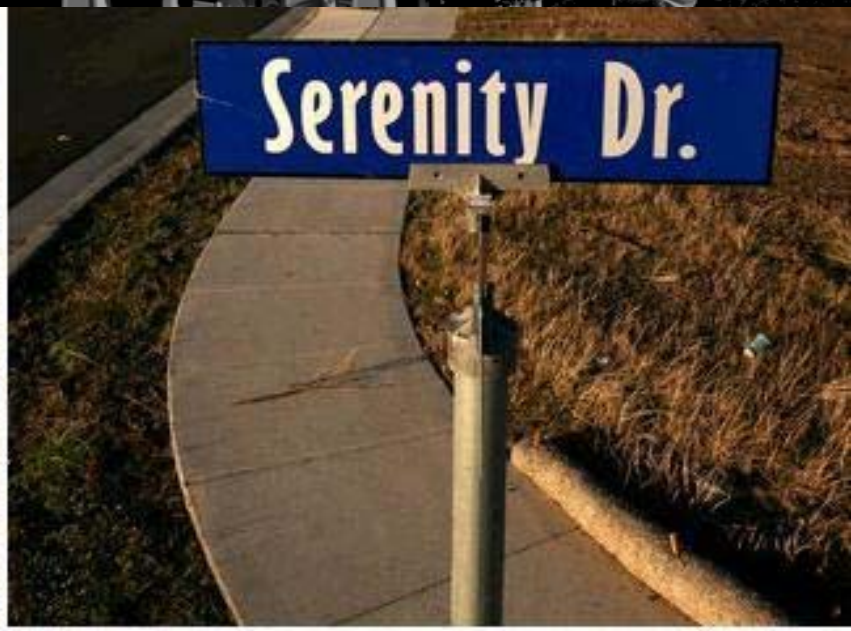
What happens on the ground and down the road will always come back to the builder.

An Opportunity for Change

The old industry process models “worked” in an economy where builders were selling homes as fast as they could build them.

An Opportunity for Change

Those days are gone and may never return.



We're in a New Era

Can you remember a better opportunity for change in the history of modern American home building?

Summary

- The great risk a builder takes in transitioning from the conventional to high performance green building is in thinking that the only thing that needs to change is the product.

Summary

Albeit simplified, here is the path to becoming a high performance home builder…

#1 Make a Decision

Make some difficult choices about what kind of builder you want to be.

#2 Establish a New Culture

Establish and cultivate a culture of quality in your organization.

Make it clear to everyone, that producing a high quality product is your first priority.

The Quality Goes In Before the Name Goes On

- Zenith

#3 Evaluate Your Process

Take a thorough look at how your business operates.

What works?

What doesn't?

Where are time and money wasted?

#4 Establish Your New Standards

Define the quality and performance standards for your product.

Create your companies “building code of ethics”.

Rebuild your scopes to truly define your product and use them to train your trades.

How far can you push the envelope?

#5 Evaluate Your Current Product

Perform a thorough evaluation of what you are currently building.

How does it compare?

How far off your new standard are you?

#6 Start with a Fresh Design

The best place to start building a high performance home at design stage.

Present your new quality standards and building code of ethics to your trades and let them in on the design process

…early!

#7 Establish Quality Control

Create new internal quality control processes that involve everyone at every level.

Develop Superintendents to truly know quality.

Develop partnerships with trades that practice internal QA control and are accountable.

#8 Measure and Monitor

Participate in performance certification programs.

Utilize third party certifications and quality assessments.

Never stop improving the product.

#9 Sell Your Product

Build your marketing strategy around high quality and high performance.

Educate your sales staff on how to sell things besides finishes.

#10 Transform Your Market

Be the builder that sets the standards for your market.

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CONFERENCE
Building Enclosure Science & Technology

Questions?

Graham Davis, IBACOS
gdavis@ibacos.com
www.ibacos.com

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Heating and Cooling

Selecting, Sizing, and Installing for Comfort (Part I)

Brad Oberg, Chief Technology Officer, IBACOS

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Air Distribution System Design

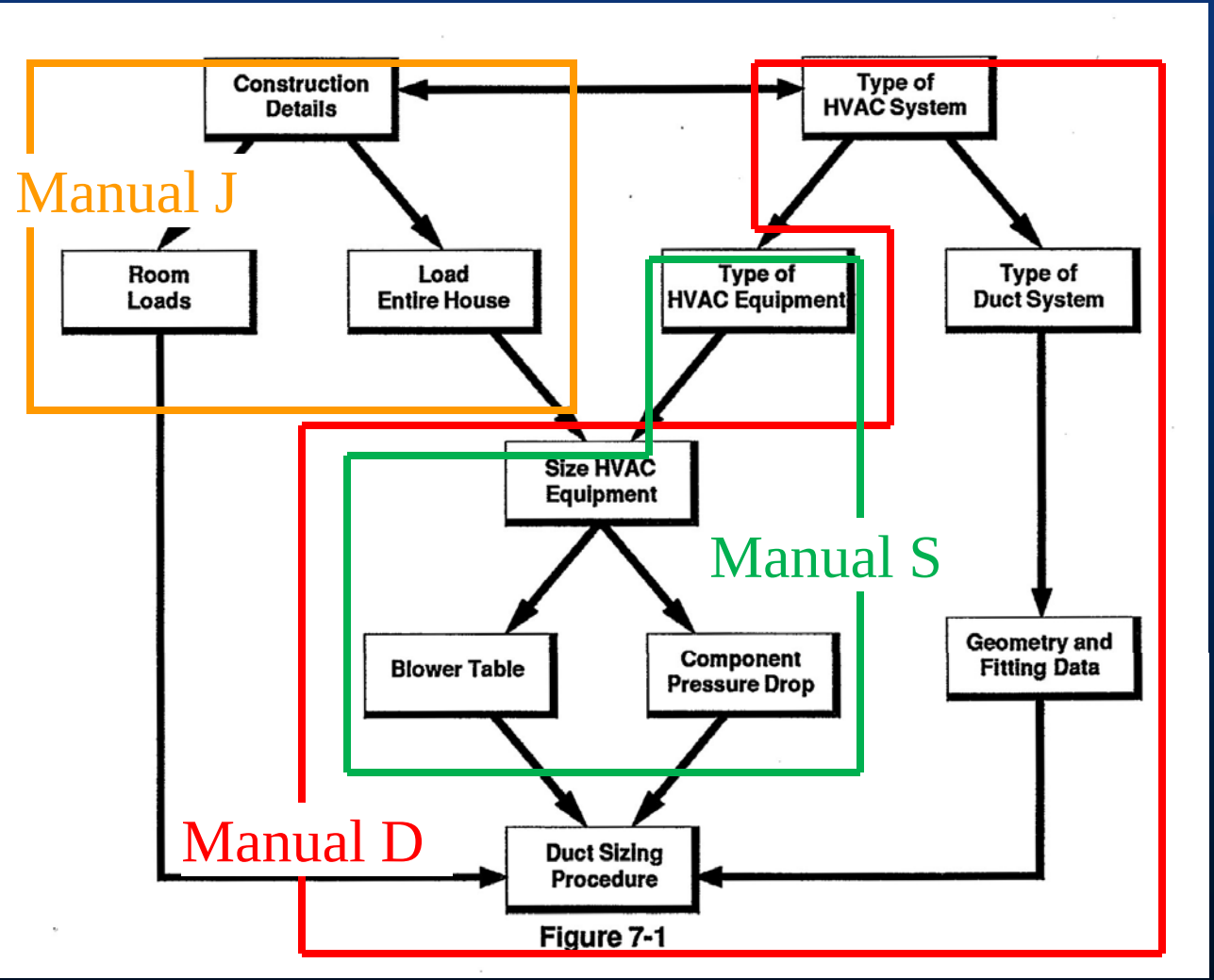

Figure 7-1

Images courtesy ACCA

Code Homes vs. High Performance

- Better Windows
- Tighter construction
- Higher R-Value
- Tighter Ducts
- Ducts in conditioned space
- Insulated crawls and basements

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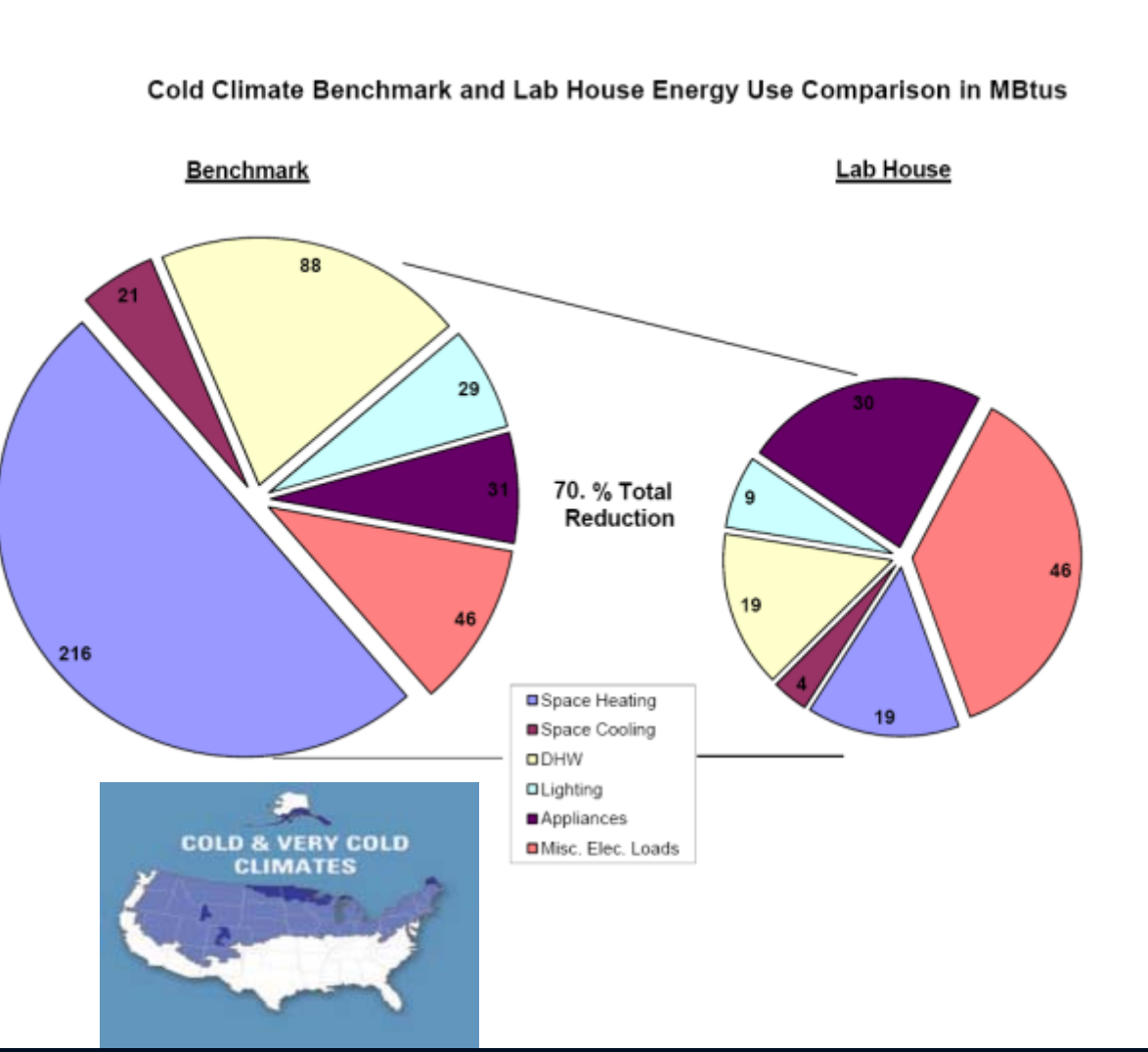
Energy Code Changes

IECC 2006 and IECC 2009						
Climate Zone	Minimum Insulation R-value					
	Ceilings	Walls IECC 2006	Walls IECC 2009	Floors	Basement Walls[2]	Crawl Space Walls[2]
1	R-30	R-13	R-13	R-13	R-0	R-0
2	R-30	R-13	R-13	R-13	R-0	R-0
3	R-30	R-13	R-13	R-19	R-0	R-5\R-13
4 except Marine	R-38	R-13	R-13	R-19	R-10\R-13	R-10\R-13
5 and Marine 4	R-38	R-19 or R-13 + R-5[1]	R-20 or R-13 + R-5[1]	R-30	R-10\R-13	R-10\R-13
6	R-49	R-19 or R-13 + R-5[1]	R-20 or R-13 + R-5[1]	R-30	R-10\R-13	R-10\R-13
7	R-49	R-21	R-21	R-30	R-10\R-13	R-10\R-13
8	R-49	R-21	R-21	R-30	R-10\R-13	R-10\R-13

Cold Climate

- Large variances of rain, temperature & geography
- Lots of basements and crawl spaces
- Lots of moisture stresses
- Forced air systems – metal ductwork
- Chicago, Denver, Minneapolis, Pittsburgh, Indianapolis



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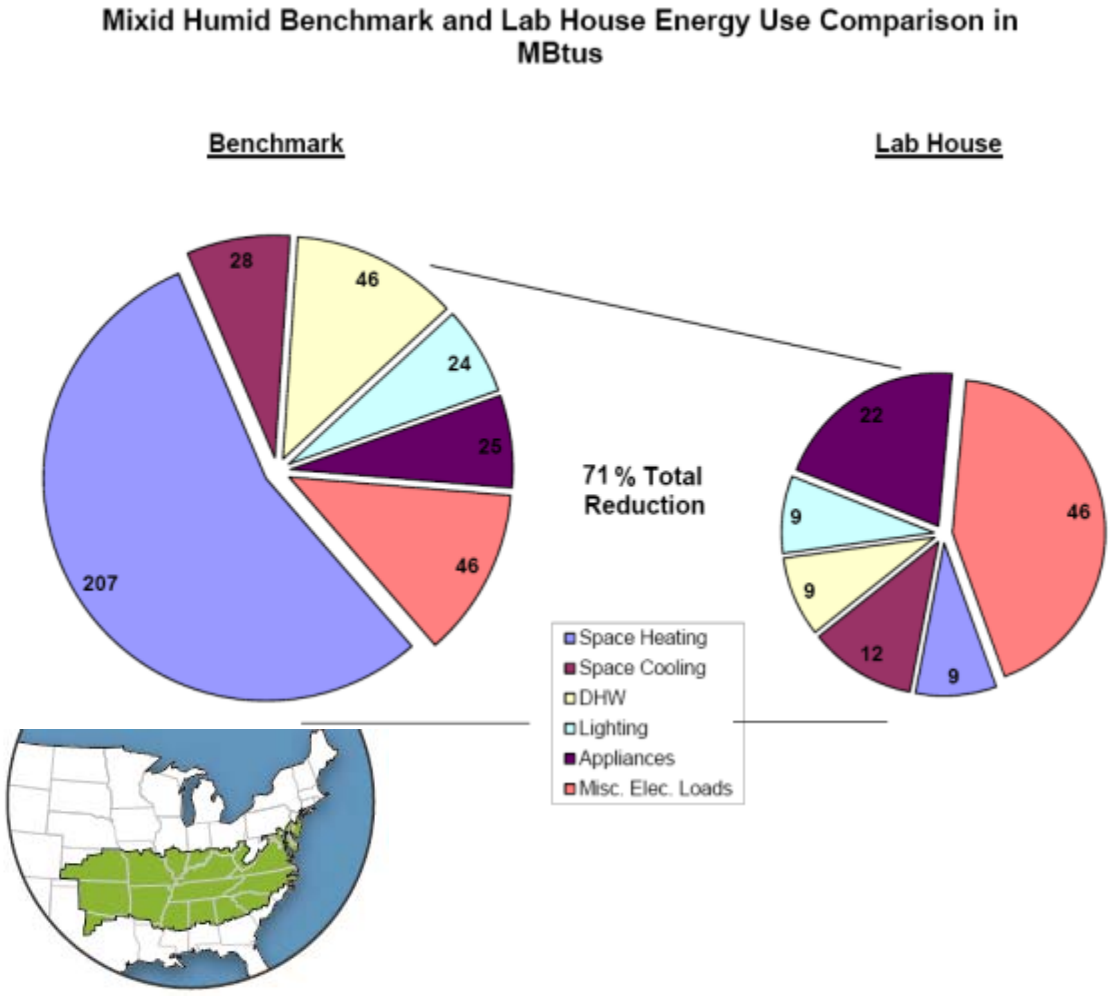
Mixed Humid

- Similar variances of rain & temperature
- Large variances of elevation
- Basements and crawl spaces
- Lots of moisture stresses
- Heat Pumps - Forced air systems – flex duct
- Charlotte, Atlanta, Louisville, Dallas



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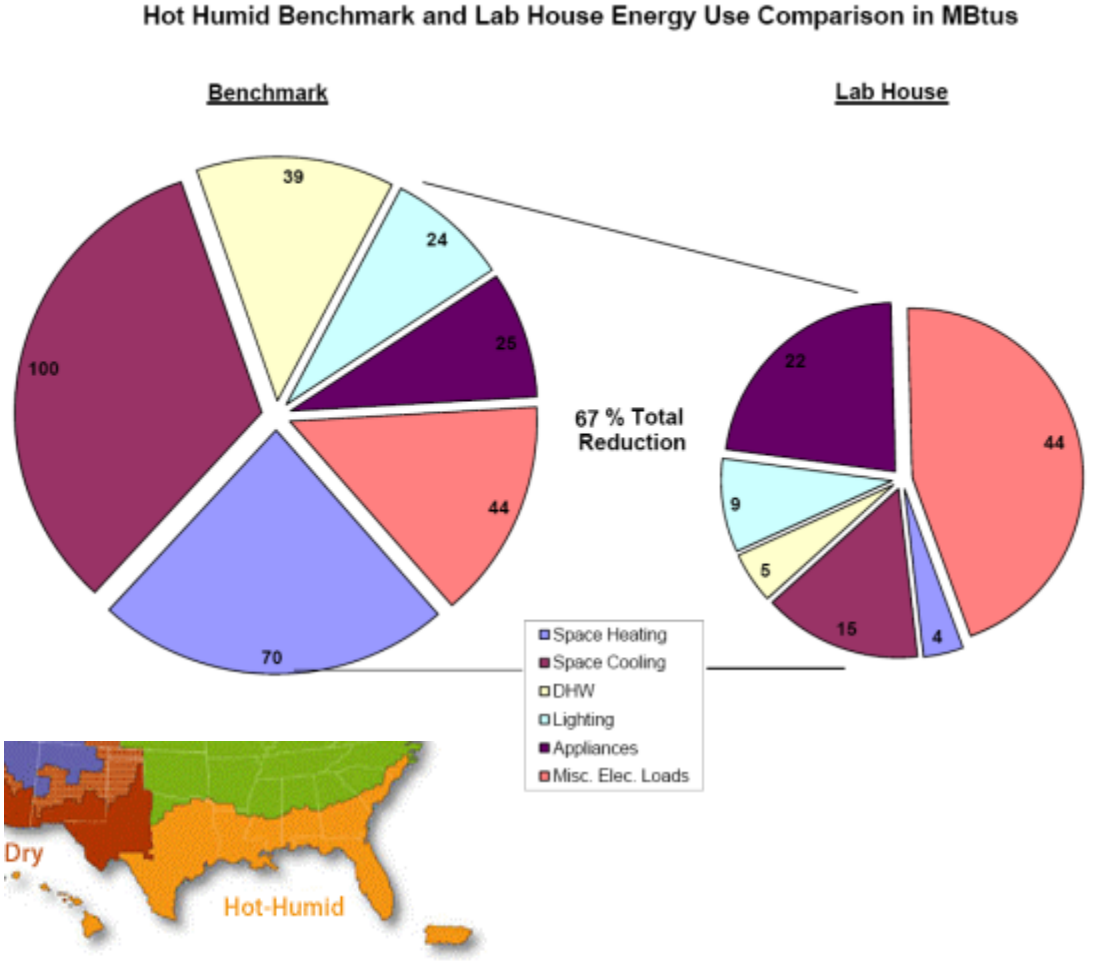
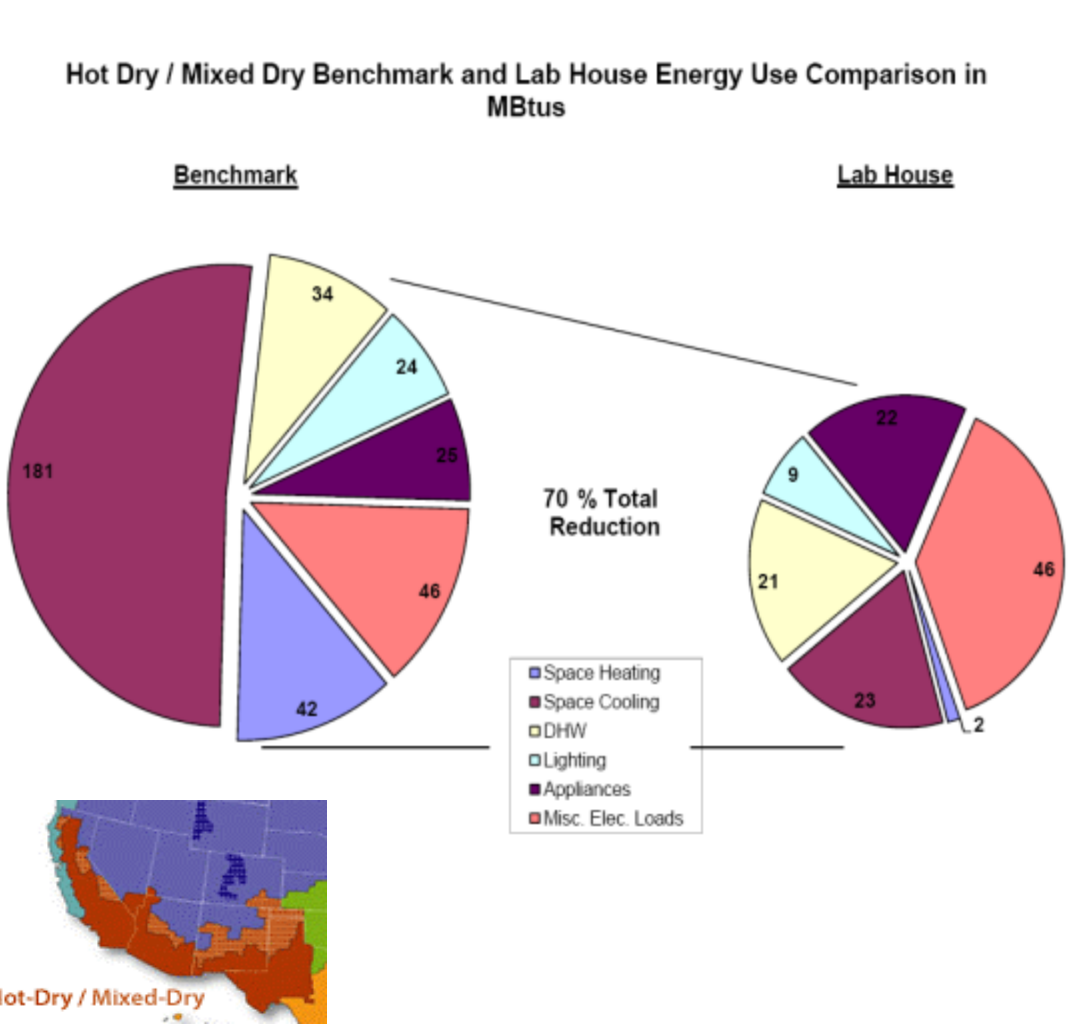
Hot Humid

- Intense solar load
- Moisture a challenge
- House types and styles vary greatly
- AC almost always installed
- Heat pumps - forced air systems, flex duct
- Houston, Orlando, West Palm, Atlanta, New Orleans



Hot Dry/ Mixed Dry

- Intense solar radiation
- Avg. rainfall of <20”/yr, but can receive large quick rain amounts
- Improper irrigation techniques can lead to moisture problems
- Slab on grade construction
- Mixture of exterior finish products – stucco predominate
- Tucson, Sacramento

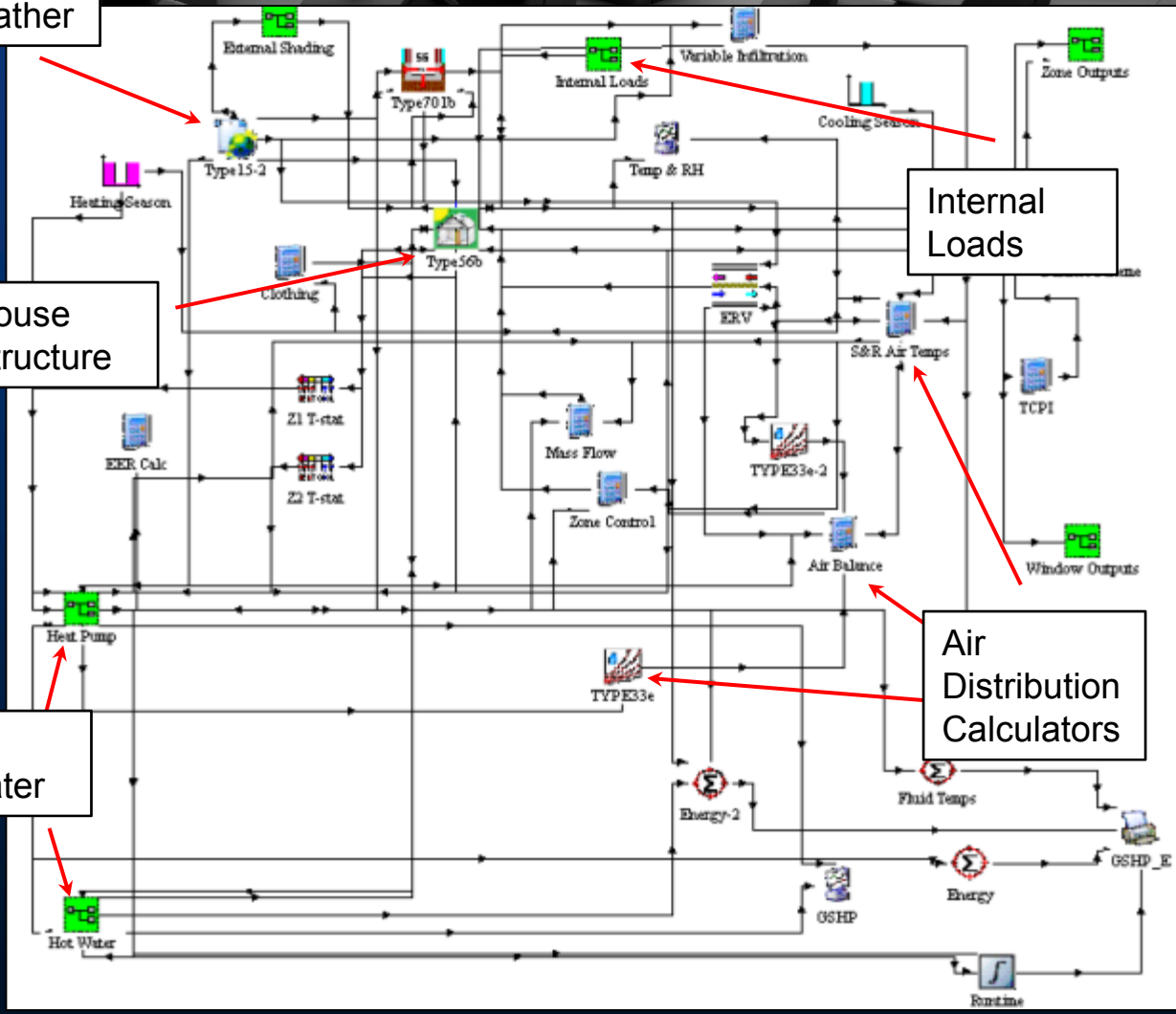


Comfort not Energy Cost

- Air temperature
- Air Velocity
- Radiant Temperatures
- Humidity
- Clothing
- Activity

Detailed Modeling with TRNSYS

- Provides more accurate modeling of sub-slab insulation systems, staggered stud wall systems, complex foundation wall systems
- Performance maps for window glazing provide detailed performance information



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TCPI – Air Distribution

Thermal Comfort Performance– Monthly Room-by-Room TCPI
No Seasonal Adjustment, Single-Zone Control, Manual J Method

Hours	Days	Months	Z1_TCPI	Z2_TCPI	Z3_TCPI	Z4_TCPI	Z5_TCPI	Z7_TCPI	Z8_TCPI	Z9_TCPI	Z10_TCPI	Z11_TCPI	Whole House
744	31	Jan	1.00	1.00	1.00	1.00	1.00	0.97	1.00	1.00	0.54	0.91	0.94
672	28	Feb	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.73	0.99	0.97
744	31	Mar	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00	1.00
720	30	Apr	0.98	0.96	0.98	1.00	1.00	0.98	0.92	0.90	0.93	0.99	0.96
744	31	May	0.80	0.78	0.77	0.81	0.83	0.76	0.70	0.68	0.64	0.79	0.76
720	30	Jun	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.94	1.00	0.99
744	31	Jul	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.00	0.99
744	31	Aug	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.91	1.00	0.99
720	30	Sep	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.92	1.00	0.99
744	31	Oct	0.96	0.95	0.95	0.96	0.97	0.95	0.94	0.94	0.91	0.96	0.95
720	30	Nov	0.98	0.98	0.98	0.98	0.99	0.97	0.96	0.95	0.89	0.98	0.97
744	31	Dec	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.79	0.99	0.98
		Average	0.98	0.97	0.97	0.98	0.98	0.97	0.96	0.96	0.84	0.97	0.96

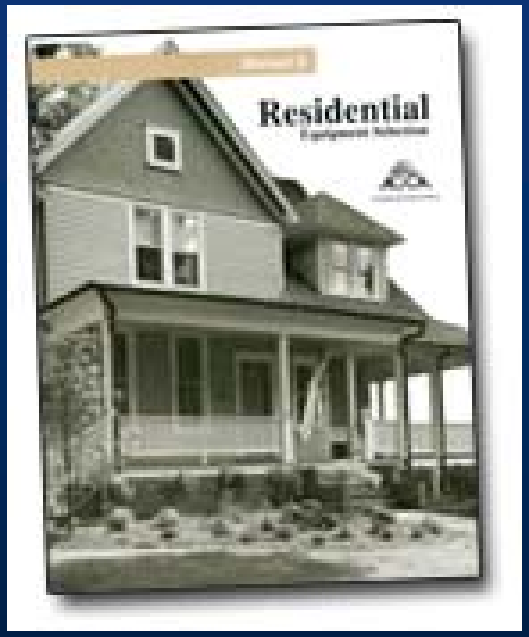
TCPI – Air Distribution

Thermal Comfort Performance– Monthly Room-by-Room TCPI
No Seasonal Adjustment, Dual-Zone Control, Manual J Method

Hours	Days	Months	Z1_TCPI	Z2_TCPI	Z3_TCPI	Z4_TCPI	Z5_TCPI	Z7_TCPI	Z8_TCPI	Z9_TCPI	Z10_TCPI	Z11_TCPI	Whole House
744	31	Jan	1.00	1.00	1.00	0.96	1.00	1.00	1.00	1.00	1.00	0.99	0.99
672	28	Feb	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00
744	31	Mar	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
720	30	Apr	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
744	31	May	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
720	30	Jun	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
744	31	Jul	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00
744	31	Aug	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
720	30	Sep	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
744	31	Oct	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00
720	30	Nov	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
744	31	Dec	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00
		Average	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

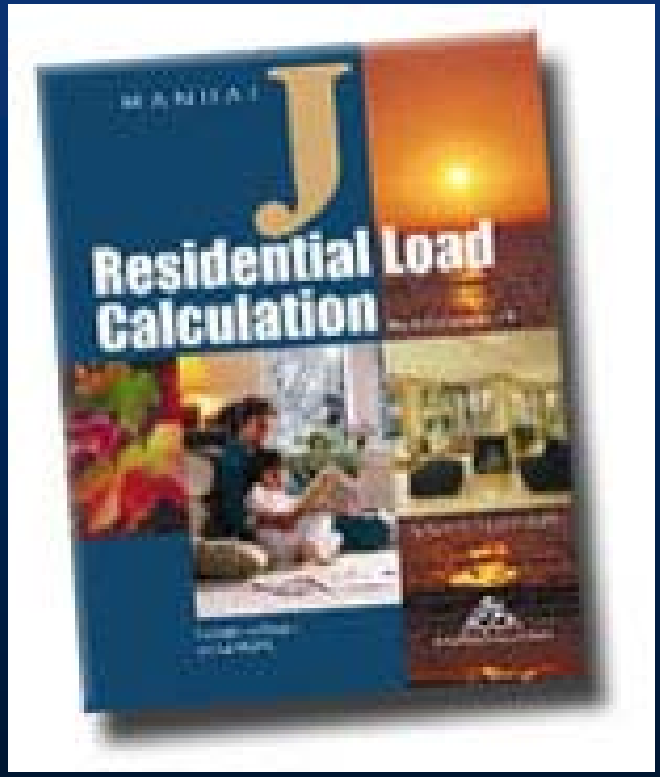
Equipment selection overview

- Basic Concepts
- Furnaces & Boilers
- Cooling Equipment Selection Procedure
- Air-Source Heat Pump
- Water-to-Air Heat Pump
- Dual Fuel Systems
- Variable & Dual Speed Equipment
- Limitations of the ARI Certification Data



Basic Concepts
Load Calculations

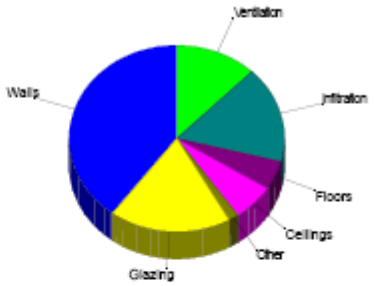
- ACCA Manual J
  - Heating Load
  - Sensible Cooling Load
  - Latent Cooling Load



606 Performance

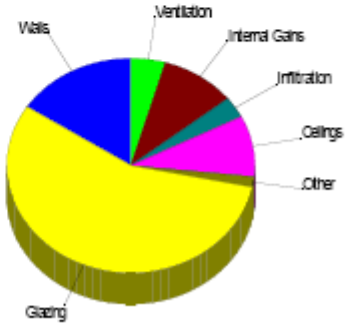
Heating

Component	Btuh/ft²	Btuh	% of load
Walls	5.8	22530	39.8
Glazing	22.3	10346	18.3
Doors	20.9	853	1.5
Ceilings	1.9	3613	6.4
Floors	1.5	2852	5.0
Infiltration	3.3	9453	16.7
Ducts		0	0
Piping		0	0
Humidification		0	0
Ventilation		6956	12.3
Adjustments		0	
Total		**56603**	**100.0**



Cooling

Component	Btuh/ft²	Btuh	% of load
Walls	1.0	4063	15.8
Glazing	31.0	14383	56.0
Doors	6.8	278	1.1
Ceilings	1.2	2358	9.2
Floors	0.1	124	0.5
Infiltration	0.3	819	3.2
Ducts		0	0
Ventilation		1159	4.5
Internal gains		2521	9.8
Blower		0	0
Adjustments		0	
Total		**25706**	**100.0**



Latent Cooling Load = 4348 Btuh
Overall U-value = 0.069 Btuh/ft²-°F

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Heatir

Component	Btuh/ft²	Btuh	% of load
Walls	5.8	22530	39.8
Glazing	22.3	10346	18.3
Doors	20.9	853	1.5
Ceilings	1.9	3613	6.4
Floors	1.5	2852	5.0
Infiltration	3.3	9453	16.7
Ducts		0	0
Piping		0	0
Humidification		0	0
Ventilation		6956	12.3
Adjustments		0	
Total		56603	100.0

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Cooli

Component	Btuh/ft²	Btuh	% of load
Walls	1.0	4063	15.8
Glazing	31.0	14383	56.0
Doors	6.8	278	1.1
Ceilings	1.2	2358	9.2
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Infiltration	0.3	819	3.2
Ducts		0	0
Ventilation		1159	4.5
Internal gains		2521	9.8
Blower		0	0
Adjustments		0	
Total		**25706**	**100.0**

Latent Cooling Load = 4348 Btuh
Overall U-value = 0.069 Btuh/ft²-°F

606 IBACOS

Efficiency	93 AFUE		Efficiency	11.0 EER, 13 SEER	
Heating input	69000	Btuh	Sensible cooling	24500	Btuh
Heating output	64000	Btuh	Latent cooling	10500	Btuh
Temperature rise	51	°F	Total cooling	35000	Btuh
Actual air flow	1167	cfm	Actual air flow	1167	cfm
Air flow factor	0.023	cfm/Btuh	Air flow factor	0.048	cfm/Btuh
Static pressure	0	in H2O	Static pressure	0	in H2O
Space thermostat			Load sensible heat ratio	0.86	

ROOM NAME	Area (ft²)	Htg load (Btuh)	Clg load (Btuh)	Htg AVF (cfm)	Clg AVF (cfm)
Basement	1325	9866	1583	232	75
Family	285	3780	2913	89	138
Den	164	2814	1868	66	89
Powder	32	837	127	20	6
Kitchen	240	2345	935	55	44
Breakfast Nook	195	2003	2078	47	99
Living	219	4594	2533	108	120
Dining	191	1950	859	46	41
Master Bedroom	284	3915	2421	92	115
Master Bath	124	1242	328	29	16
Bath 2	64	536	152	13	7
Bedroom 2	237	3514	1665	83	79
Master Wic	73	137	94	3	4
Master Wic 2	118	1131	303	27	14
Bedroom 4	199	3379	2167	79	103
Bedroom 3	194	2424	1687	57	80

606 Fox Valley

Zone Sizing Data

Zone Name	Maximum Cooling Sensible (MBH)	Design Air Flow (CFM)	Minimum Air Flow (CFM)	Time of Peak Load	Maximum Heating Load (MBH)	Zone Floor Area (ft²)	Zone CFM/ft²
Zone 1	22.2	1055	1055	Aug 1500	40.0	4168.0	0.25

Zone Terminal Sizing Data

No Zone Terminal Sizing Data required for this system.

Space Loads and Airflows

Zone Name / Space Name	Mult.	Cooling Sensible (MBH)	Time of Load	Air Flow (CFM)	Heating Load (MBH)	Floor Area (ft²)	Space CFM/ft²
Zone 1							
0606-0-Basement	1	1.9	Aug 1500	88	11.3	1222.0	0.07
0606-1st-Breakfast Nook	1	0.8	Aug 1500	38	1.4	161.0	0.24
0606-1st-Den	1	0.9	Aug 1500	41	1.7	155.0	0.27
0606-1st-Family Room	1	1.9	Aug 1500	89	2.7	215.0	0.41
0606-1st-Kitchen/Pantry	1	1.5	Aug 1500	70	1.3	254.0	0.28
0606-1st-Living/Dining	1	4.6	Aug 1500	219	5.4	415.0	0.53
0606-1st-Powder	1	0.1	Aug 1500	3	0.2	25.0	0.12
0606-2nd-Bathroom	1	0.1	Aug 1500	7	0.3	5.0	1.31
0606-2nd-Bedroom 2	1	1.4	Aug 1500	65	2.4	220.0	0.30
0606-2nd-Bedroom 3	1	1.5	Aug 1500	71	1.8	186.0	0.38
0606-2nd-Bedroom 4	1	2.0	Aug 1500	94	2.3	188.0	0.50
0606-2nd-Bonus Room	1	2.1	Aug 1500	100	3.0	292.0	0.34
0606-2nd-Hallway	1	0.4	Aug 1500	17	0.8	195.0	0.09
0606-2nd-Laundry	1	0.1	Aug 1500	6	0.3	74.0	0.08
0606-2nd-Master Bath	1	0.3	Aug 1500	15	0.9	114.0	0.13
0606-2nd-Master Bedroom	1	2.8	Aug 1500	132	4.2	447.0	0.29

Detailed Analysis

- Size take-off
- Occupancy
- Ventilation and Infiltration
- Treatment of unconditioned spaces (or Not)
  - Garages
  - Crawl spaces
  - Basements
- Glazing Characteristics

System evolution

Traditional

- 400 cfm / ton +- 75, 1 cfm per sq ft
- Displacement strategy, Horsepower overcomes defects

Air Systems Now

- 400 cfm / ton +- 75, 0.25 cfm per sq ft
- Mixing, Tight Ducts, inside conditioned space, Horsepower overcomes defects

Future

- 400 cfm / ton +- 75, 0.10 cfm per sq ft
- Convective Mixing
- Ventilation scaled delivery
- Design used to eliminate defects

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Basic Concepts
Operating Conditions for Cooling Equipment

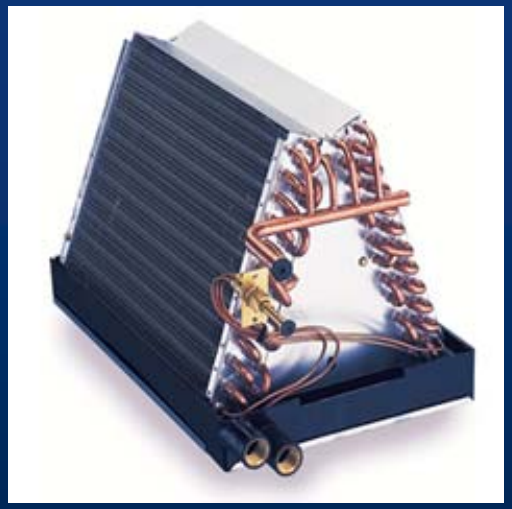
- Air-Cooled Condensing Units
  - Manual J - 2 ½% dry-bulb temperature
  - Add 10 F to 20 for roof – mounted

- Water-Cooled Condensing Units
  - Local ‘maximum’ ground water temperature
  - Alternative reference – “Closed-Loop/Ground-Source Heat Pump Systems Installation Guide, NRECA Research Project 86-1”

Basic Concepts
Operating Conditions for Cooling Equipment

- Indoor Coil with No Ventilation

Relative Humidity	Entering db°F	Entering wb°F
55%	75	64
50%	75	62.5 (use 63)
45%	75	61.5 (use 62)



- Indoor Coil with Return-side Ventilation

Relative Humidity	Humid Climate		Dry Climate	
	Entering db°F	Entering wb°F	Entering db°F	Entering wb°F
55%	77	65.5	77	64.0
50%	77	64.0	77	62.5
45%	77	62.5	77	61.0

Refer to Manual P for calculation procedure

Basic Concepts
Operating Conditions for Heat Pump Heating

- Air-Source Heat Pumps
  - Manual J - 97 ½% dry-bulb temperature
- Water-Source Heat Pumps
  - Local 'minimum' ground water temperature
  - Alternative reference – "Closed-Loop/Ground-Source Heat Pump Systems Installation Guide, NRECA Research Project 86-1"
- Indoor Air Design Conditions
  - 70 F (no ventilation)

Entering Conditions - 10% Outdoor Air, 70°F Return Air							
Outdoor db	-10	0	10	20	30	40	50
Entering db	62	63	64	65	66	67	68

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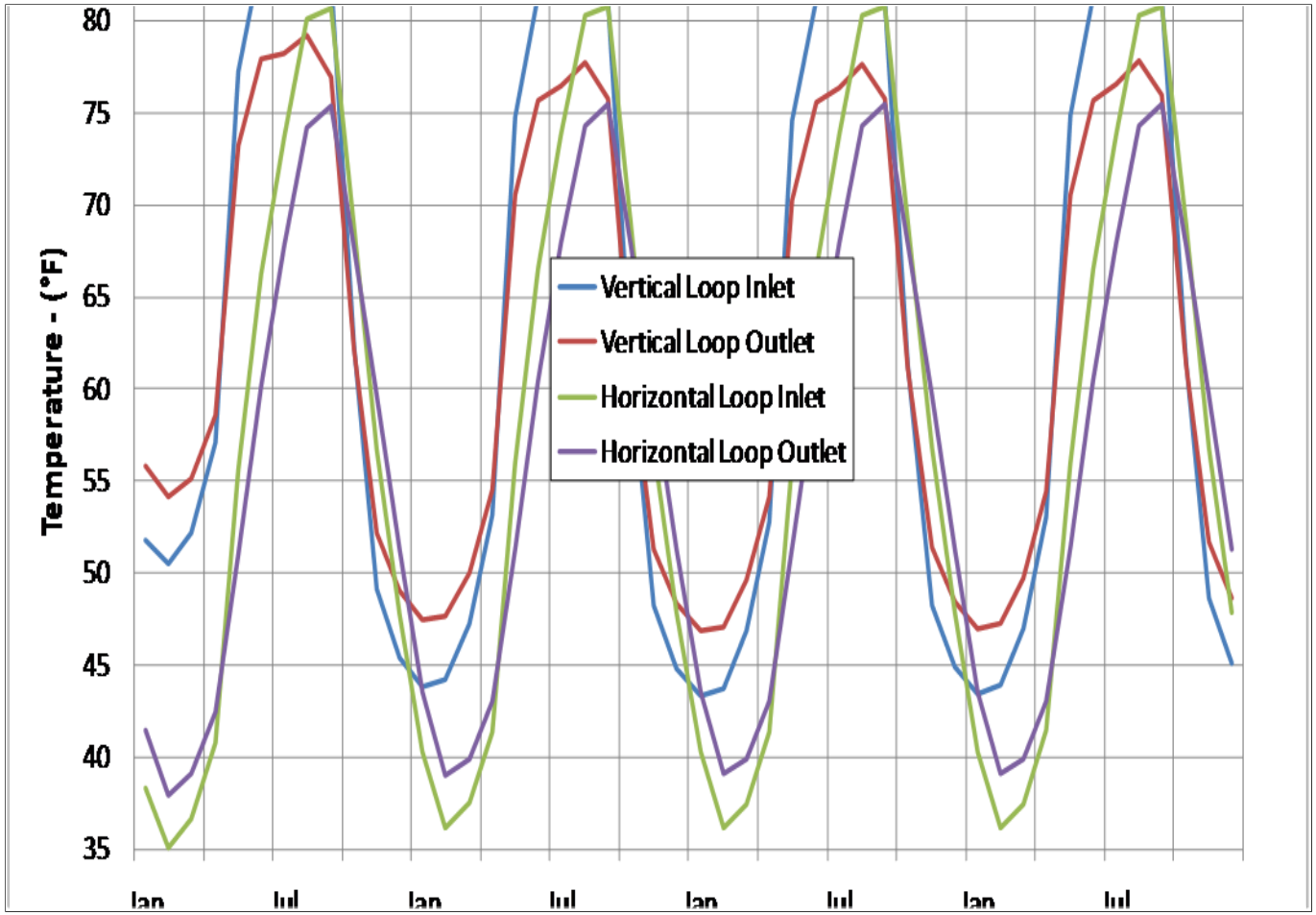
Building Energy Simulations
GSHP System with Loop Alternatives



Heat Pump Ground Loop Temperatures

Basic Concepts
Estimating the Cooling CFM

- Use Manual J, Form J-1 to determine SHR
- Select desired supply air temperature
  - Up to 58 F for high SHR
  - Down to 54 F for low SHR

SHR	LAT (°F)	Room db°F	ΔT (°F)
Below 0.80	54	75	21
0.80 to 0.85	56	75	19
Above 0.85	58	75	17

- Determine CFM

$$CFM = \frac{\text{Manual J Sensible Load}}{1.1 \times \Delta T}$$

Basic Concepts
Equipment Selection Data Summary

- Design Loads
  - Sensible
  - Latent
  - Heating
- Room Conditions
  - Dry-bulb – Cooling
  - Relative Humidity
  - Dry-bulb – Heating
- Air Flow Estimate
  - ΔT
  - CFM
- Outdoor Conditions
  - Summer dry-bulb
  - Summer wet-bulb
  - Winter dry-bulb
- Air Entering Indoor Coil
  - Dry-bulb – Cooling
  - Wet-bulb – Cooling
  - Dry-bulb – Heating
- Water Temperature
  - Late summer (maximum)
  - Late winter (minimum)

Basic Concepts
Comprehensive Cooling Data Required

- Data format is specific to each manufacturer

EVAPORATOR AIR		75			85		
CFM	EWB	Capacity MBtuh†		Total System KW**	Capacity MBtuh†		Total System KW**
		Total	Sens‡		Total	Sens‡	
24ANA724A30 O							
440	72	18.84	9.72	0.93	17.34	9.14	1.03
	67	16.76	11.63				
	63	15.32	11.15				
	62	14.91	13.53				
	57	14.27	14.27				
490	72	19.33	10.18				
	67	17.20	12.32				
	63	15.72	11.80				
	62	15.32	14.44				
	57	14.93	14.93				
	72	19.62	10.49				

24ANA724A30 Outdoor Section With FE4ANF003 Indoor Section

Cooling Indoor Model	High Speed Capacity	Power	Low Speed Capa-ciy	Power	Furnace Model
CSPH*3612A**	1.01	1.02	1.01	1.03	58MVB040–14
CSPH*3012A**	0.99	1.01	1.00	1.02	58MVB040–14
CSPH*2412A**	0.99	1.02	1.00	1.03	58MVB040–14
CNPV*3621A**	0.99	1.01	1.00	1.02	58MVB040–14
CNPH*3617A**	0.99	1.01	1.00	1.02	58MVB040–14
CNPH*3017A**	0.99	1.01	1.00	1.02	58MVB040–14

NOTE: When the required data fall between the published data, interpolation may be performed. Extrapolation is not an acceptable practice.

* Detailed cooling capacities are based on indoor and outdoor unit at the same elevation per ARI standard 210/240–94. If additional tubing length and/or indoor unit is located above outdoor u occur.

** Total system kW is total of indoor and outdoor unit kilowatts.

† Total and sensible capacities are net capacities. Blower motor heat has been subtracted.

‡ Sensible capacities shown are based on 80°F (27°C) entering air at the indoor coil. For sensible capacities at other than 80°F (27°C), deduct 835 Btuh (245 kW) per 1000 CFM (480 L/S) of indoor coil air for each degree below 80°F (27°C), or add 835 Btuh (245 kW) per 1000 CFM (480 L/S) of indoor coil air per degree above 80°F (27°C). When the required data fall between the published data, interpolation may be performed.

Basic Concepts
Heat Pump – Heating Performance Data

- Data format is specific to each manufacturer

INDOOR AIR		OUTDOC								
		7			17			27		
EDB	CFM	CAPACITY MBTUH		TOTAL SYSTEM KW†	CAPACITY MBTUH		TOTAL SYSTEM KW†	CAPACITY MBTUH		TOTAL SYSTEM KW†
		TOTAL	INTEG‡		TOTAL	INTEG‡		TOTAL	INTEG‡	
25HNA924A30 Outdoor Section Wi										
65	600	7.32	6.72	1.00	9.69	8.83	1.09	12.17	10.81	1.20
	665	7.39	6.79	0.99	9.83	8.96				
	700	7.43	6.82	0.99	9.89	9.02				
70	600	7.10	6.52	1.08	9.39	8.56				
	665	7.17	6.59	1.07	9.50	8.66				
	700	7.21	6.62	1.07	9.55	8.71				
75	600	6.90	6.34	1.17	9.09	8.29				
	665	7.00	6.44	1.16	9.19	8.38				
	700	7.03	6.46	1.16	9.25	8.43				

HEATING INDOOR MODEL	HIGH SPEED CA-PACITY	POW-ER	LOW SPEED CA-PACITY	POW-ER	FURNACE MODEL
*FE5ANB004	1.00	1.00	1.00	1.00	
FE4ANF002	1.01	1.03	0.99	1.01	
FE4ANF003	1.01	1.03	0.98	1.00	
CAP**4817A**	1.02	1.05	1.00	1.02	58CV(A,X)090–16
CAP**4821A**	1.01	1.04	0.99	1.01	58CV(A,X)090–16
CAP**6021A**	1.01	1.04	0.99	1.02	58CV(A,X)090–16
CNPH*4821A**	1.01	1.04	0.99	1.00	58CV(A,X)090–16
CNPH*6024A**	1.00	1.03	0.99	1.01	58CV(A,X)090–16
CNPV*4821A**	1.01	1.04	0.99	1.00	58CV(A,X)090–16

NOTE: When the required data falls between the published data, interpolation may be performed. Extrapolation is not an acceptable practice.
† The kW values include the compressor, outdoor fan motor, and indoor blower motor. The kW from supplement heaters should be added to these values to obtain total system kilowatts.
‡ The Btuh heating capacity values shown are net integrated values from which the defrost effect has been subtracted. The Btuh heating from supplement heaters should be added to thos
* Tested Combination
EDB — Entering Dry Bulb

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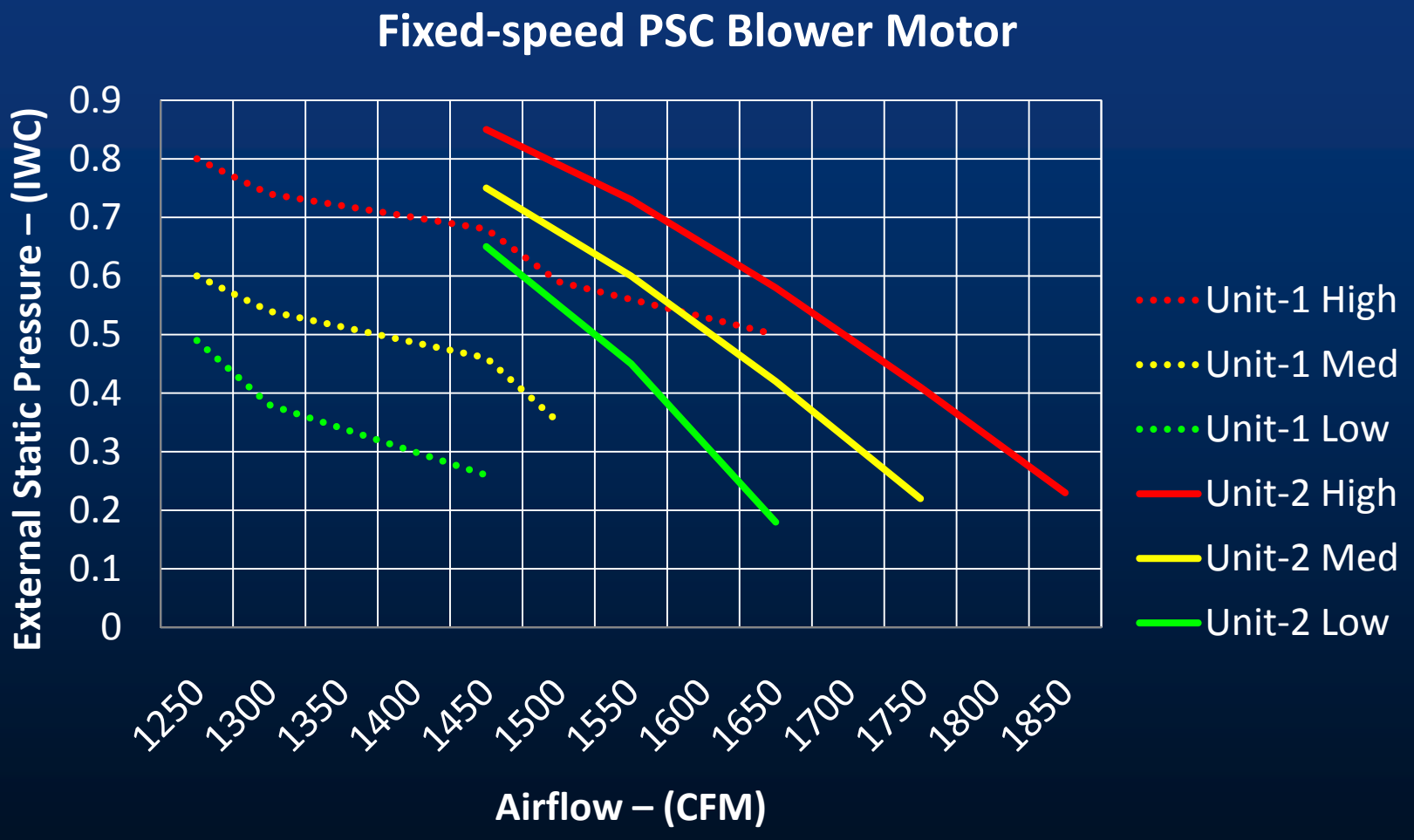
Basic Concepts
Blower Performance Data



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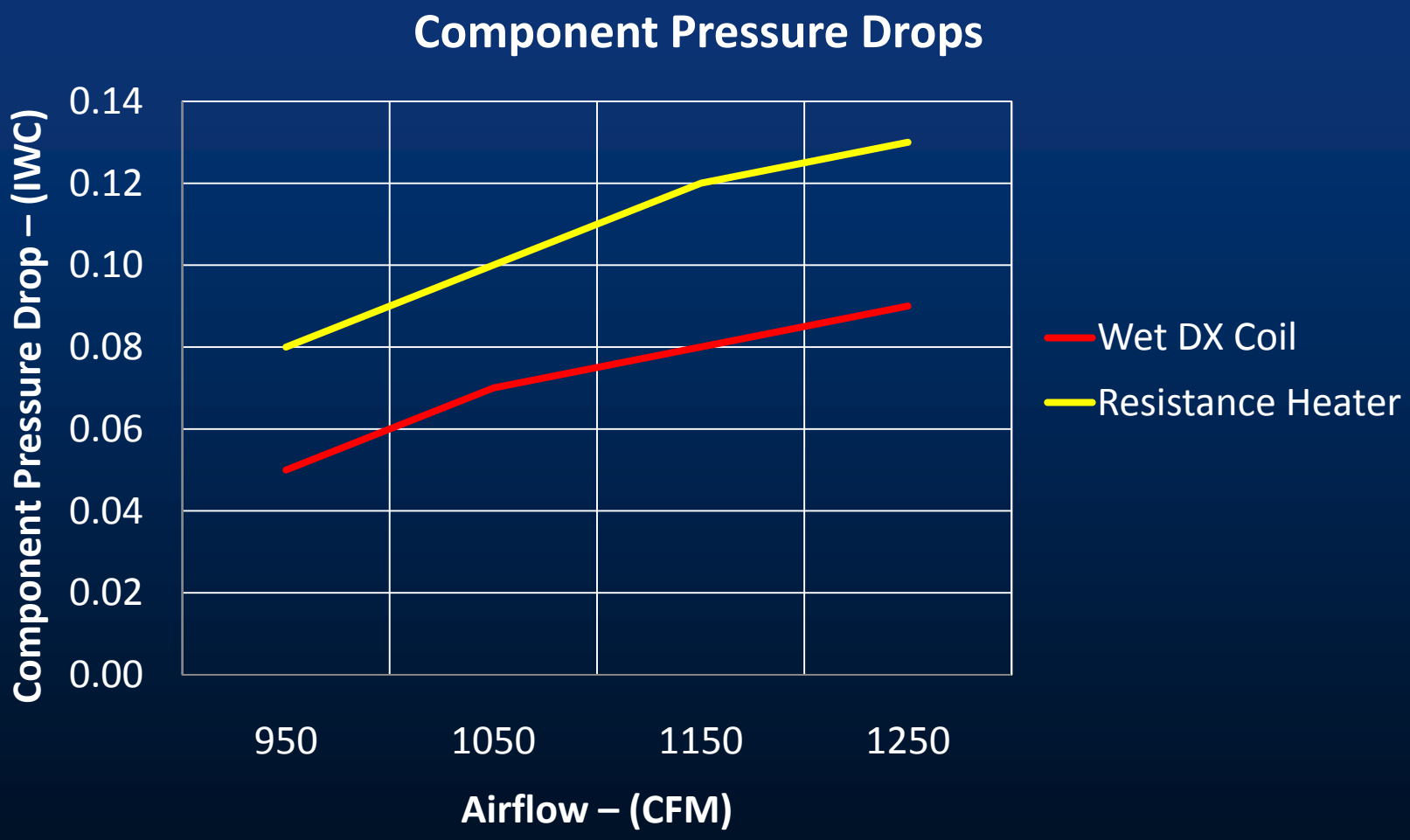
Basic Concepts
Blower Performance Data



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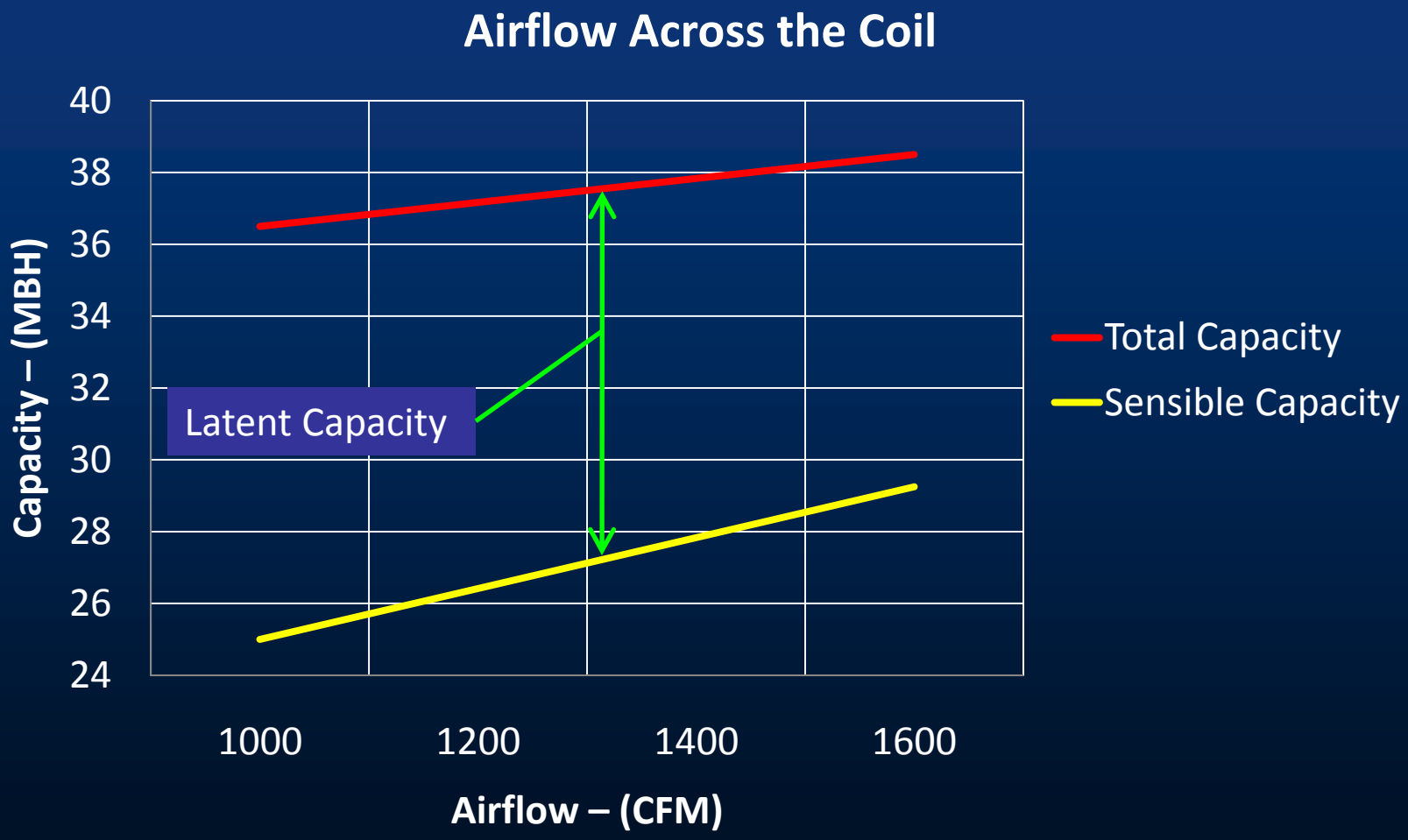
Cooling Equipment Selection Procedure

- Basic Types of 'Central' Cooling Equipment
  - Direct Expansion (DX) cooling only
  - Air-to-air heat pump
  - Water-to-air heat pump
  - All options in either a 'split' or 'packaged' configuration
- Manufacturer's Application Data Required
  - Some unpublished but may be available upon request
  - Consider alternatives if data is unavailable
  - Do not use ARI data for equipment selection
- Design loads shall be calculated using Manual J
- Sizing Limitations
  - Cooling-only equipment should not exceed the total cooling load by more than 15%
  - Heat pump (air or water) oversizing limitations
  - 15% - warm or moderate climate
  - 25% - cold climate

Cooling Equipment Selection Procedure
Cooling Capacity is Conditional



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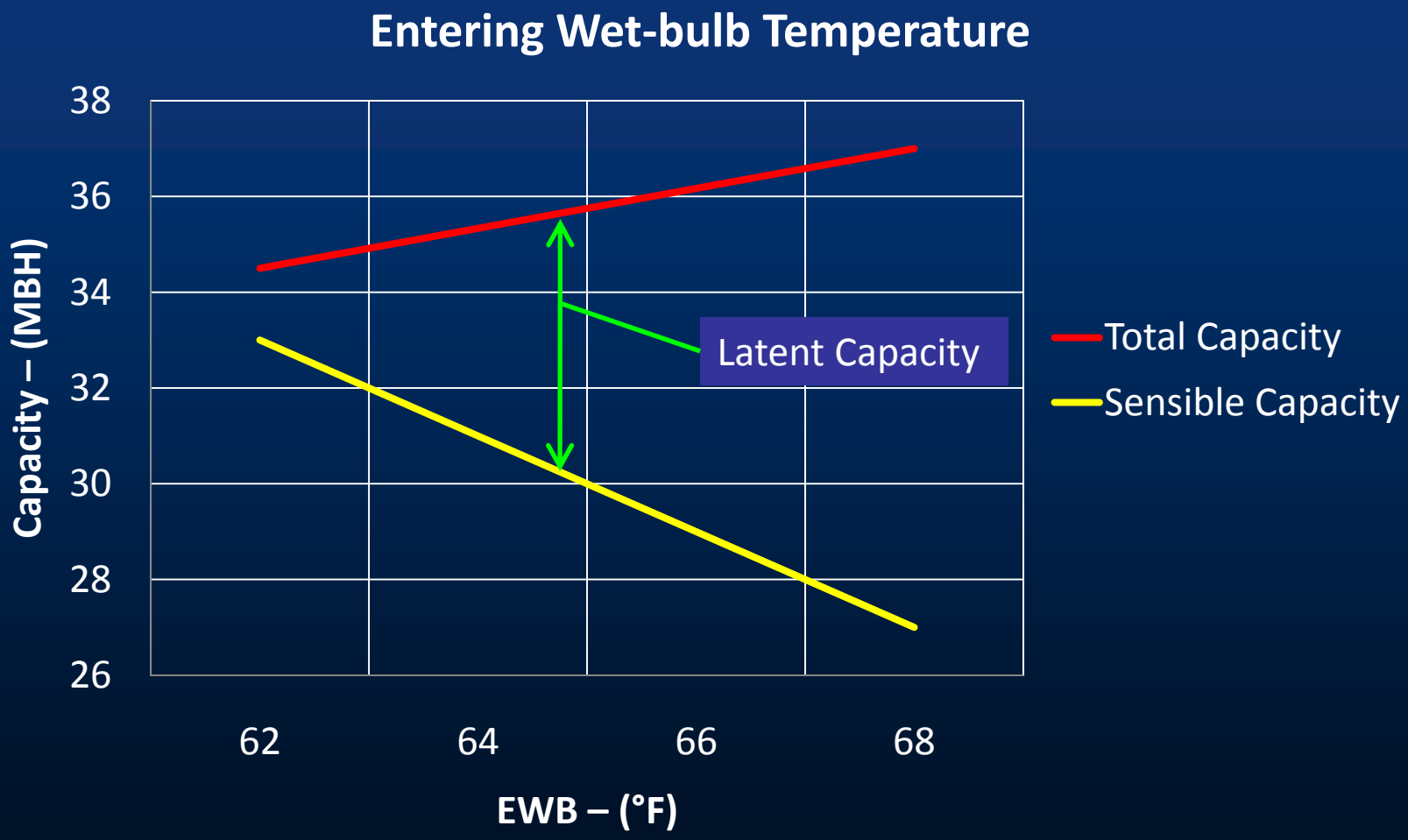
Cooling Equipment Selection Procedure
Cooling Capacity is Conditional



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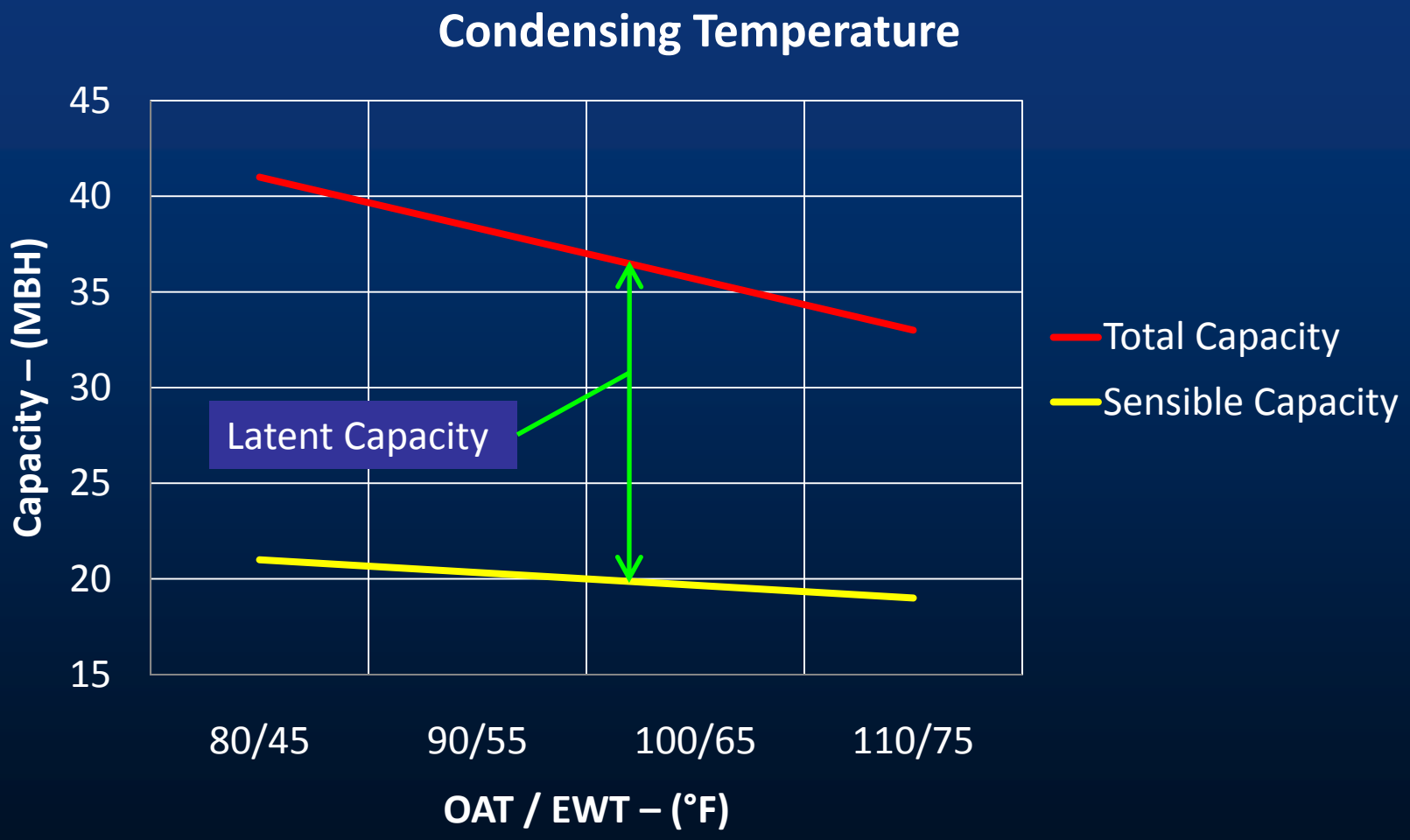
Cooling Equipment Selection Procedure
Cooling Capacity is Conditional



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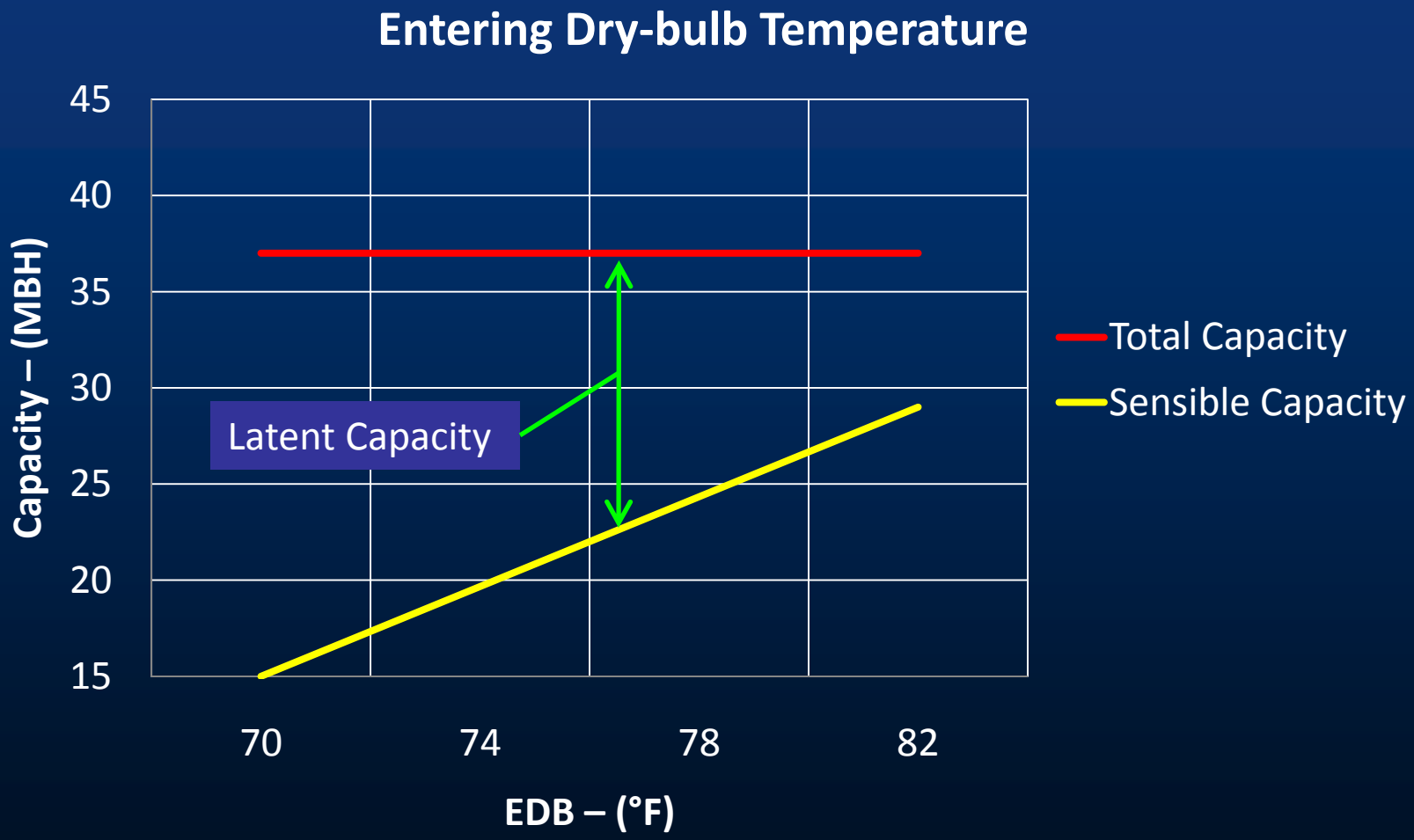
Cooling Equipment Selection Procedure
Cooling Capacity is Conditional



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Cooling Equipment Selection Procedure
Step-by-step Sizing Procedure

1. Establish Design Parameters
    1. Outdoor air dry-bulb temperature
    2. Indoor dry-bulb temperature
    3. Indoor wet-bulb temperature
    4. Sensible load (Manual J, Form J-1)
    5. Latent load (Manual J, Form J-1)
    6. Entering ‘coil’ dry-bulb temperature
    7. Entering ‘coil’ wet-bulb temperature
    8. Ground water temperature (open system)
    9. Maximum loop-water temperature (closed system)

Cooling Equipment Selection Procedure
Step-by-step Sizing Procedure

2. Estimate the Cooling CFM
   1. Calculate the sensible heat ratio

$$SHR = \frac{\text{Sensible Load}}{\text{Sensible Load + Latent Load}}$$

   2. Find ΔT value compatible with the sensible and latent loads.

SHR	LAT (°F)	Room db°F	ΔT (°F)
Below 0.80	54	75	21
0.80 to 0.85	56	75	19
Above 0.85	58	75	17

   3. Calculate a cooling CFM value.

$$CFM = \frac{\text{Manual J Sensible Load}}{1.1 \times \Delta T}$$

Air-Source Heat Pump
Equipment Size is Based on the Cooling Load

"So for any type of climate, the size of the heat pump should be based on the cooling load."

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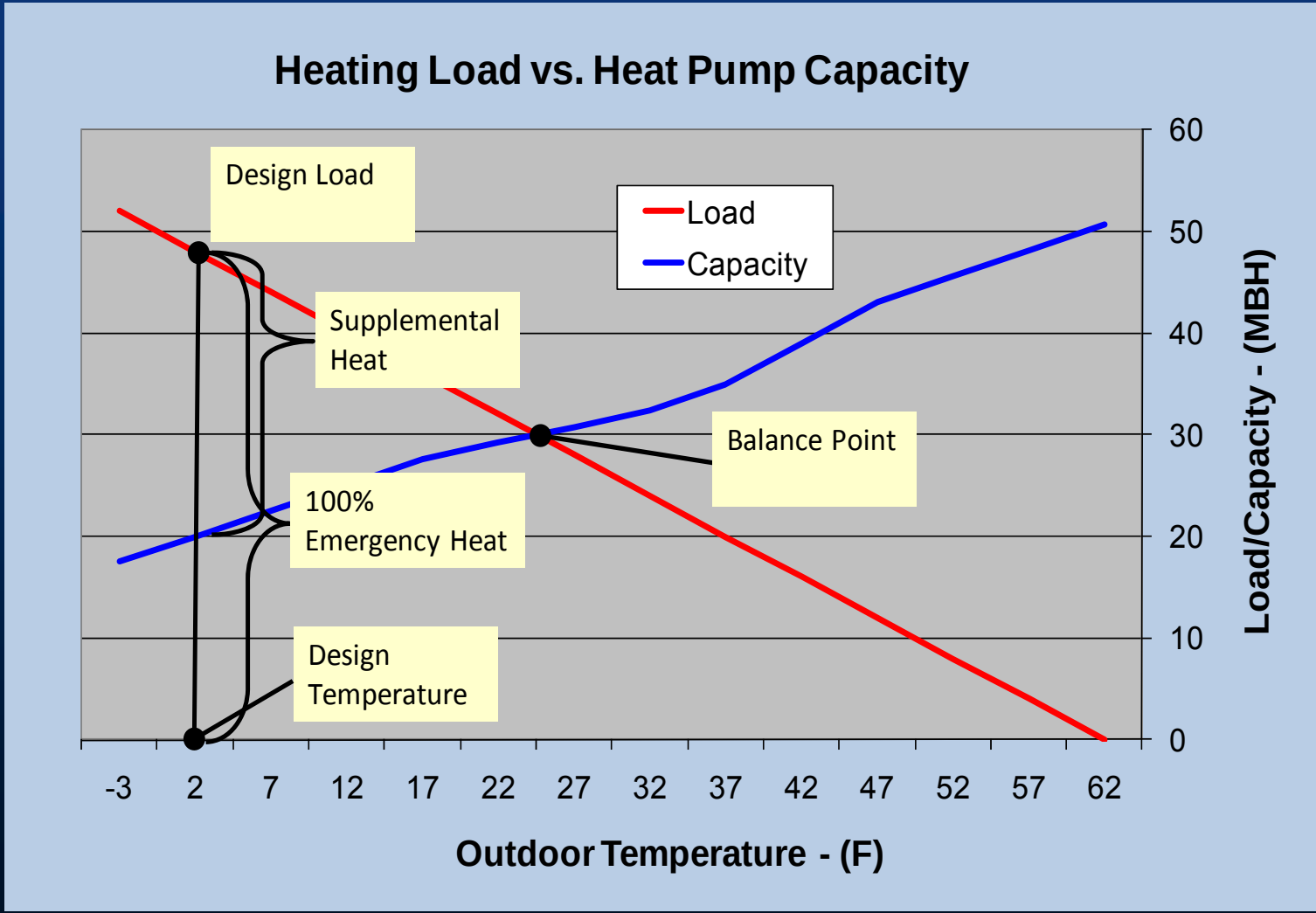
Air-Source Heat Pump
Balance Point Diagram



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Air-Source Heat Pump
Optimum Balance Point

Bigger is not always better and sometimes savings aren't large enough to justify additional first costs.

Akron, OH ($/KWH = 0.055)					
Capacity	**% TC**	**Bal. Pt.**	**$ Heat**	**$ Cool**	**$ Total**
2.5 Tons	1.15	34	1,026	166	1,192
3.0 Tons	1.40	31	978	170	1,148

$44 Savings

Atlanta, GA ($/KWH = 0.055)					
Capacity	**% TC**	**Bal. Pt.**	**$ Heat**	**$ Cool**	**$ Total**
3.0 Tons	1.18	33	364	422	786
3.5 Tons	1.43	31	366	433	799

$13 More

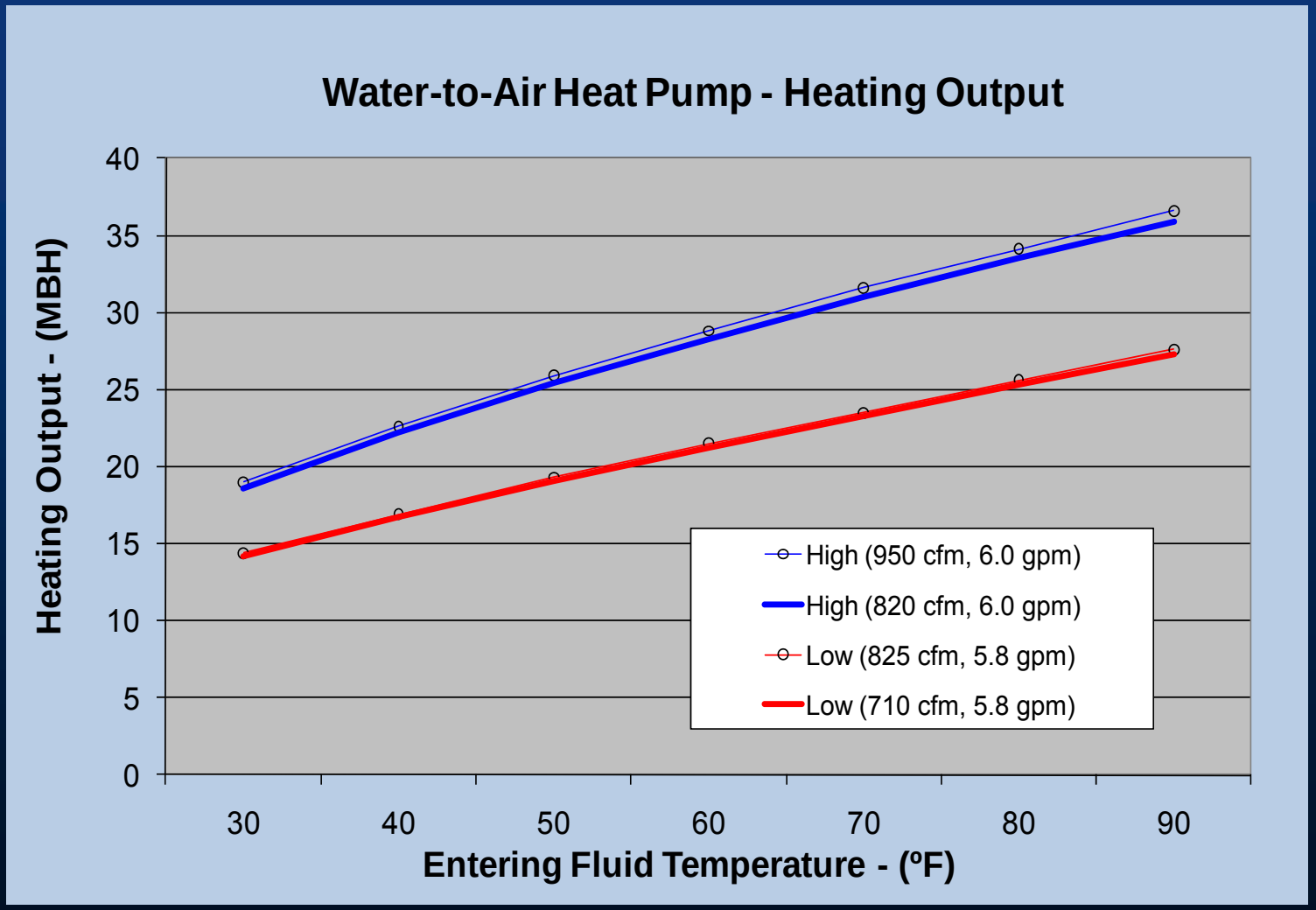
Water-to-Air Heat Pump
Equipment Size is Based on the Cooling Load

- Equipment selection procedure is identical to the procedure that would be used to select air-to-air equipment.
- A balance-point diagram is required to evaluate heating performance

Water-to-Air Heat Pump
Entering Water Temperature

- Open loop
  - Well water temperature fairly constant
  - A single water temperature can be used to evaluate both cooling and heating performance
- Closed loop
  - Water temperatures change on a monthly basis
  - Design should be based on extreme conditions that occur at the end of each season
  - Extremes can be 10 F to 20 F hotter or colder than the Manual J design temperatures
  - *Alternative reference – "Closed-Loop/Ground-Source Heat Pump Systems Installation Guide, NRECA Research Project 86-1"*

Water-to-Air Heat Pump
Heating Performance



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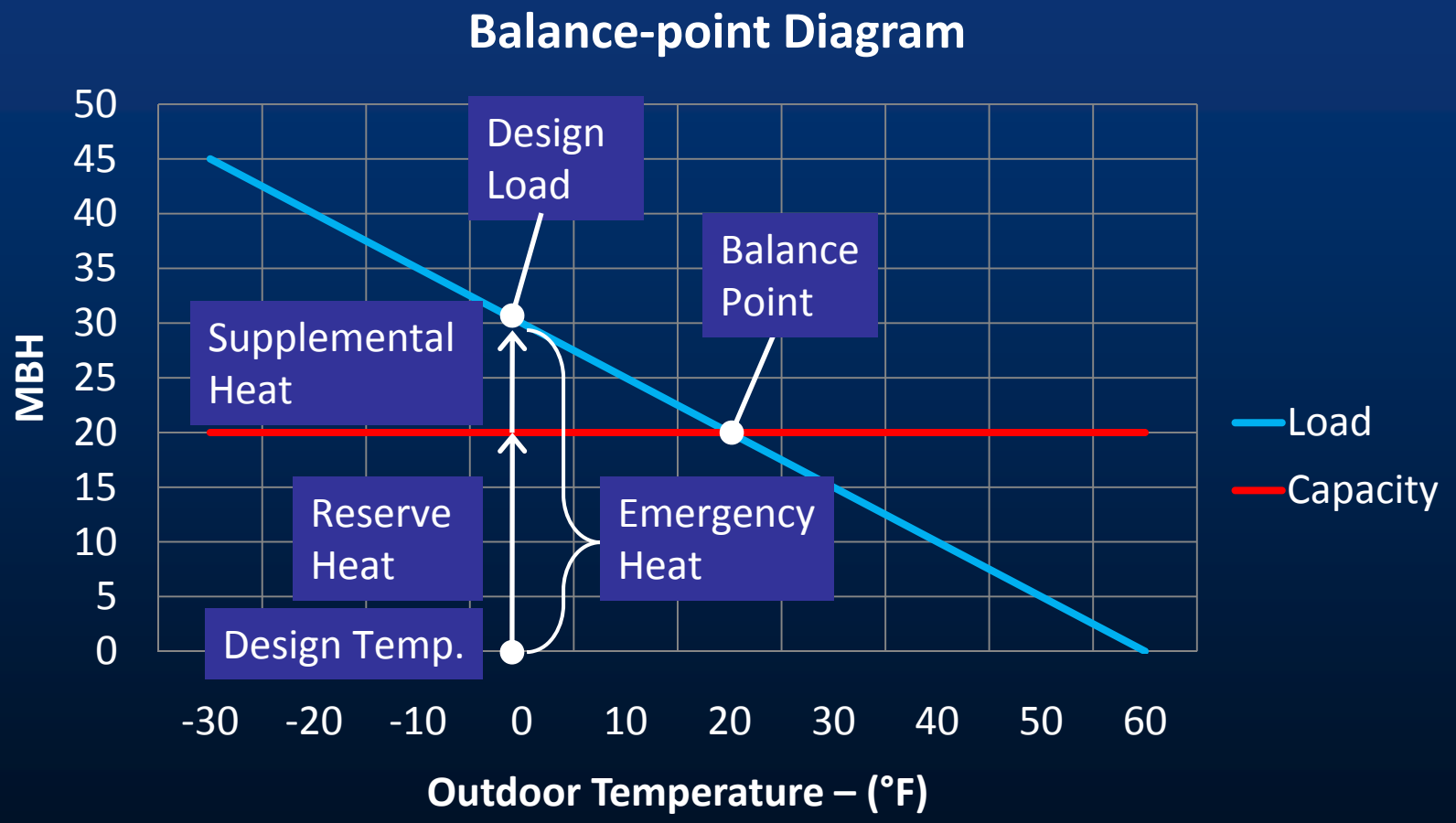
Water-to-Air Heat Pump
Heating Performance



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Water-to-Air Heat Pump
Optimum Balance Point

Bigger is not always better and sometimes savings aren't large enough to justify additional first costs.

Akron, OH ($/KWH = 0.055)					
Capacity	**% TC**	**Bal. Pt.**	**$ Heat**	**$ Cool**	**$ Total**
2.5 Tons	1.05	33	773	119	892
3.0 Tons	1.34	30	758	122	880

$12 Savings

Atlanta, GA ($/KWH = 0.055)					
Capacity	**% TC**	**Bal. Pt.**	**$ Heat**	**$ Cool**	**$ Total**
2.5 Tons	1.23	32	311	326	637
3.0 Tons	1.35	28	320	331	651

$14 More

Water-to-Air Heat Pump
Step-by-step Sizing Procedure

2. Size the Equipment for Cooling
    1. Refer to Section 3 of Manual S ‘Cooling Equipment Selection Procedures’
3. Evaluate the Heating Season Performance
    1. Total cooling capacity shall not exceed the cooling load by more than 25%
    2. Conduct life-cycle cost analysis to determine optimum equipment selection (Note: electric utility time-of-use rates are not addressed by Manual S)
4. Determine the Supplemental Heat Requirement
5. Determine the Emergency Heat Requirement
6. Select a Resistance Heating Coil
    1. Do not oversize
    2. Refer to manufacturer’s guidelines
    3. Consider multiple coils for better control

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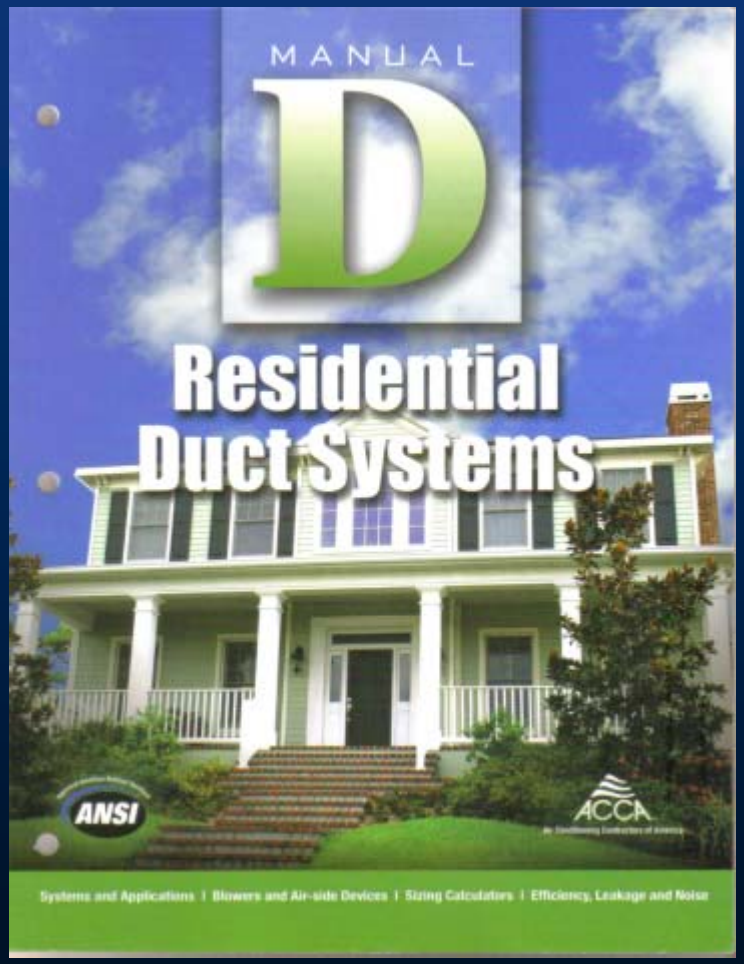
Overview

- Basic Duct Sizing Principles
- System Operating Point
- Blowers
- System Performance Issues
- Prerequisites for Air Distribution System Design
- Duct Sizing Calculations
- Sizing Rigid Constant Volume Duct Systems



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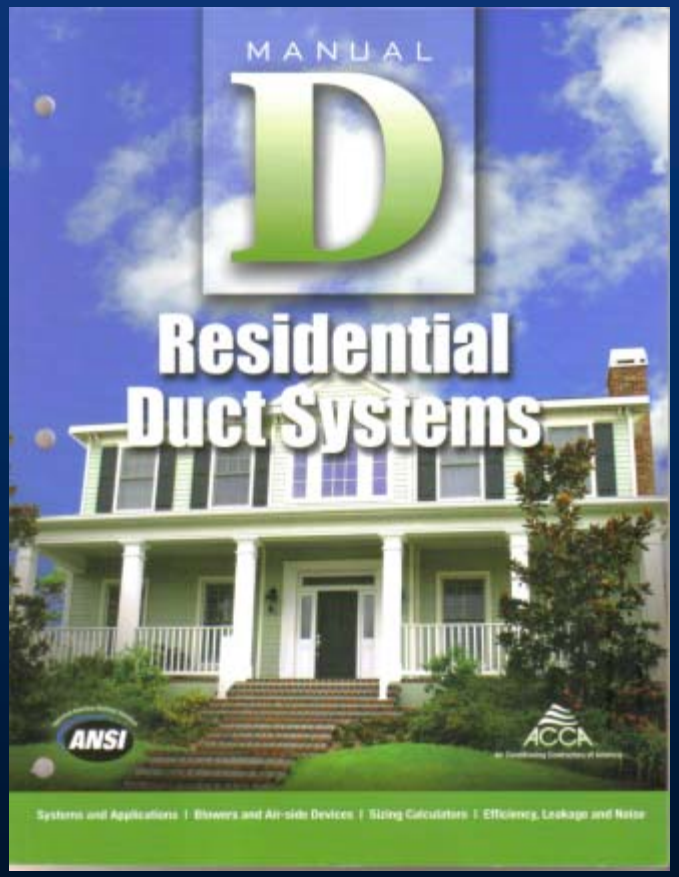
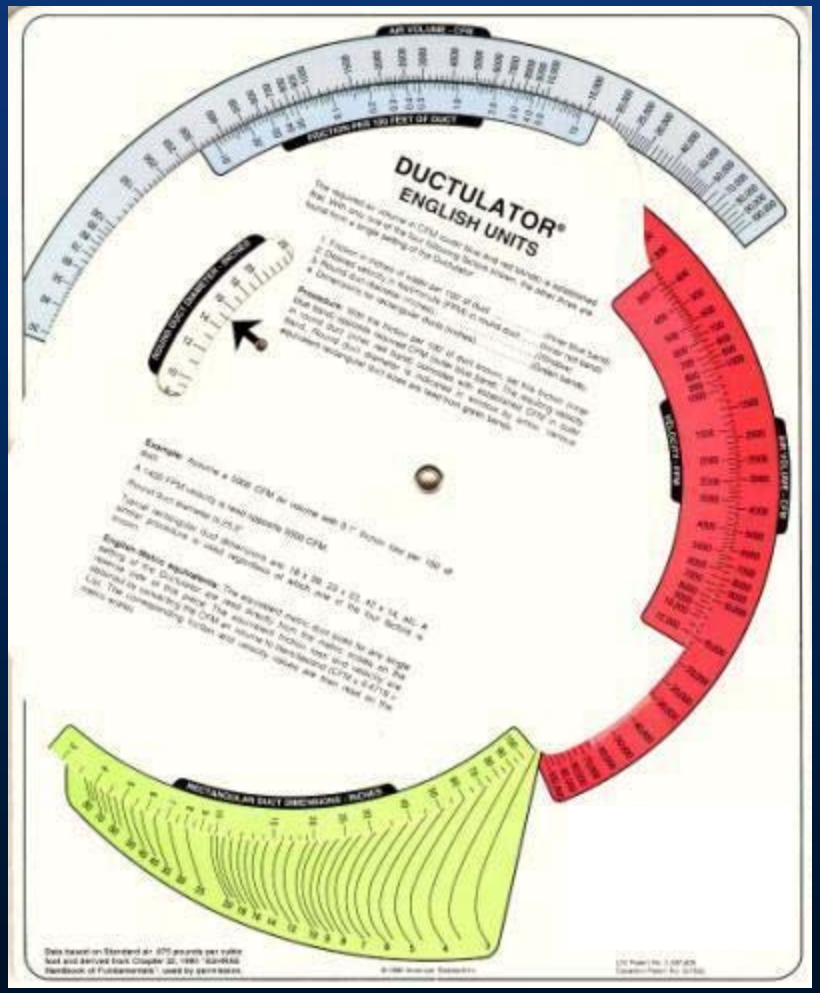
Overview

- Sizing Flexible Constant Volume Systems
- Variable Volume Systems
- ~~Sizing Rigid Variable Volume Duct Systems~~
- Sizing Two-Zone Bi-level Duct Systems
- ~~Sizing Variable Volume Retrofit Systems~~



Basic Duct Sizing Principles

- Pressure Units (0.10 IWC ≈ 25 Pa)
- Blower Performance
- Duct Performance
- System Operating Point
- Objective of the Sizing Procedure
- Pressure Drop and Friction Rate
- Effective Length
- Ducted Return
- Branch Ducts
- Pressure Drop of Air-Side Components
- Available Static Pressure
- Velocity Limits
- Generic Air Flow Calculation
- Blower CFM and Room CFM



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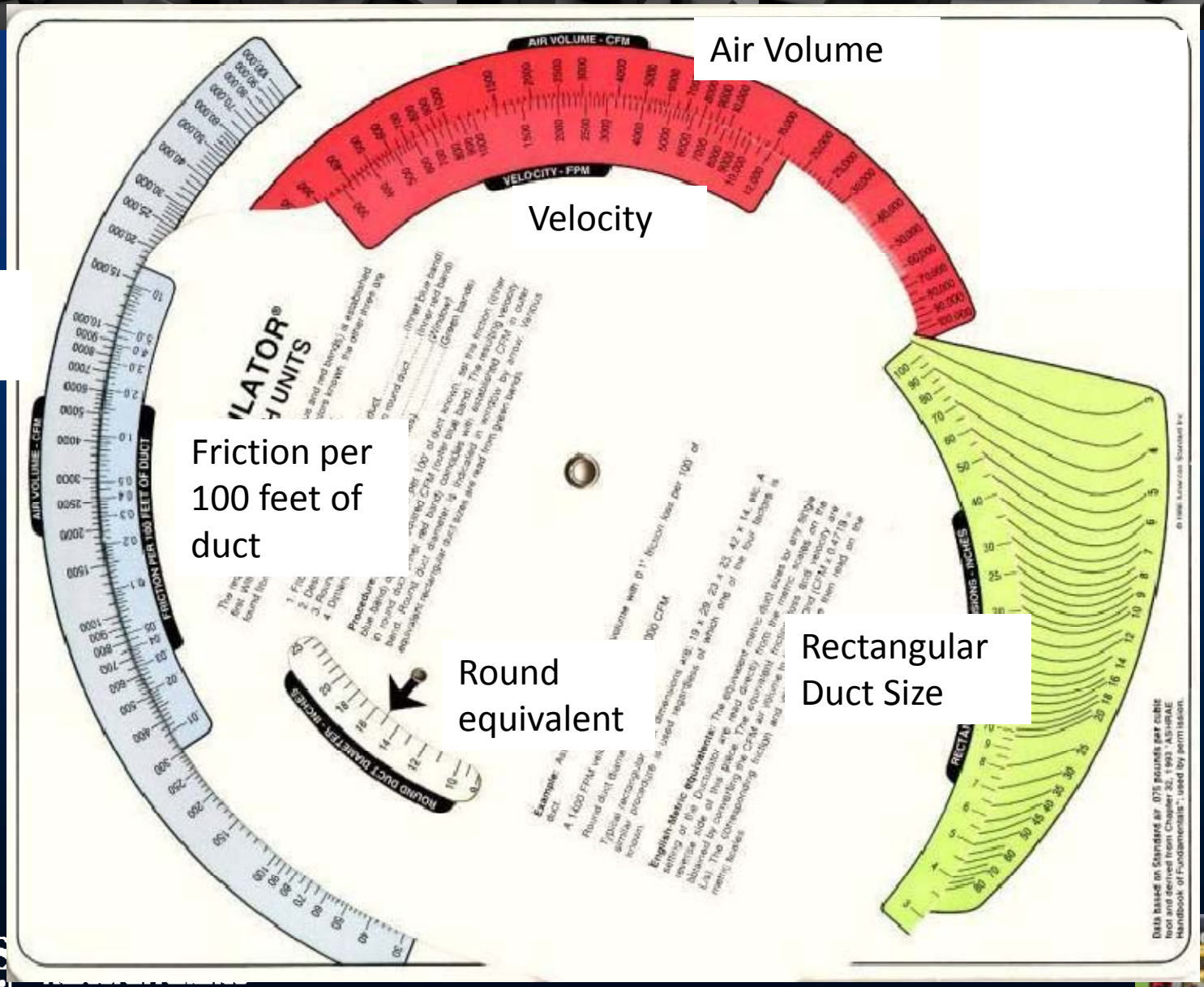
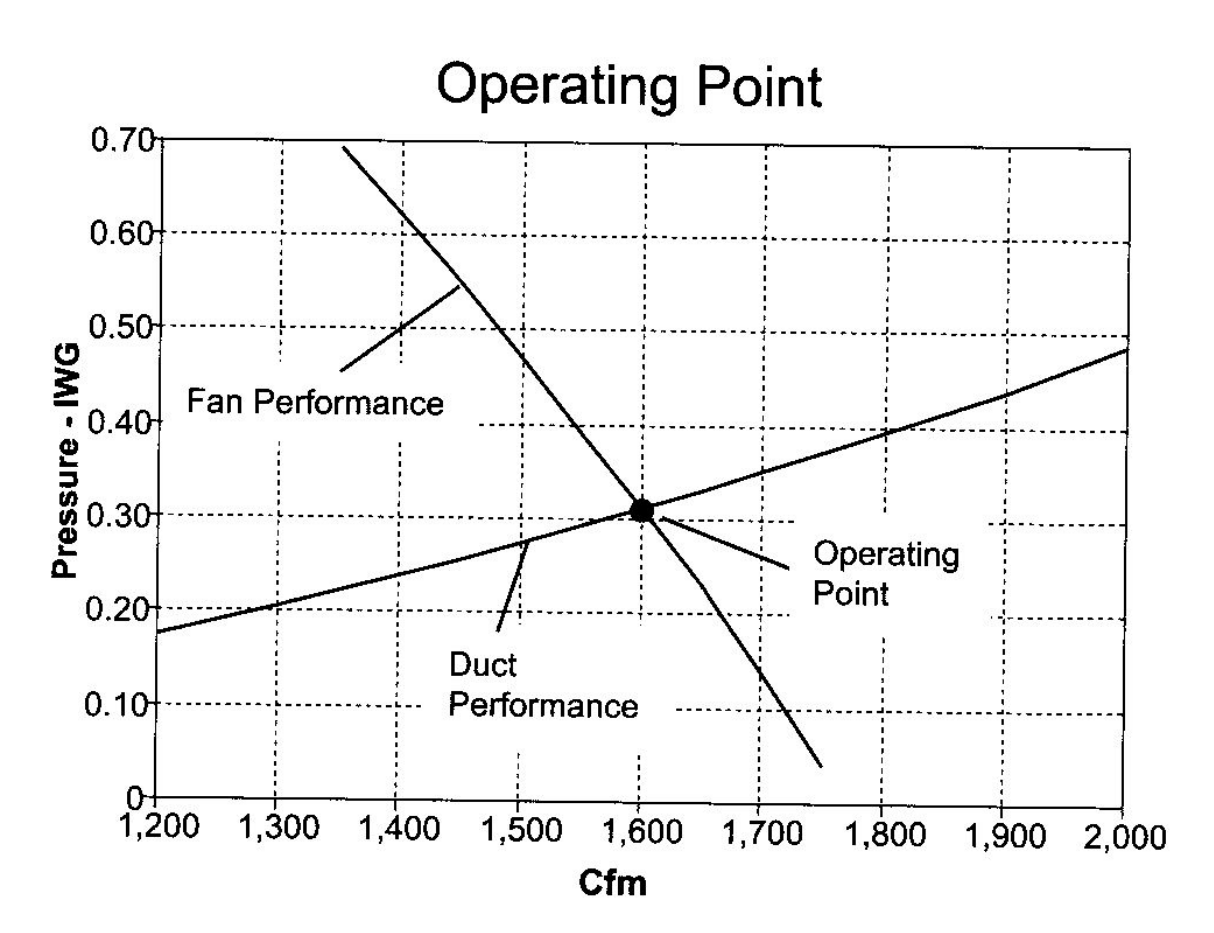
Basic Duct Sizing Principles



Basic Duct Sizing Principles

Operating Point



Basic Duct Sizing Principles

- Objective – Design resistance in duct system to match fan capacity
- Friction Rate is pressure drop / 100 ft. of duct

$$FR = \frac{PD \times 100}{TEL}$$

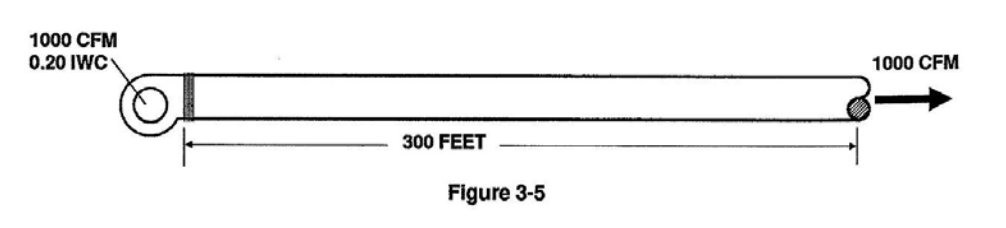
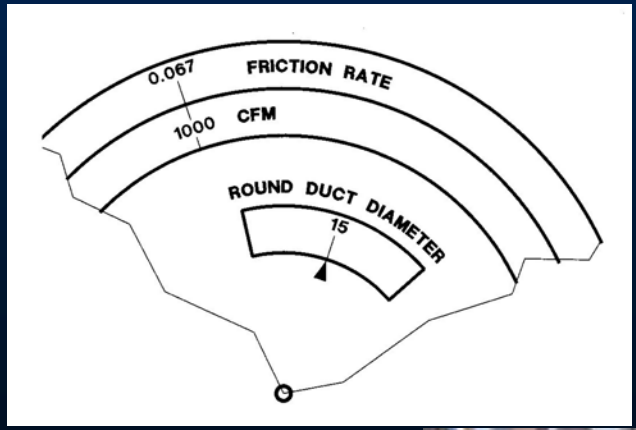


Figure 3-5

$$FR = \frac{0.20 \times 100}{300} = 0.067 \text{ IWC}/100$$



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Basic Duct Sizing Principles

Effective Length

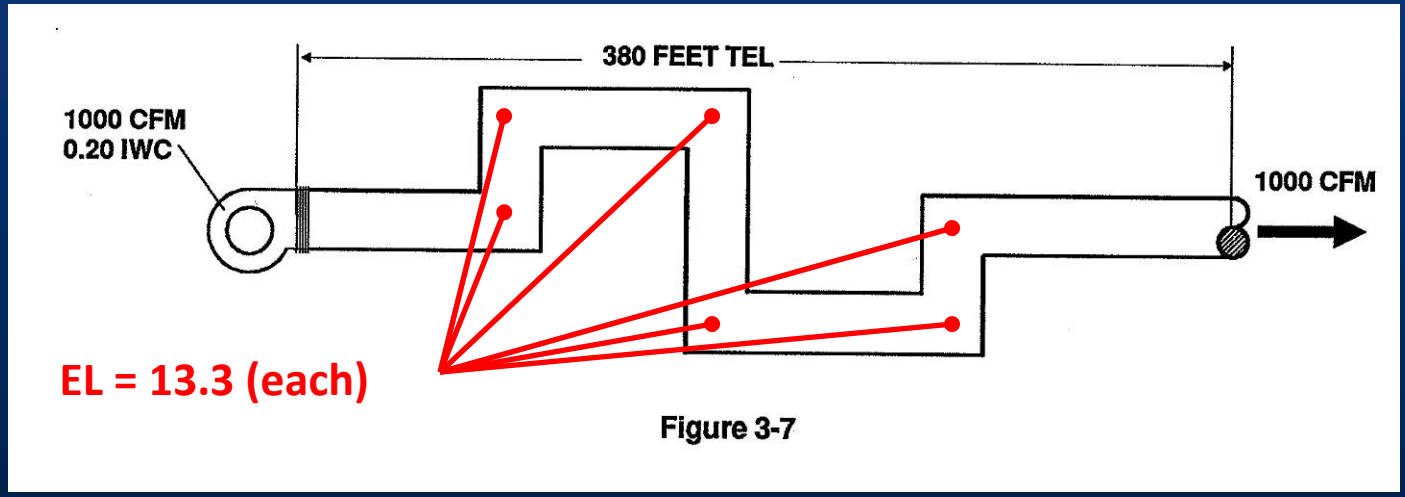


Figure 3-7

$$FR = \frac{0.20 \times 100}{380} = 0.053 \text{ IWC}/100$$

Duct size changes from 15” to 16” round pipe

Basic Duct Sizing Principles

Branch Ducts – Constant Friction Rate (FR = 0.042)

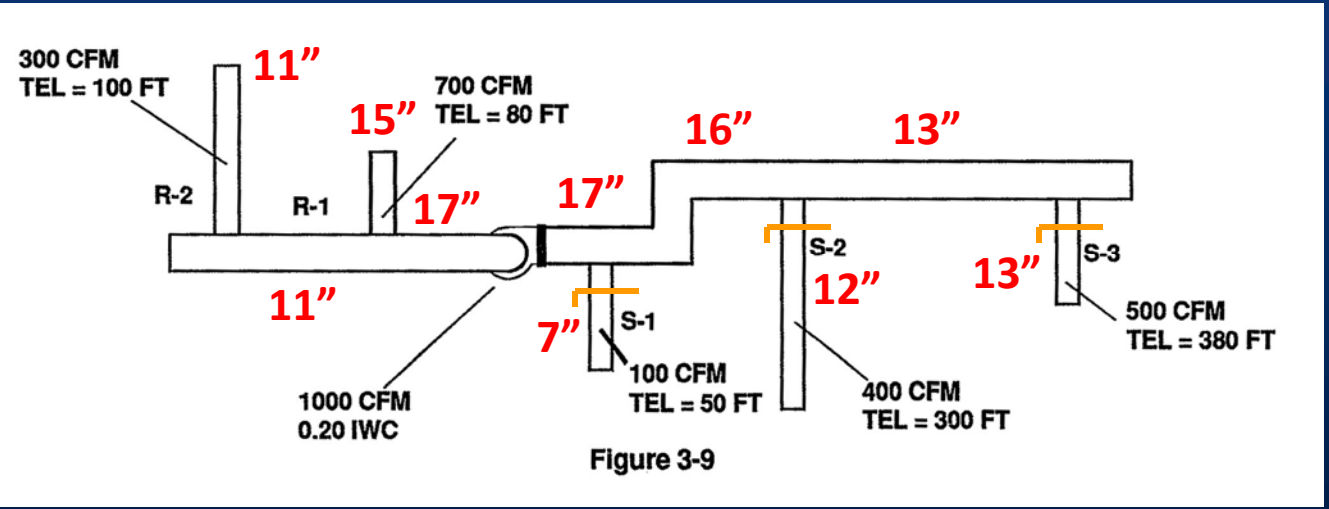


Figure 3-9

This is NOT how IBACOS designs systems

Basic Duct Sizing Principles

Component Pressure Drops

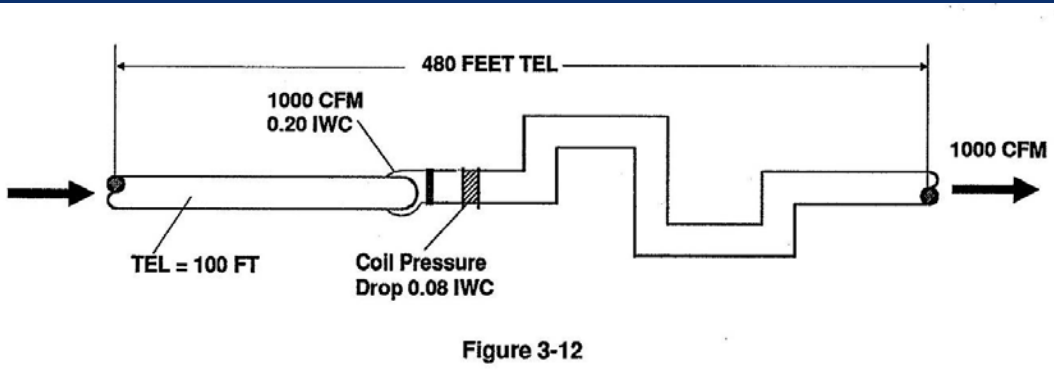
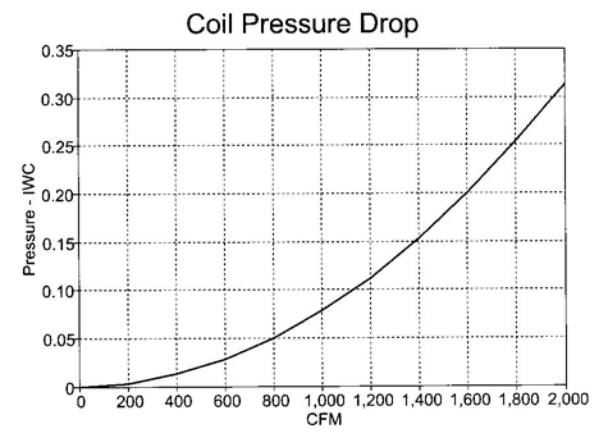


Figure 3-12



$$FR = \frac{(0.20 - 0.08) \times 100}{480} = 0.053 \text{ IWC}/100$$

Duct size changes from 16” to 19” round pipe

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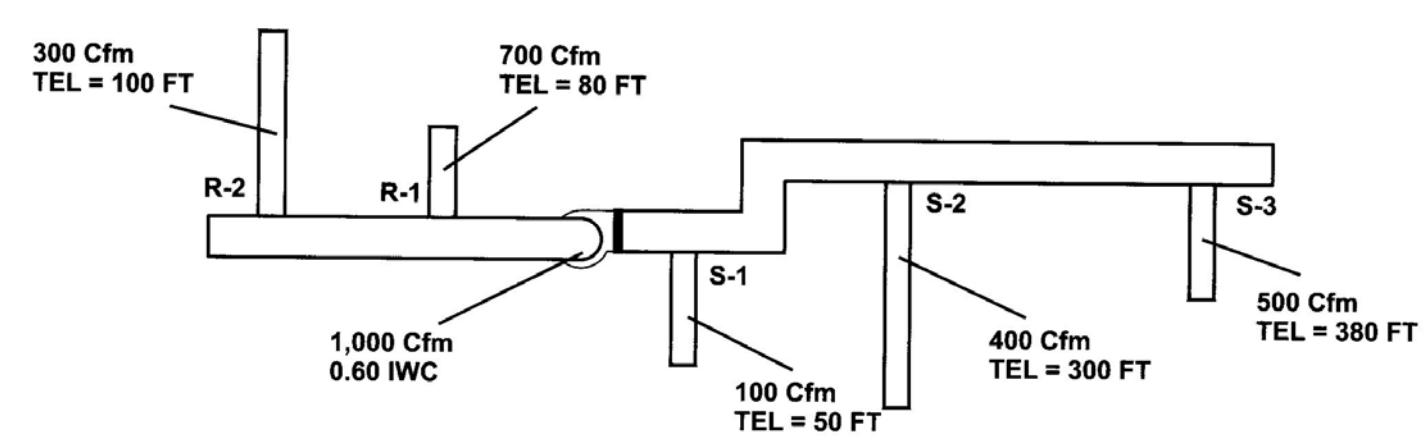
Basic Duct Sizing Principles

Velocity Limits



$$FR = \frac{0.6 \times 100}{480} = 0.125 \text{ IWC}/100$$

Basic Duct Sizing Principles

Velocity Limits

Trunk Section	Cfm	FR	Diameter for Air flow	Velocity (Fpm)	Design Velocity (Fpm)	Diameter for Velocity	Design Diameter
Fan to S1	1,000	0.125	13.5"	1,050	900	14.5"	15"
S1 to S2	900	0.125	13.0"	1,000	900	13.8"	14"
S2 to S3	500	0.125	10.3"	890	900	10.2"	11"
Fan to R1	1,000	0.125	13.5"	1,050	700	16.5"	17"
R1 to R2	300	0.125	8.5"	780	700	9.0"	9"

Runouts	Cfm	FR	Diameter for Air flow	Velocity (Fpm)	Design Velocity (Fpm	Diameter for Velocity	Design Diameter
S1	100	0.125	5.5"	600	900	4.5"	6"
S2	400	0.125	9.5"	840	900	9.1"	10"
S3	500	0.125	10.3"	880	900	10.2"	11"
R1	700	0.125	11.7"	960	600	14.8"	15"
R2	300	0.125	8.5"	780	600	9.6"	10"

Velocity is typically the limiting factor as the supply FR is above 0.08 IWC or the return FR is above 0.05 IWC

Heating and Cooling

Selecting, Sizing, and Installing for Comfort (Part II)

Brad Oberg, Chief Technology Officer, IBACOS

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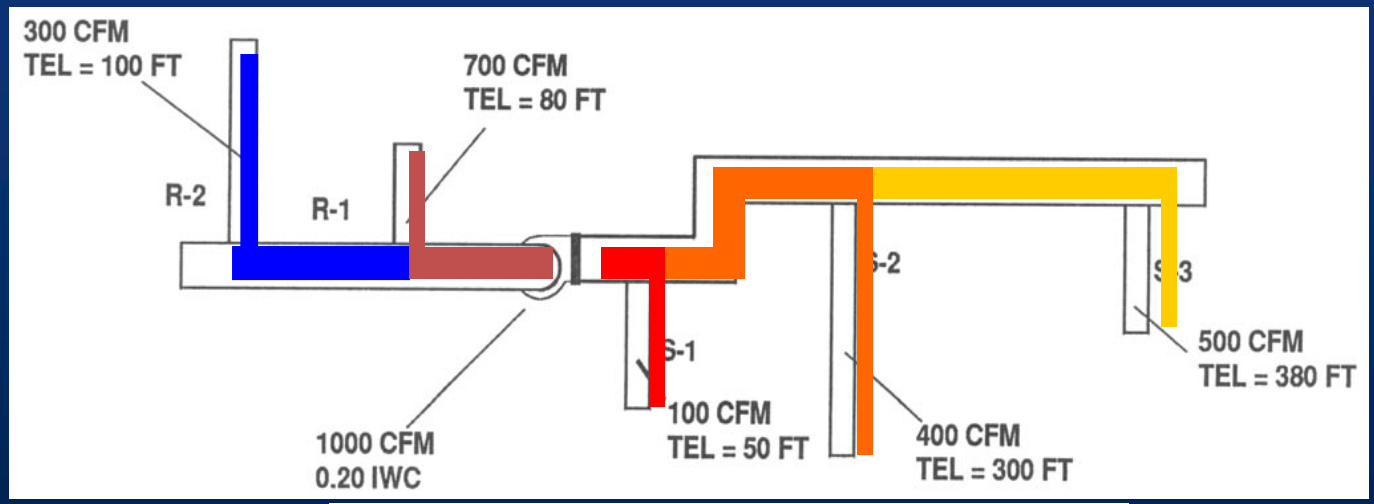
Fundamental Principles

- Calculate the total effective length, then calculate friction rate, then size all ductwork



FR = $\frac{0.20 \times 100}{480}$ = 0.042 IWC/100

Trunks	CFM	F/100	Diameter
Fan to S-1	1000	0.042	17"
S-1 to S-2	900	0.042	16"
S-2 to S-3	500	0.042	13"
Fan to R-1	1000	0.042	17"
R-1 to R-2	300	0.042	11"

Runouts	CFM	F/100	Diameter
S-1	100	0.042	7"
S-2	400	0.042	12"
S-3	500	0.042	13"
R-1	700	0.042	15"
R-2	300	0.042	11"

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Why is velocity critical to loads

Ducts outside the thermal enclosure

- Heat gain and loss during non operation
- Heat gain and loss during operation

Ducts inside the thermal enclosure

- Heat gain and loss during non operation
- Heat gain and loss during operation

Duct size and load response

Bigger ducts

- More surface area
- Slower delivery
- More air at wrong temperature

Some ducts big and some ducts small

- Differential rates of delivery
- Impossible to balance
- Who has control of thermostat?

15 to 30% increase to the load

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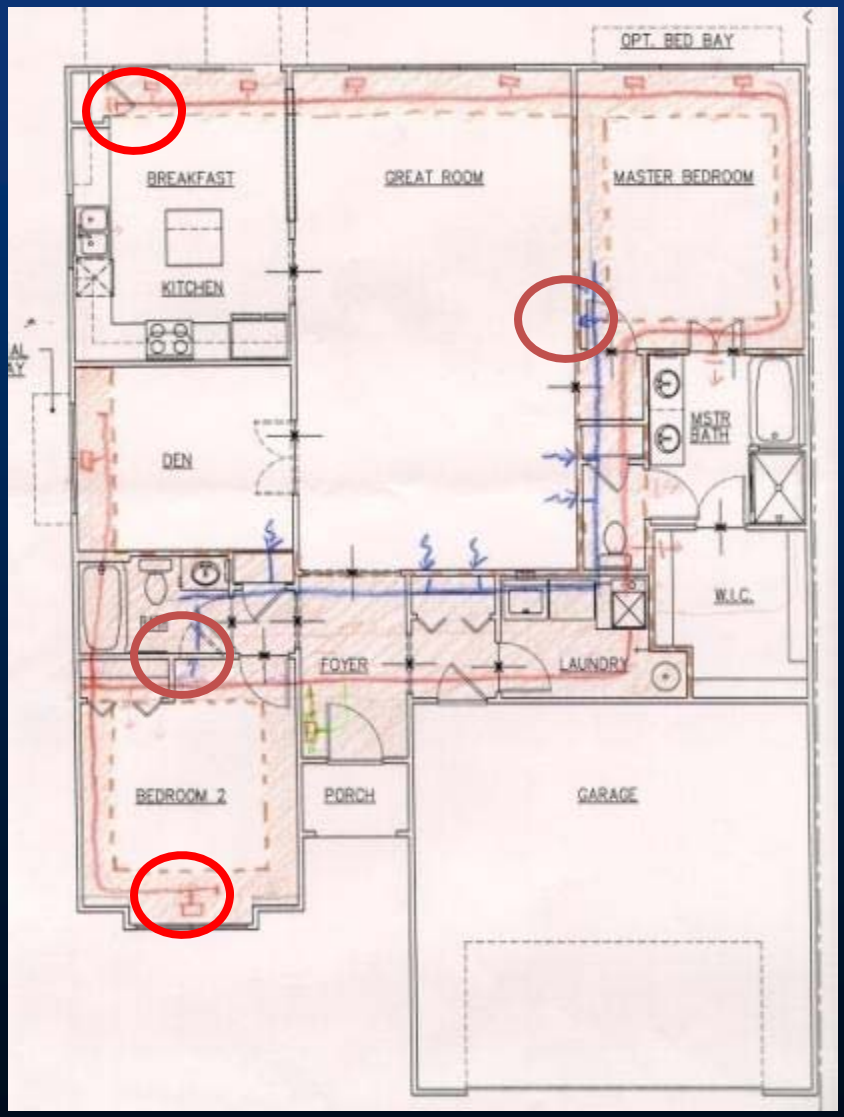
Manual D Duct Sizing Procedure

- Sketch a duct configuration
- Calculate total effective length



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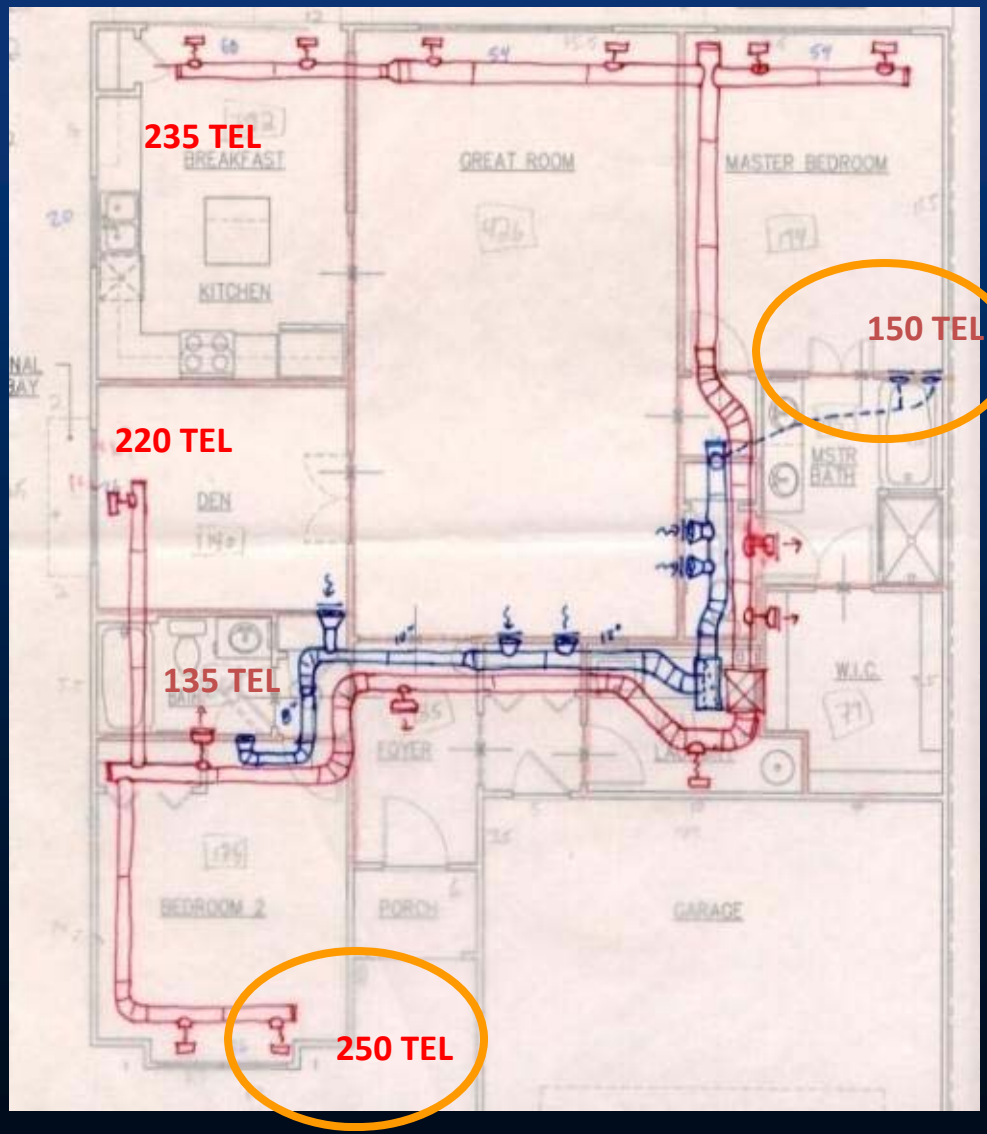
Manual D Duct Sizing Procedure

- Sketch a duct configuration
- Calculate total effective length



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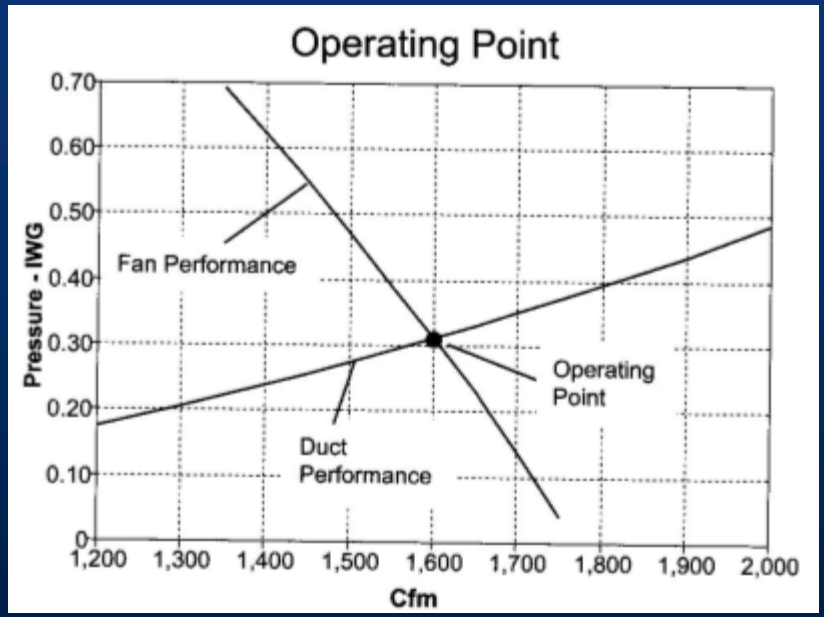
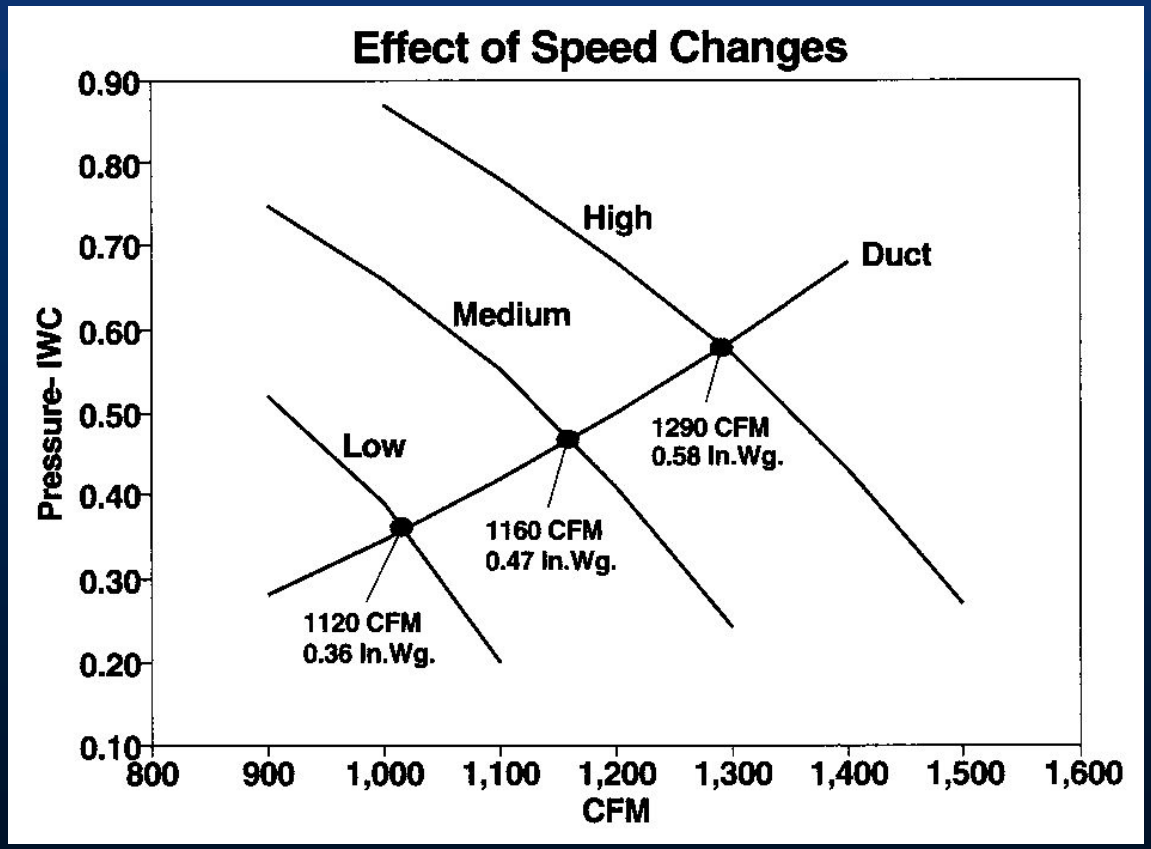
System Operating Point

- System Operating Point
- Changing Blower Wheel Speed
- Changing System Resistance
- Operating Range
- Drawing the System Curve
- Drawing the Blower Curve
- Establishing the Operating Point
- Wheel Speed Design Value
- Balance Point Diagram - Application



System Operating Point

Changing Blower Wheel Speed



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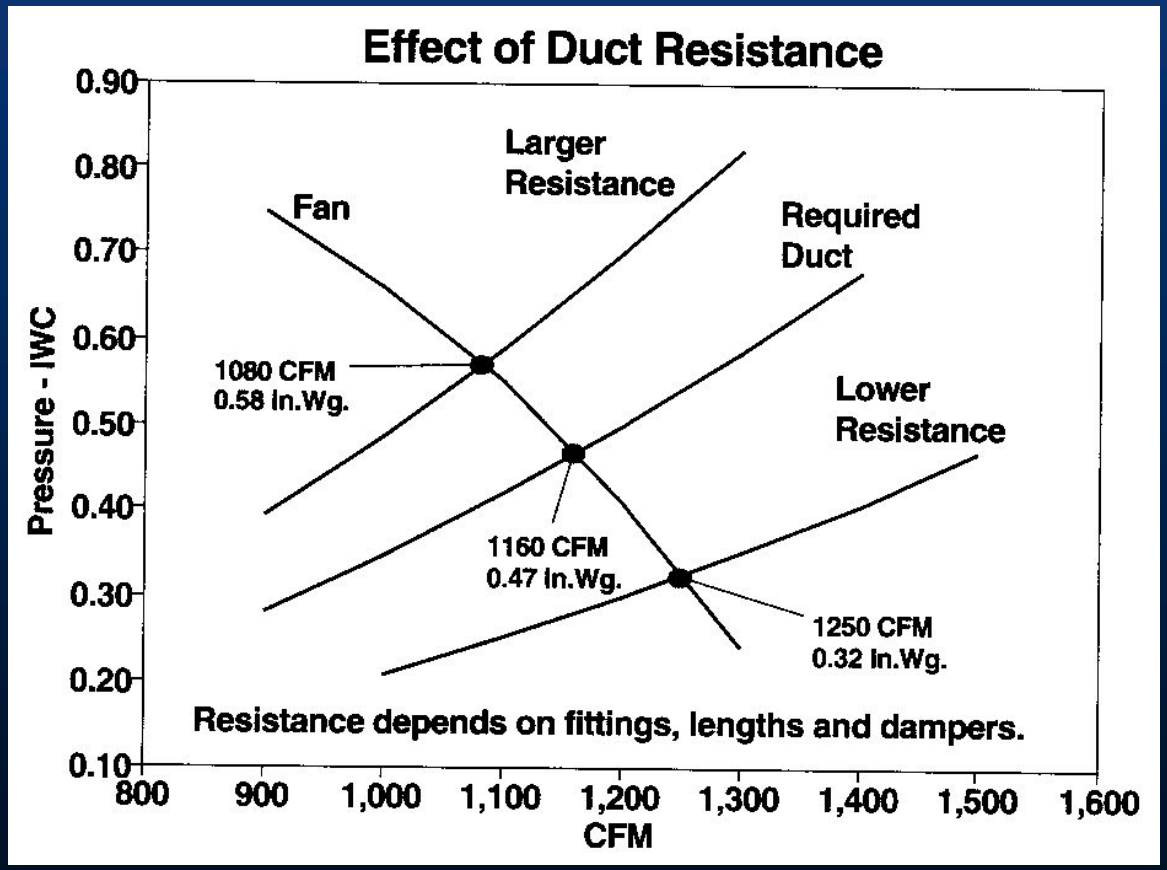
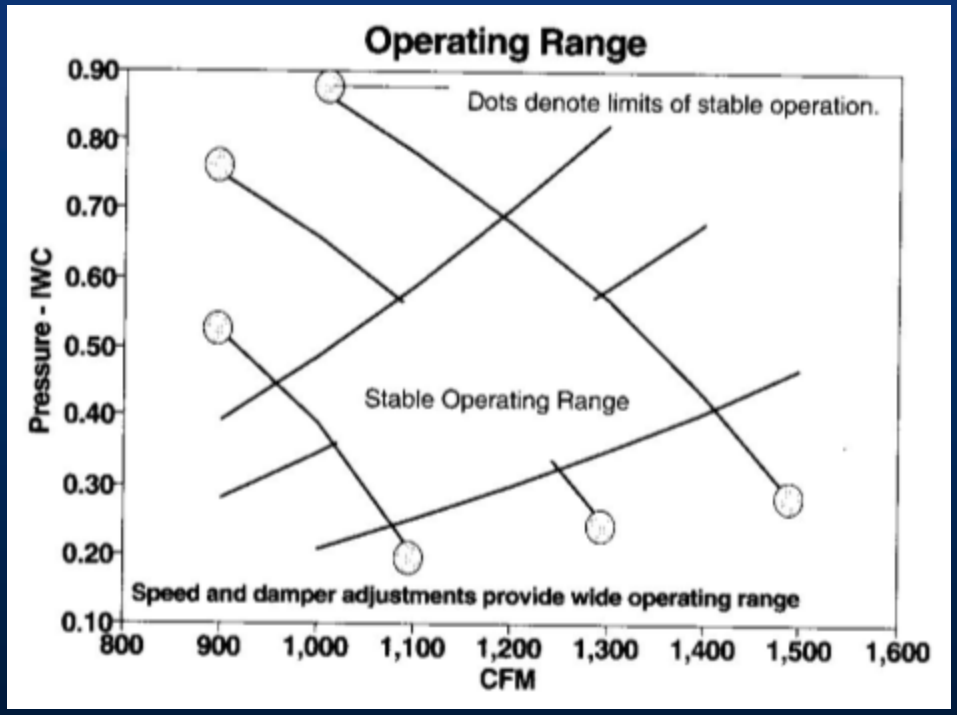
System Operating Point

Changing System Resistance



System Operating Point

Operating Range



Blower CFM should slightly exceed design CFM when all the registers, balancing dampers and control dampers are in the wide open position.

Blowers

- Blower Selection
- Multi-Speed Operating Point Blower
- Variable Speed, Operating Range Blower
- Blower Wheel Speed Vs. System Type
- External Static Pressure
- Air Density Correction
- Inlet and Discharge Conditions

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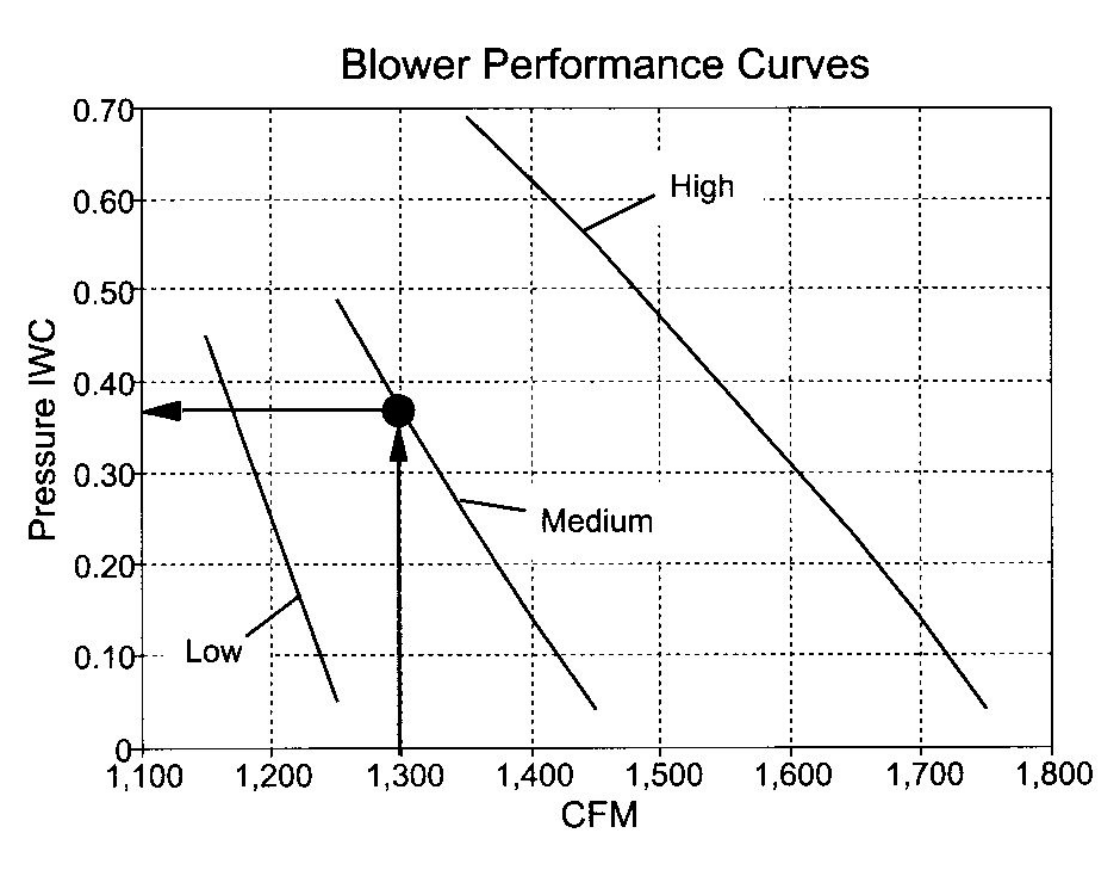
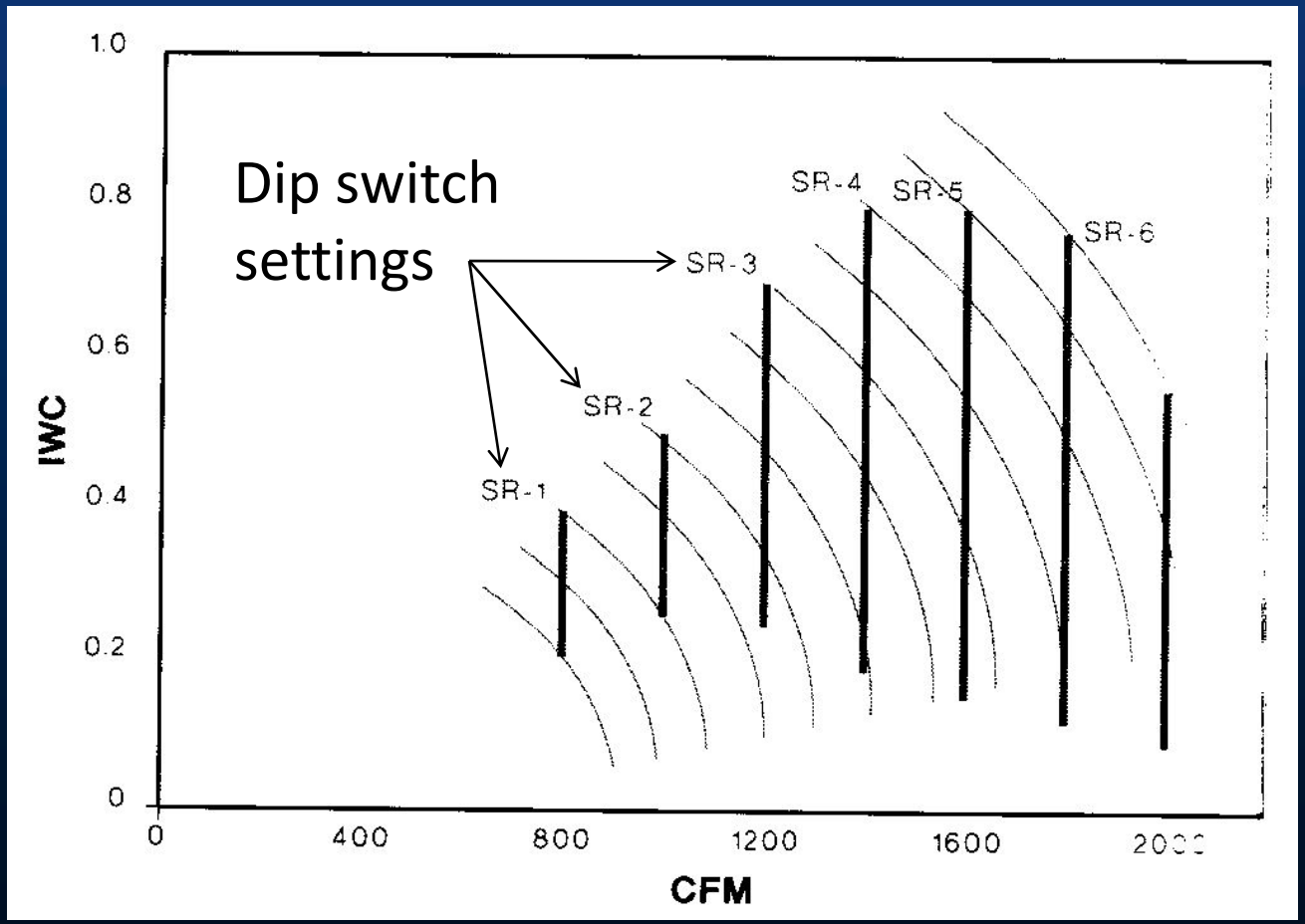
Blowers

Multi-Speed Operating Point Blower



Blowers

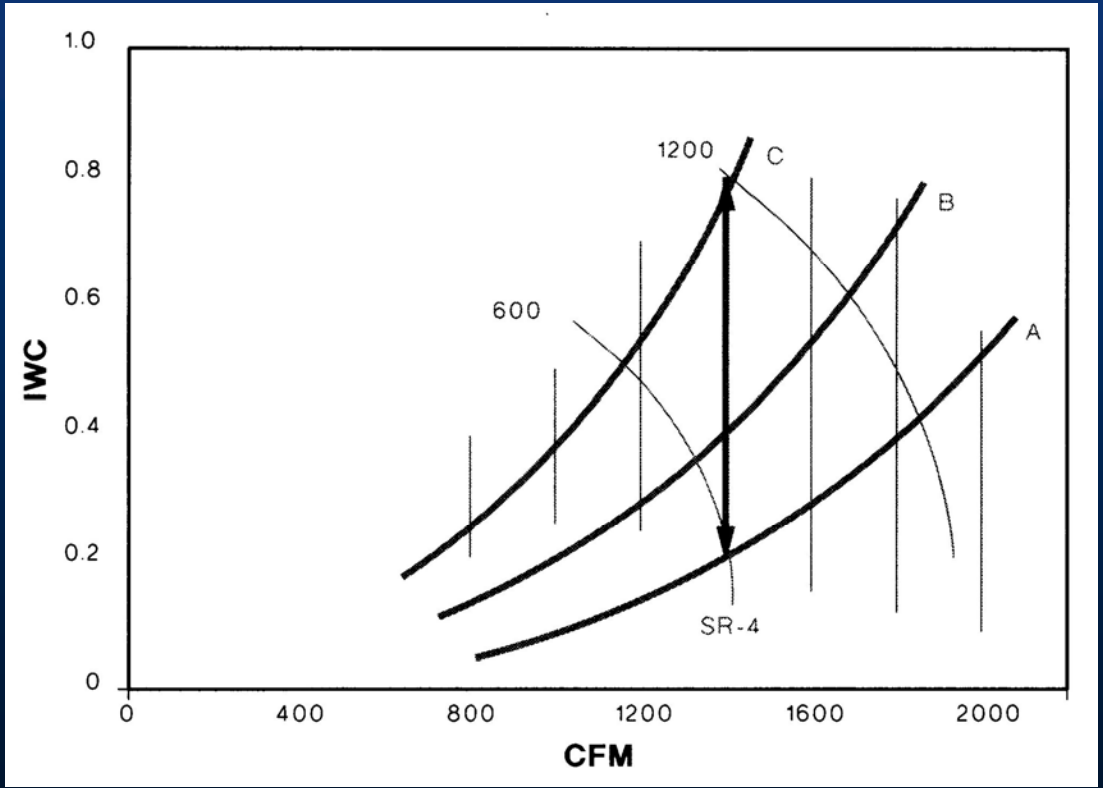
Variable Speed, Operating Range Blower



Blowers

Variable Speed, Operating Range Blower

- Constant CFM across variable system resistance is achieved by variable speed blower
- Variable speed equipment should not be used to compensate for poorly designed ductwork!



Blowers

Single-Speed Operation

- Min/Max air flow requirements for heat exchangers and coils are specified by manufacturers.
- Can compromise heating or cooling performance when one season dominates
- Desirable for optimum performance of diffusers

Two-Speed Operation

- Provides better match between system and load
- Provides more consistent airflow in zoned systems
- May cause air distribution problems at terminal outlets

System Performance Issues

- Straight Section Pressure Drop
- Duct Material
- Required Standard of Care for Installing Flex-Duct
- Excess Length for Flex-Duct
- Panned Joist/Stud Space
- Fitting Pressure Losses
- ΔP for Air-Side Components
- Supply Outlet, Return Grille and Hand Damper ΔP
- Low Resistance Return Path

System Performance Issues

Duct Material

- Material construction differences affect friction loss.
- Metal duct friction depends on seam spacing, seam construction and is marginally affected by surface roughness.
- Flex-duct friction rates vary widely due to variations in materials and manufacturing
- Duct board and duct liner is affected by seam spacing, seam construction, fasteners and the roughness of he facing material.

System Performance Issues

Installing Flexible Wire Helix Duct

- Duct sections cut to length (0% to 4% longer than the straight line span.)
- Duct centerline relatively straight, no significant sag or snaking (2.5 inches sag per 5 feet of span, or less).
- The radius of a bend or turn shall not be less than the diameter of the airway (R/D shall be 1.0 or greater.)
- No crimping or crushing at any point in a duct run.

System Performance Issues

Flex Duct Installation

- Keep ducts stretched
- Avoid tight radius turns
- Size with appropriate friction chart

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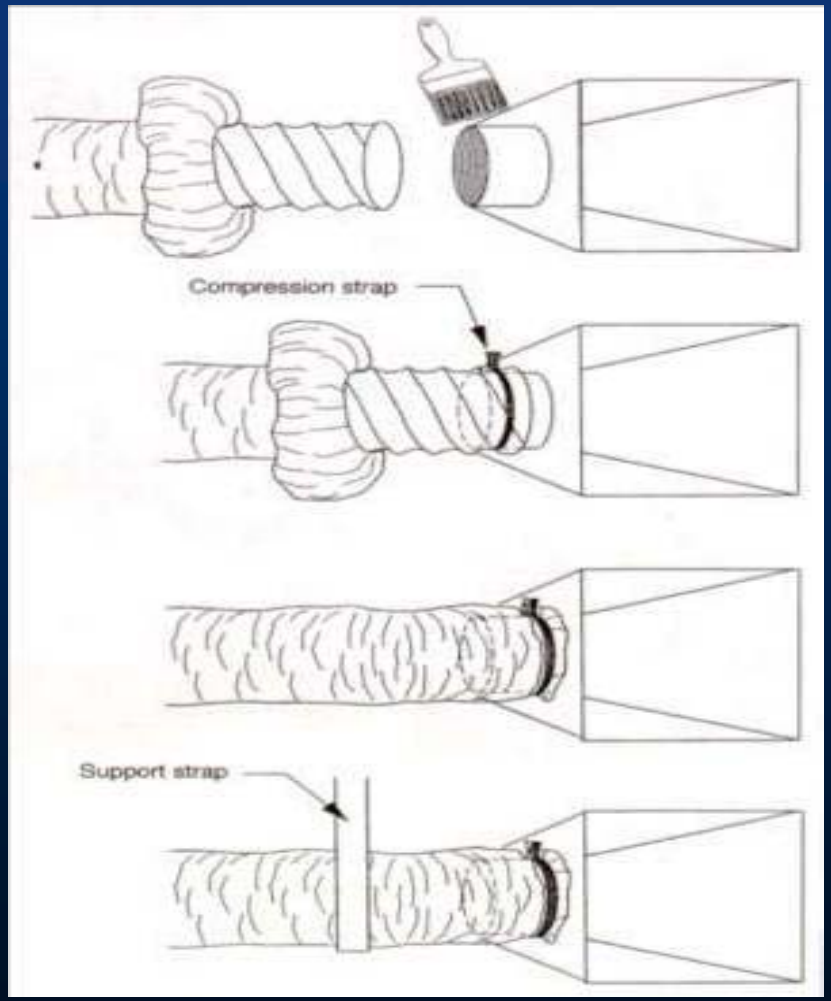
System Performance Issues

Installing Flexible Wire Helix Duct

1. Apply mastic to collar
2. Secure liner to collar
3. Secure outer cover to form a vapor tight connection
4. Support duct adequately to assure distribution



System Performance Issues

Air Leakage – Duct Sealing

System Performance Issues

Observations

Most crews expect the worst, but are surprised.

After about three jobs, they decide when the best time is to apply mastic. Many crews get the extra time down to 3 hours

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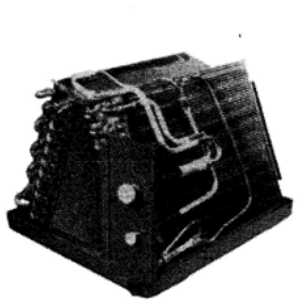
System Performance Issues

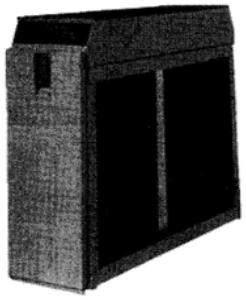
Pressure Drop for Air-Side Components

- Pressure drop increases exponentially as air flow increases linearly.

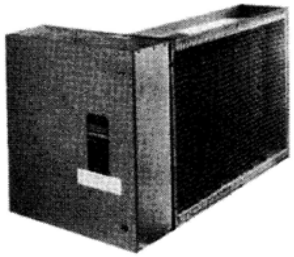
$$P_x \text{ (IWC)} = \text{Resistance}_x = P_1 \times (CFM_x/CFM_1)^2$$



Coil Resistance (IWC)		
Cfm	Dry	Wet
1,000	0.11	0.18
1,200	0.15	0.26
1,400	0.22	0.35
1,600	0.28	0.46



Electronic Filter Resistance	
Cfm	IWC
1,000	0.06
1,200	0.08
1,400	0.12
1,600	0.15



Heater Resistance	
Cfm	IWC
1,000	0.09
1,200	0.13
1,400	0.18
1,600	0.23

Air Distribution System Design

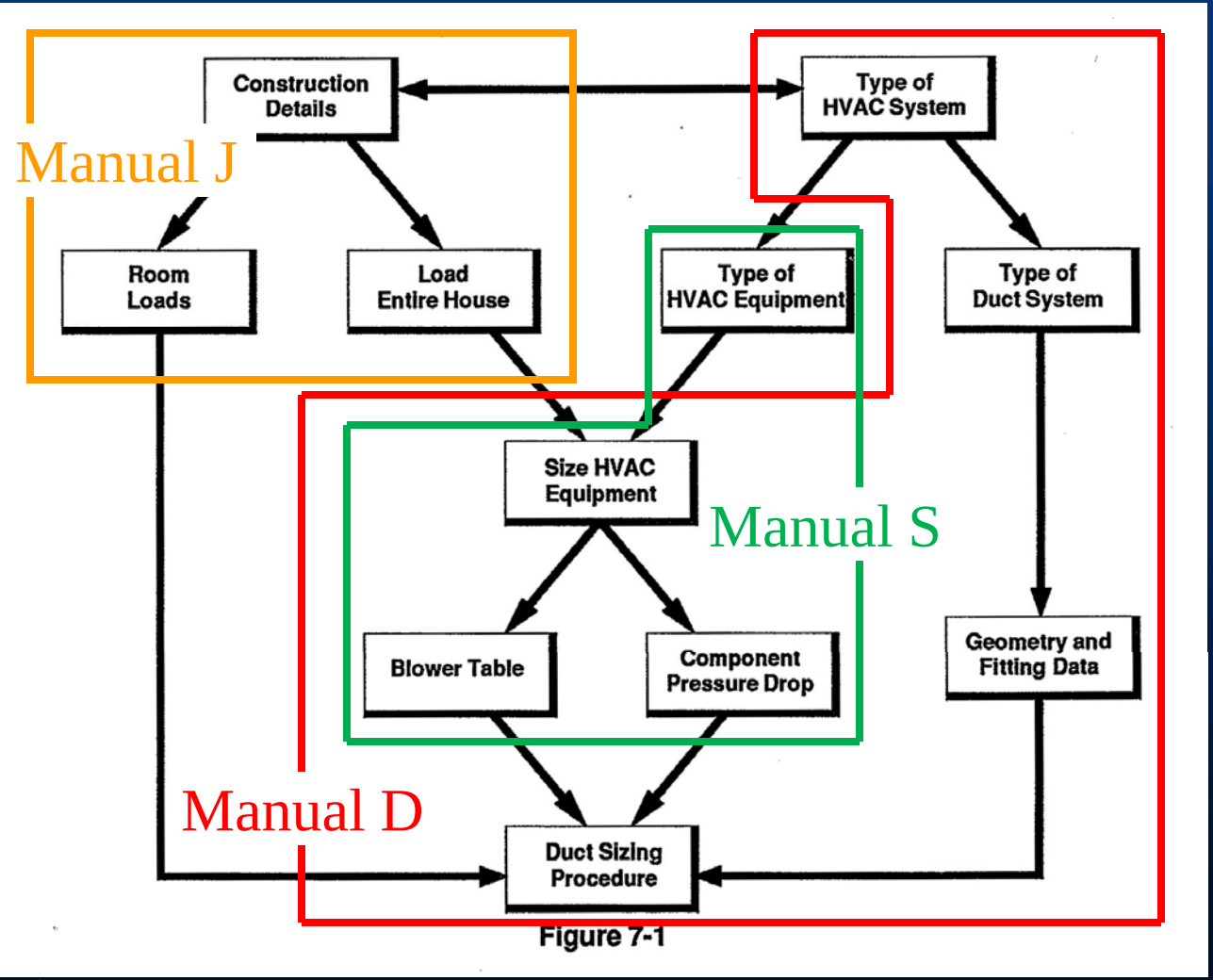


Figure 7-1

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Images courtesy ACCA

Air Distribution System Design

- System Selection
- Load Calculations
- Equipment Sizing
- Fittings
- Geometry
- Duct Material and Fabrication
- Perform the Duct Sizing Calculations

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Air Distribution System Design

Geometry – Radial

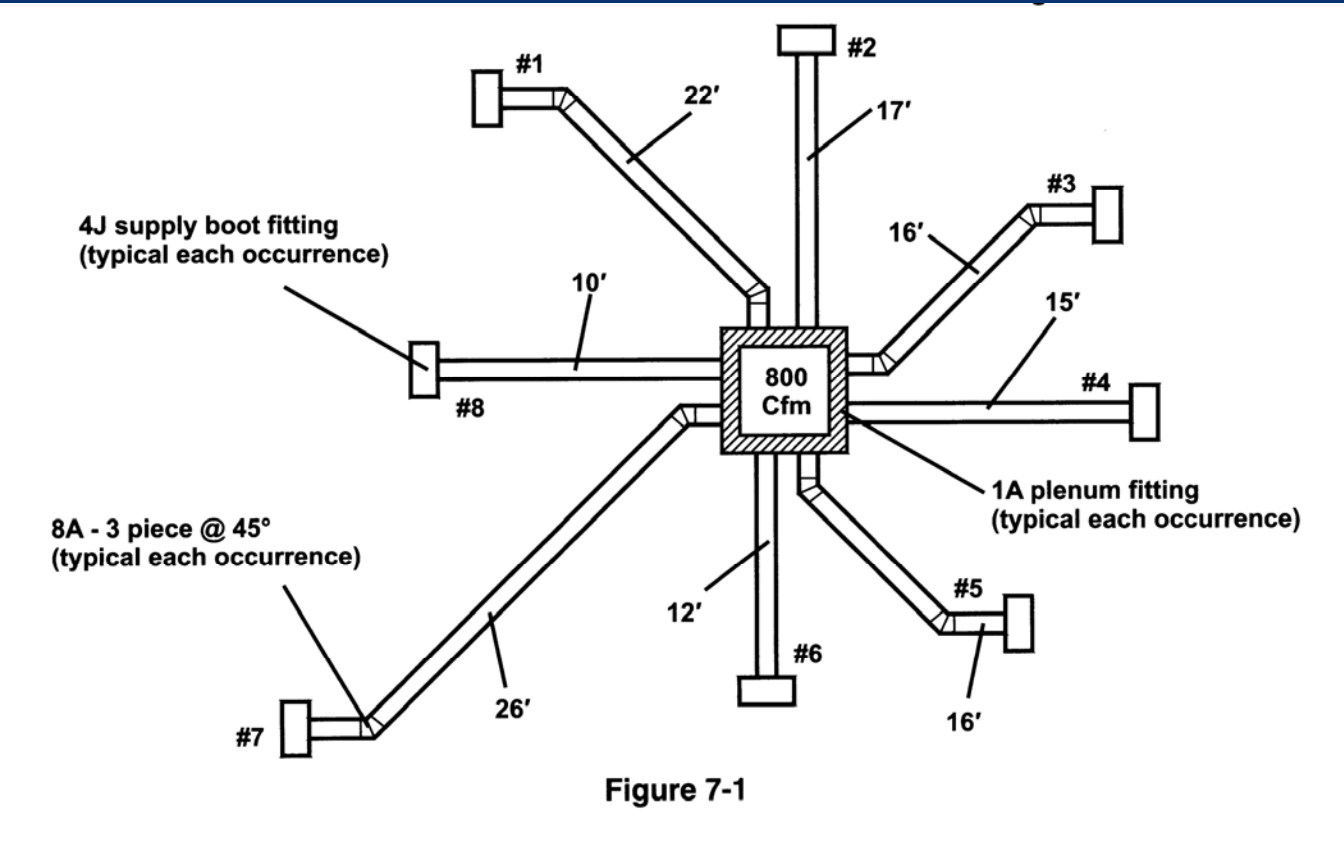
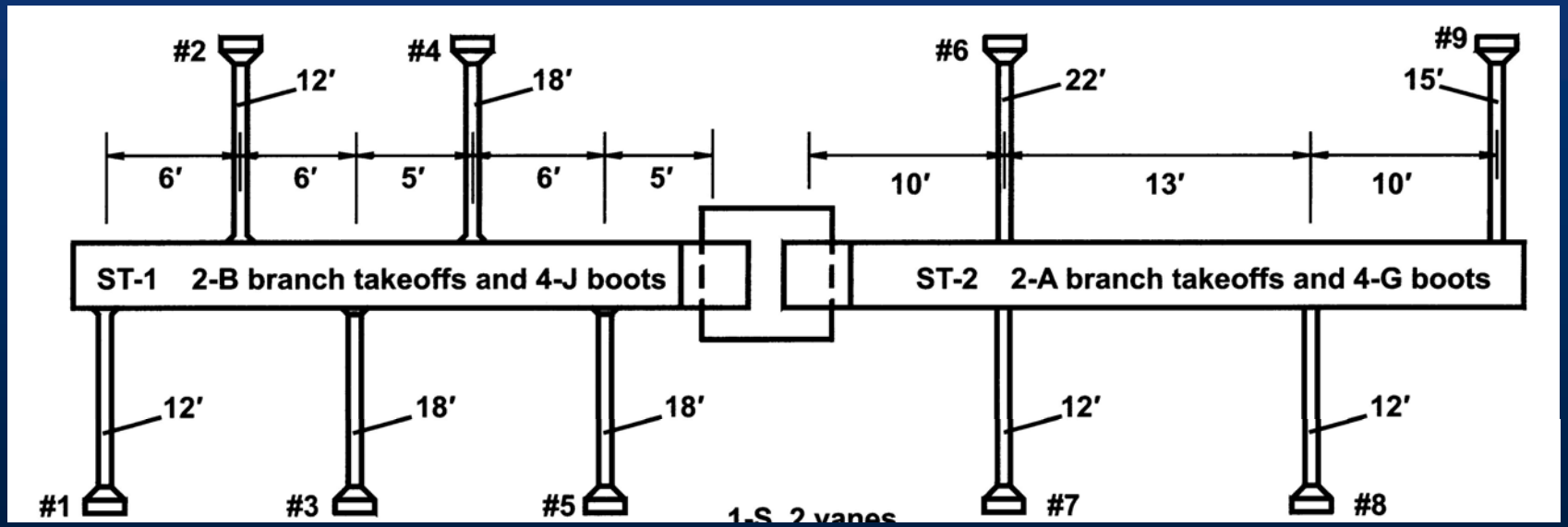


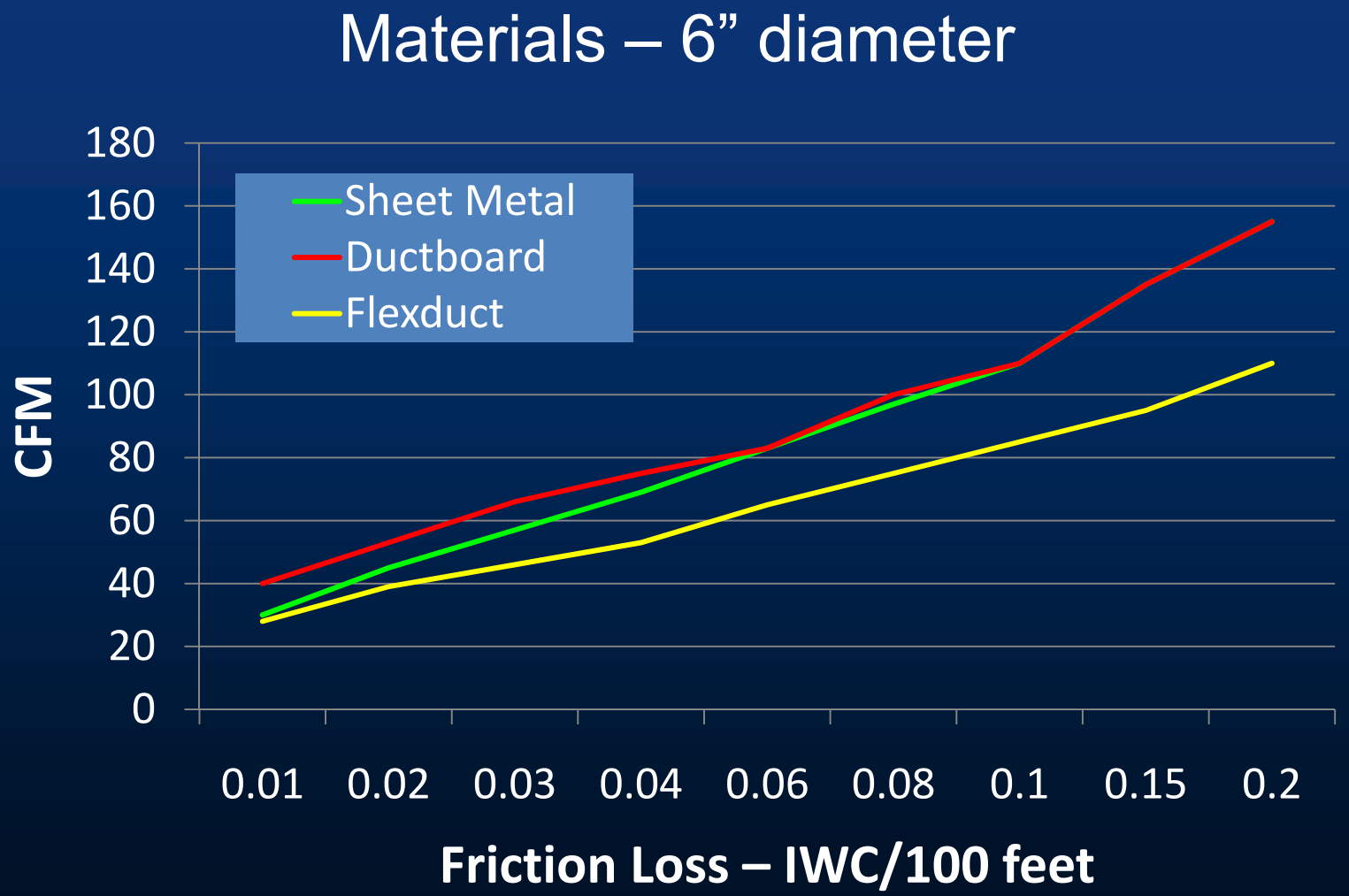
Figure 7-1

Air Distribution System Design

Geometry – Trunk and Branch



Air Distribution System Design



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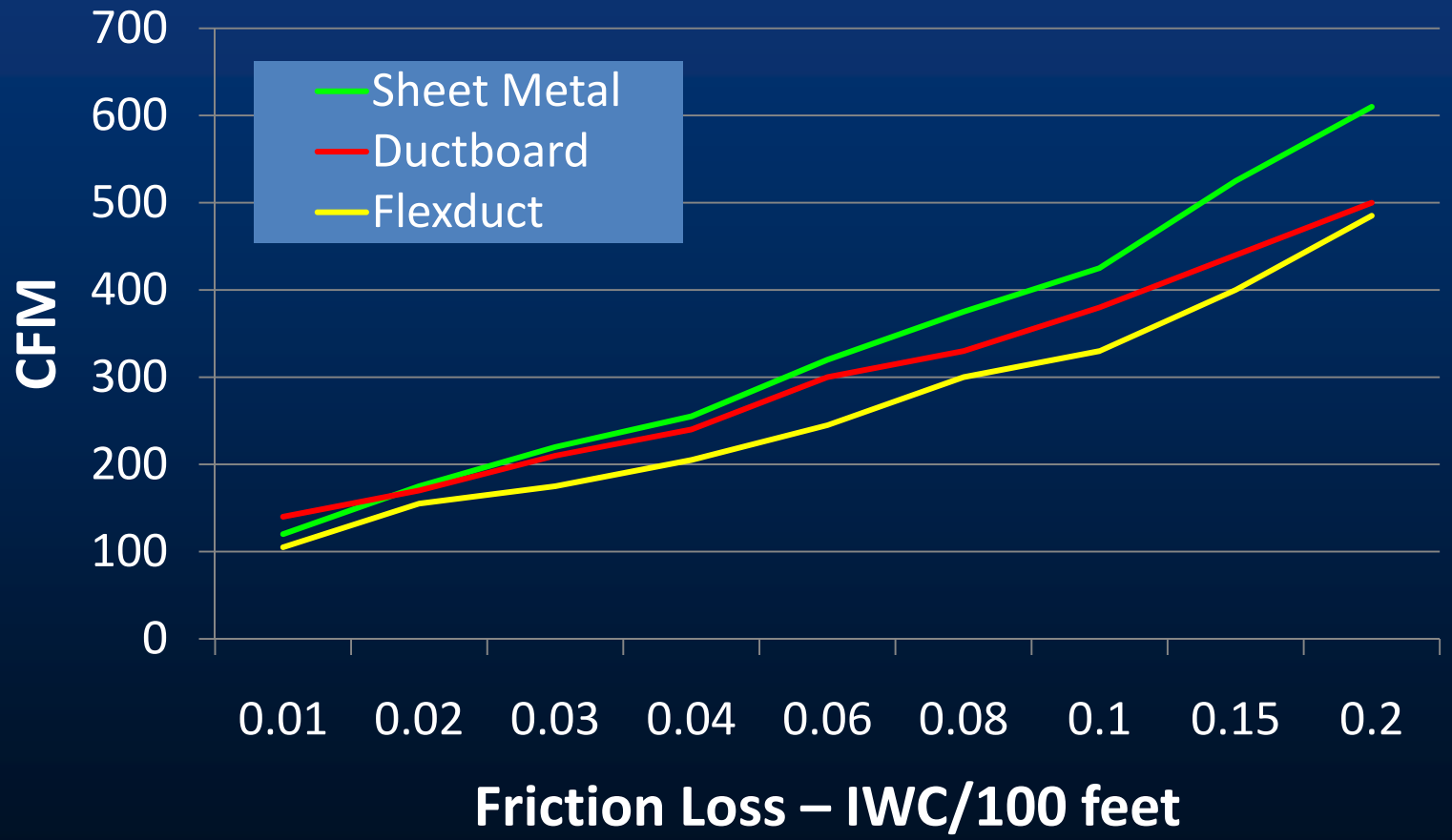
Air Distribution System Design

Materials – 10” diameter



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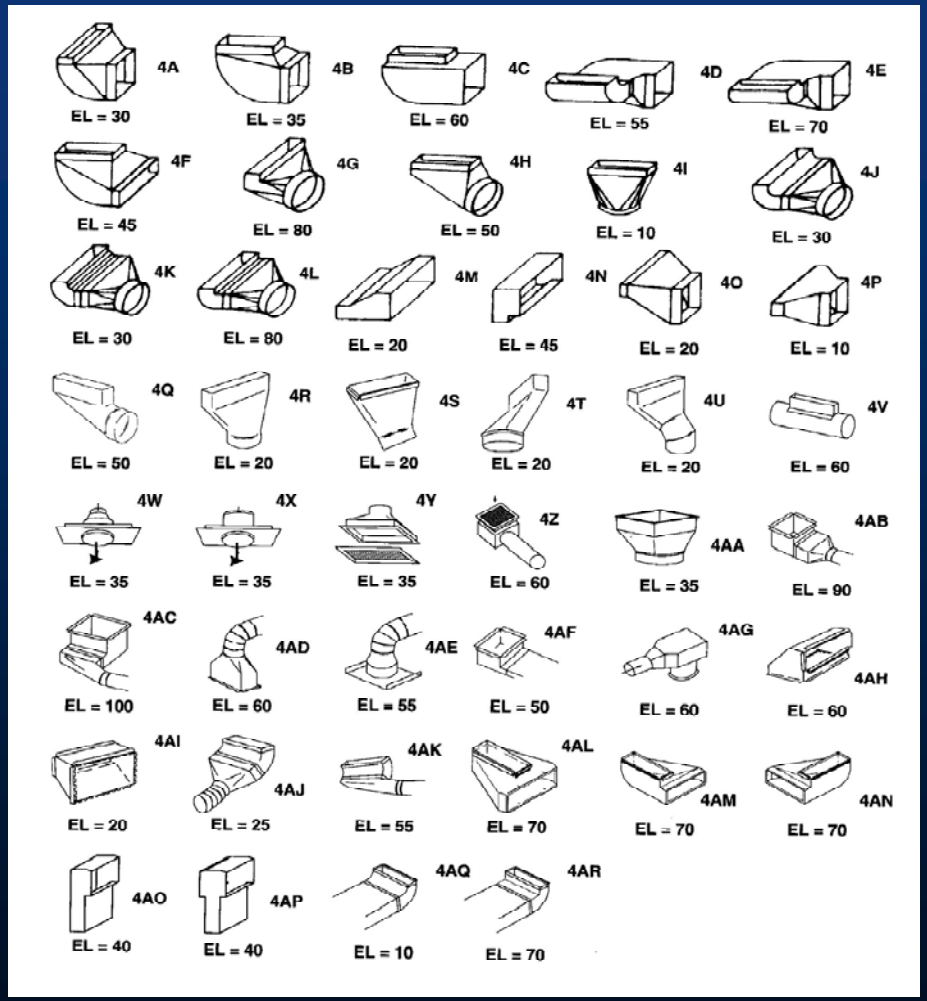
Air Distribution System Design

Fittings

- Not like ASHRAE loss coefficients
- EL only accurate @ 900 fpm and FR=0.08 IWC



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Air Distribution System Design

- We are looking for Straight
- Little resistance
- Proper Velocity (500 to 700 fpm)
- Direct Path
- Quality Approach

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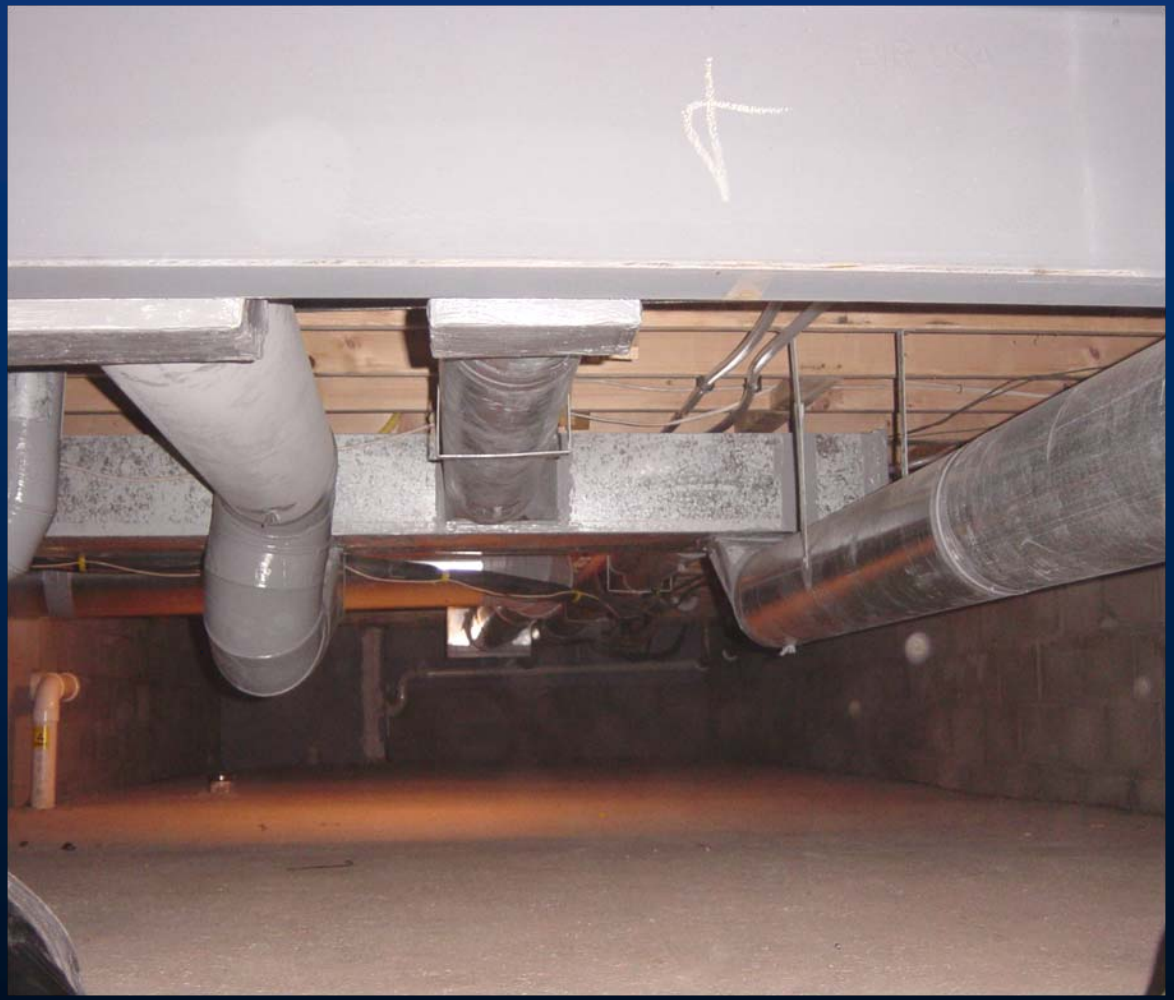
Air Distribution design

Construction Concerns

- *Improper Fittings*
- *Poor system balance*
- *Increased pressure drop*



Supply Main in Crawl space with Branch Takeoffs

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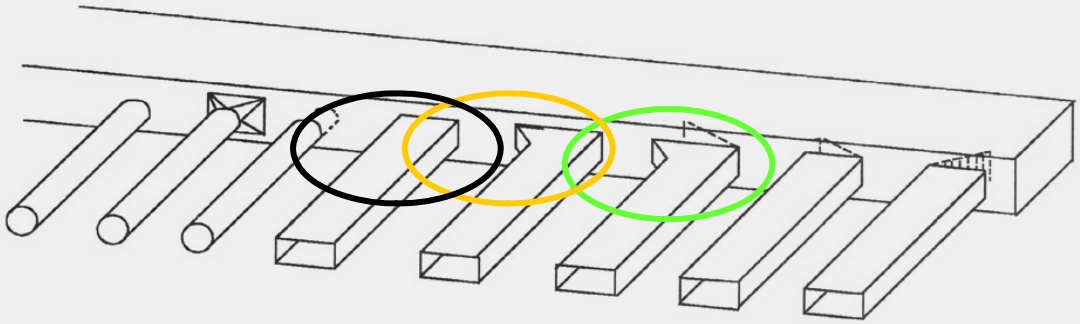
Air Distribution Design

System Design Principles

- *Balance branch run-outs*
- *Convenience*
- *Tradition*
- *Performance*



EL Values		Number of Downstream Branches to End of Trunk Duct or Number of Downstream Branches to a Trunk Reducer					
Fitting		0	1	2	3	4	5 or More
	2-A	35	45	55	65	70	80
	2-B	20	30	35	40	45	50
	2-C	65	65	65	65	70	80
	2-D	40	50	60	65	75	85
	2-E	25	30	35	40	45	50
	2-F	20	20	20	20	25	25
	2-G	65	65	65	70	80	90
	2-H	70	70	70	75	85	95

Note: If the trunk has a reducer, count down to the reducer; then begin counting (again) after the reducer

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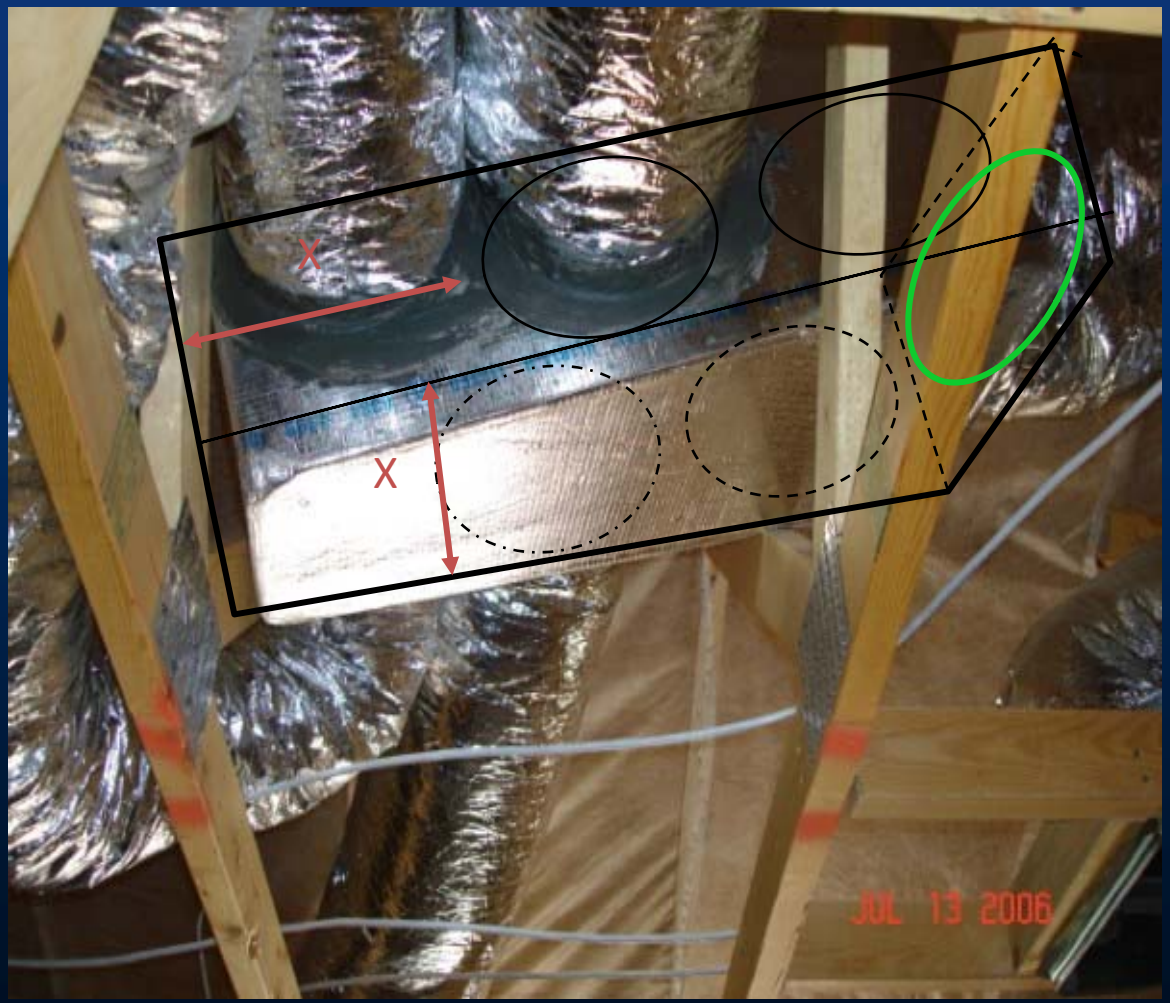
Pressure regain plenum

- Round metal duct section at end of flex run out creates a plenum. The blank end converts velocity pressure to static pressure yielding relatively uniform pressure to all ducts.
- Flow is proportioned by downstream friction and opening size

Pressure regain plenum

- Plenums must create equal pressure across openings to yield proportional flow
- Do not place outlets in last third of plenum. This section must convert velocity pressure to static pressure.
- Duct in NO Zone drain off distribution energy



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Splitter Boxes

- Make splitter boxes as small as needed to just fit the supply duct
- For square splitter boxes, do not take a duct off opposite supply duct connection

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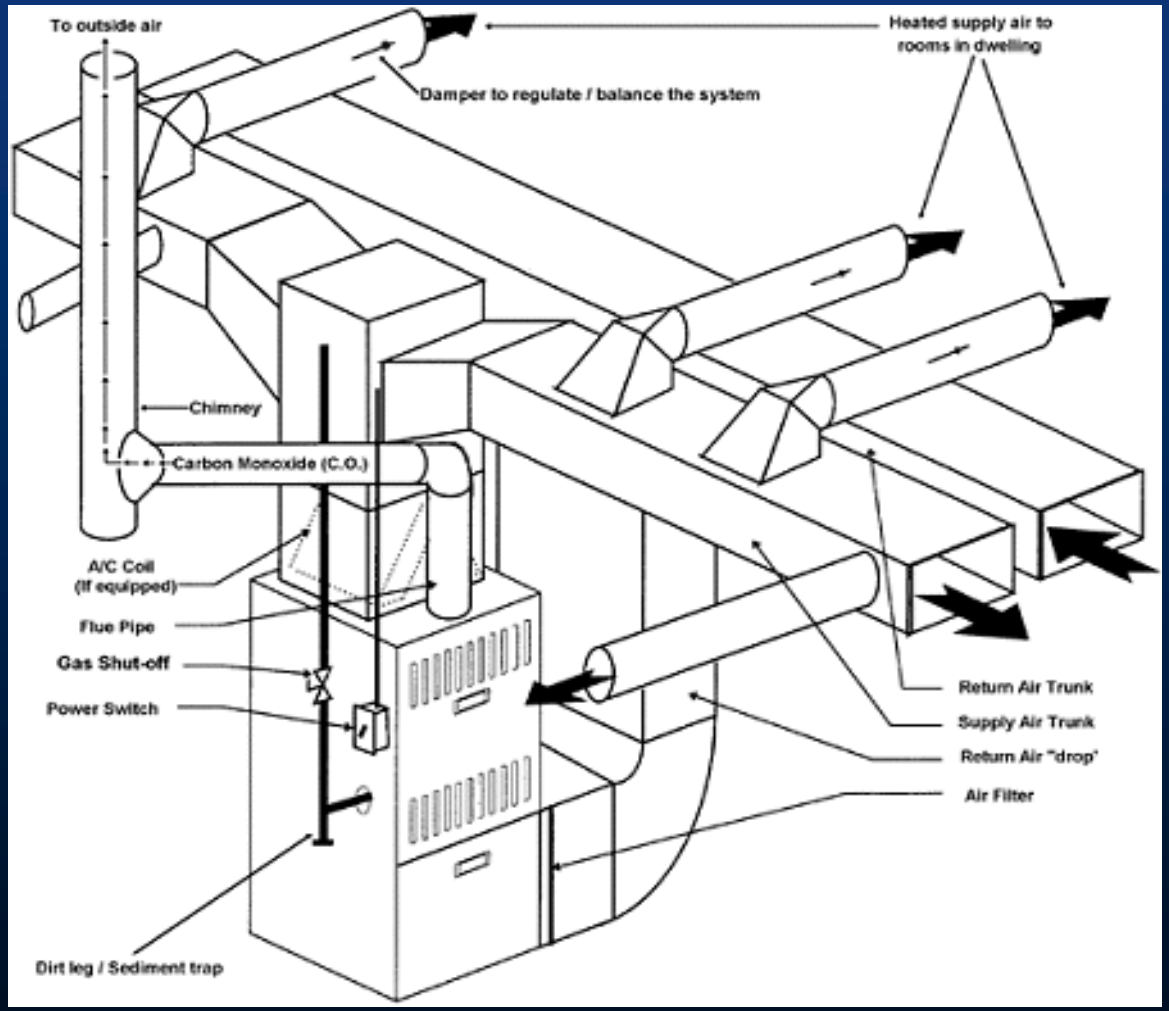
Distribution Strategy

- These are very hard to balance.
- Equal size ducts on opposite sides of inlet/outlet, create no or little static pressure to force distribution to side branches
- In Round duct, two takeoffs on same side shadow each other and reduce flow to second duct

Air Distribution System Design

Performance is controlled by the ten worst decisions

And not the two-hundred good ones



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Duct Sizing Calculations

- Basis for Sizing Procedure
- Balancing Damper Function
- Balancing Damper Requirement
- Design Value for Blower CFM
- Available Static Pressure
- Total Effective Length
- Design Friction Rate Value
- Sensible Cooling Loads
- Summing Room Cooling Loads
- Room CFM
- Summing of Room CFM Values

~~Duck~~ Duct Sizing Calculations

- Number of Runouts for a Room or Space
- Primary Trunks and Secondary Trunks
- Supply Trunk Flow Rates
- Flow Rates for Reducing Trunk Sections
- Return Branch Flow Rates
- Return Trunk Flow Rates
- Branch Airway Sizing
- Trunk Airway Sizing
- Equivalent Rectangular Sizes
- Optional Airway Sizes
- Air Distribution Hardware

Sizing Constant Volume Duct

- Radial Duct System
- Extended Two-Way Plenum System
- Reducing Plenum System
- Primary and Secondary Trunk System with an Operating Point Blower
- Scrutinize Blower Data Footnotes
- Extended Plenum System with Flex Runouts
- Flexible Duct System

Design Implications

- Supply

65	dT	T-sec
110	45	90
120	55	74
130	65	62
140	75	54

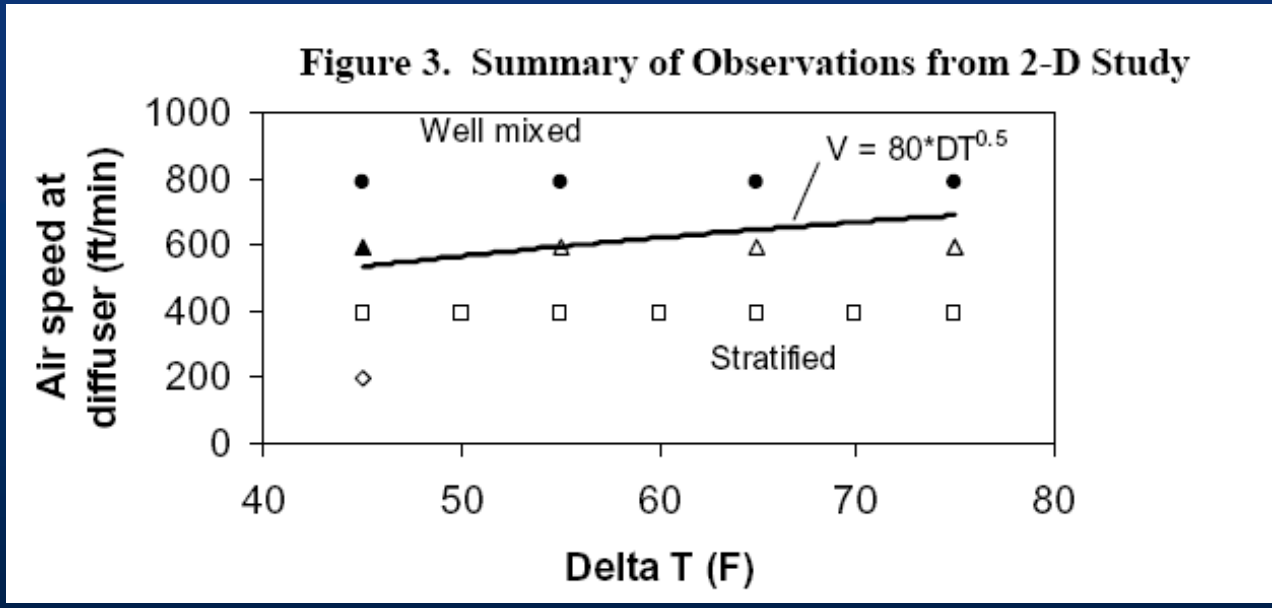

Table 1. Initial Register Specifications (100F Supply @ 470 fpm)			
cfm	Area (in2)	Size	Peak Heating Energy Demand (BTU/hr)
50	15	2"x8"	1512
100	31	2"x15	3024
150	46	3"x15"	4536
200	61	2-2"x15"	6048

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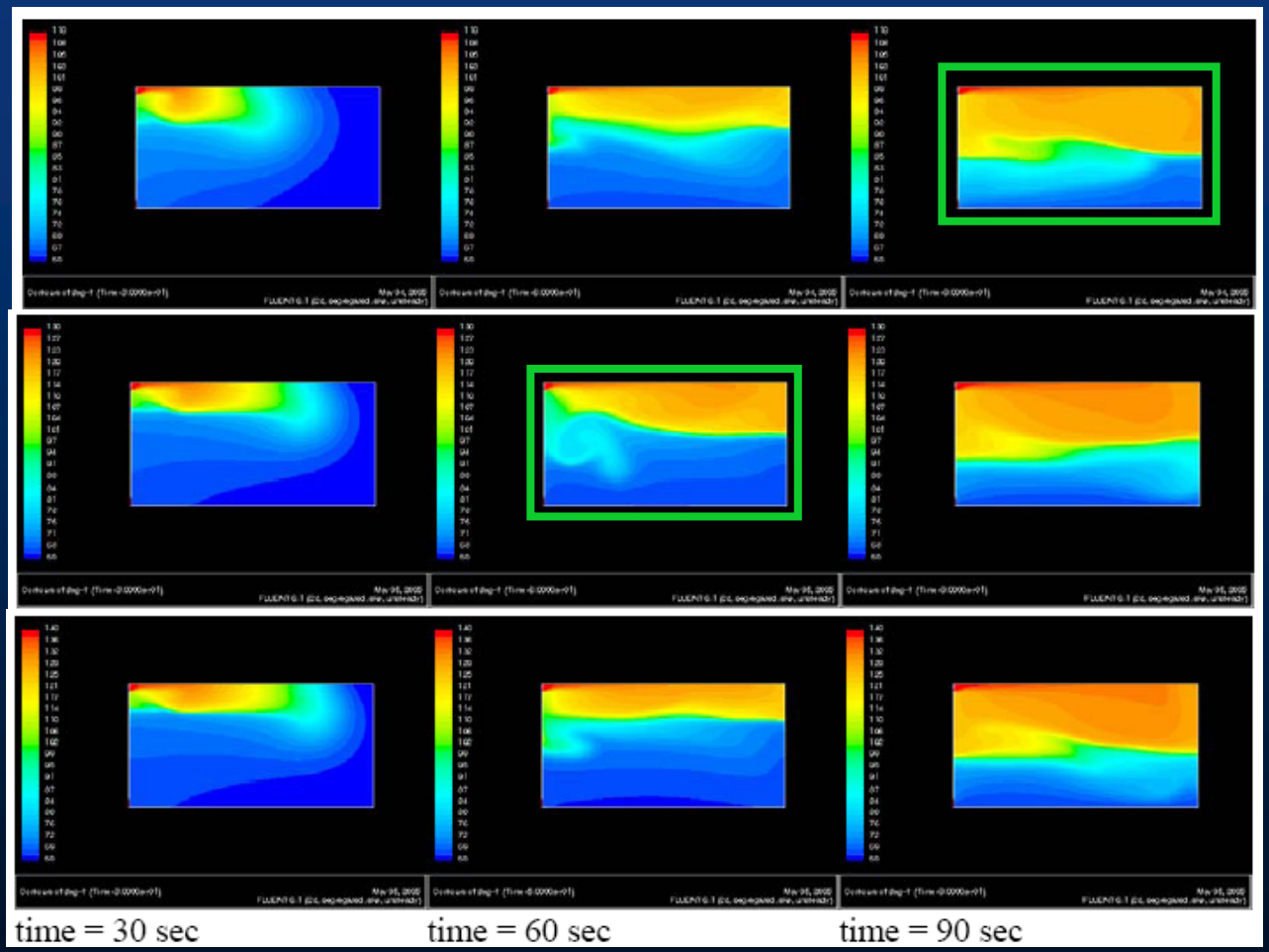
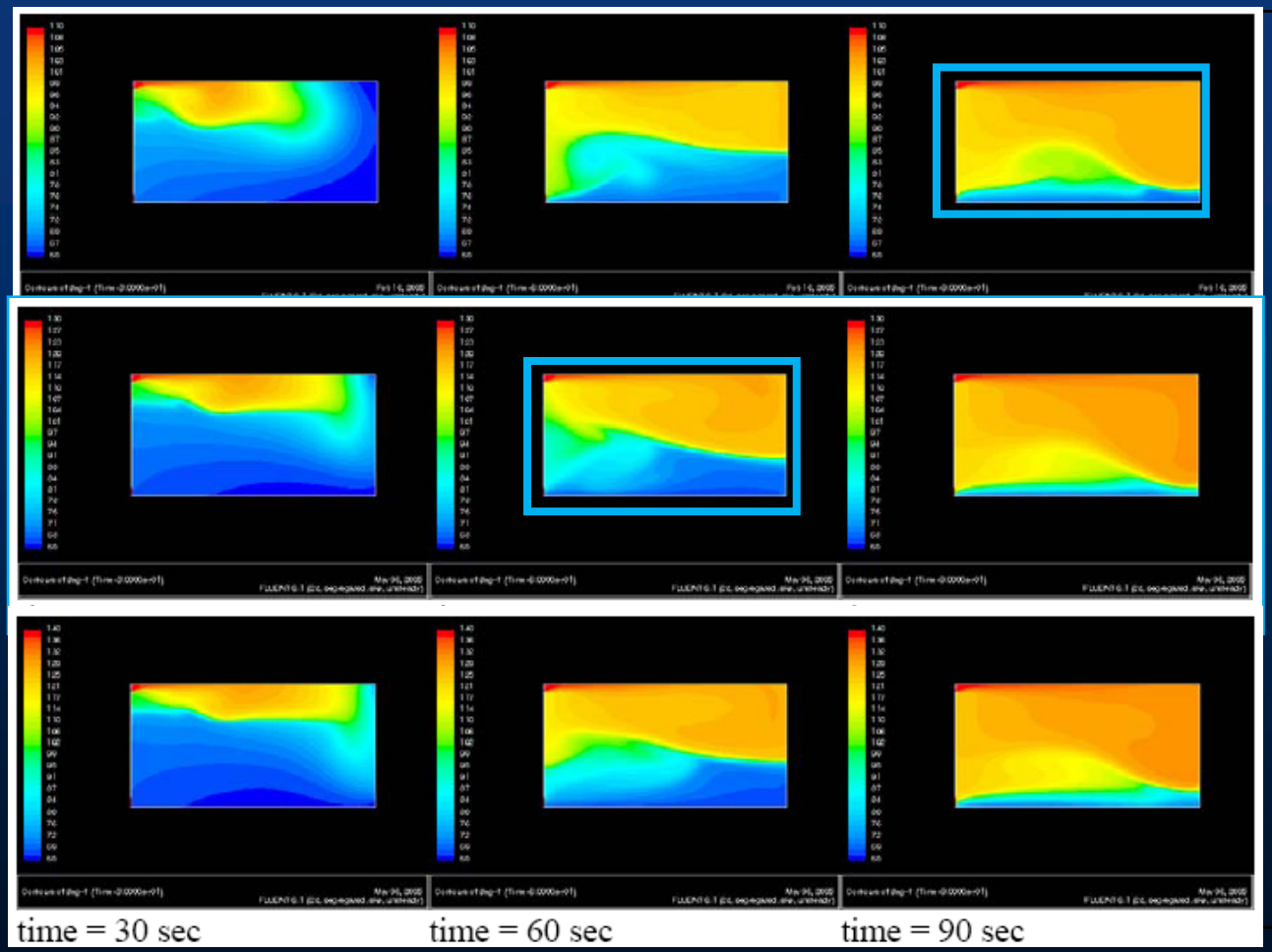
394 f/m supply velocity

- 110 F
- 130 F
- 140 F



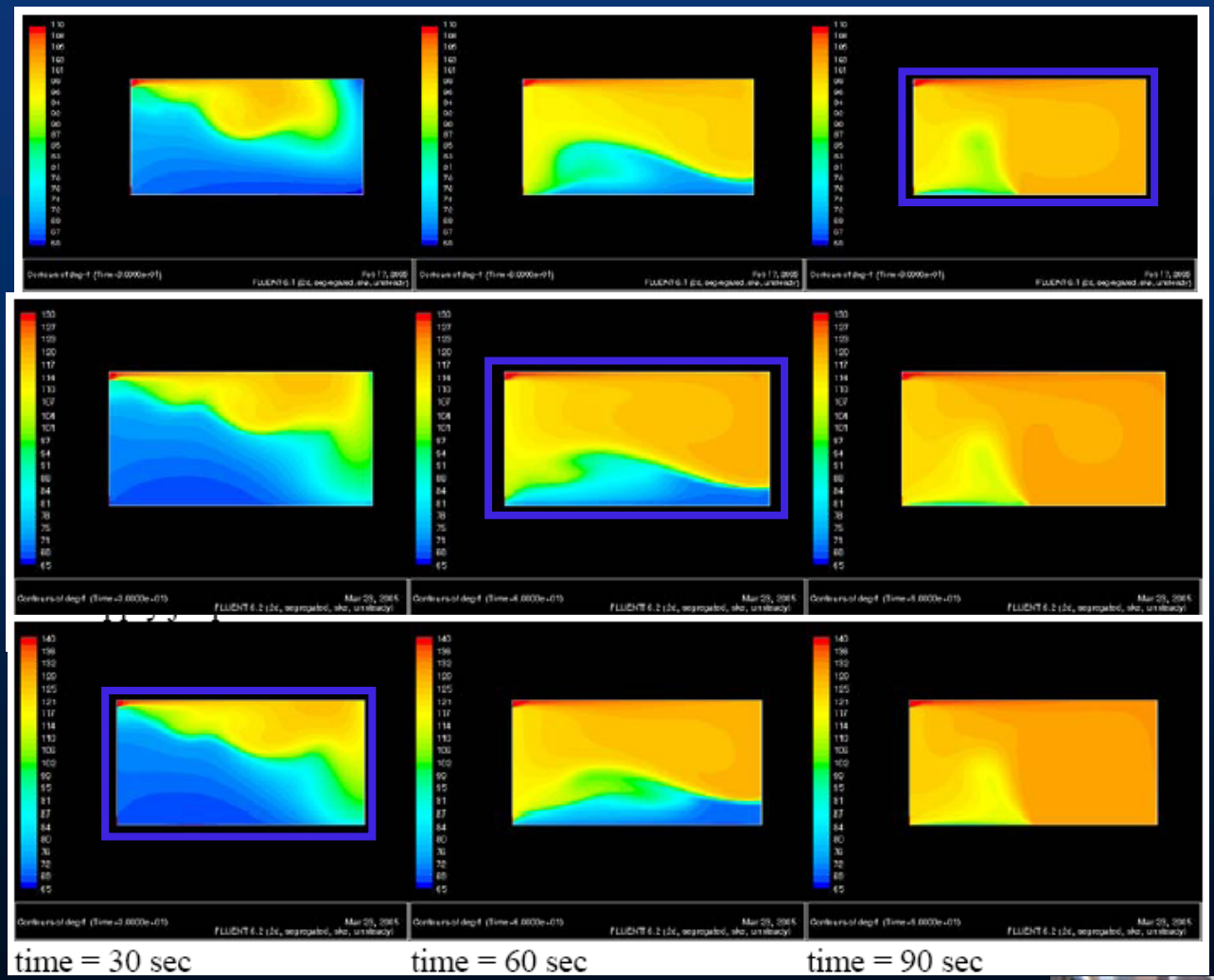
591 f/m supply velocity

- 110 F
- 130 F
- 140 F



787 f/m supply velocity

- 110 F
- 130 F
- 140 F



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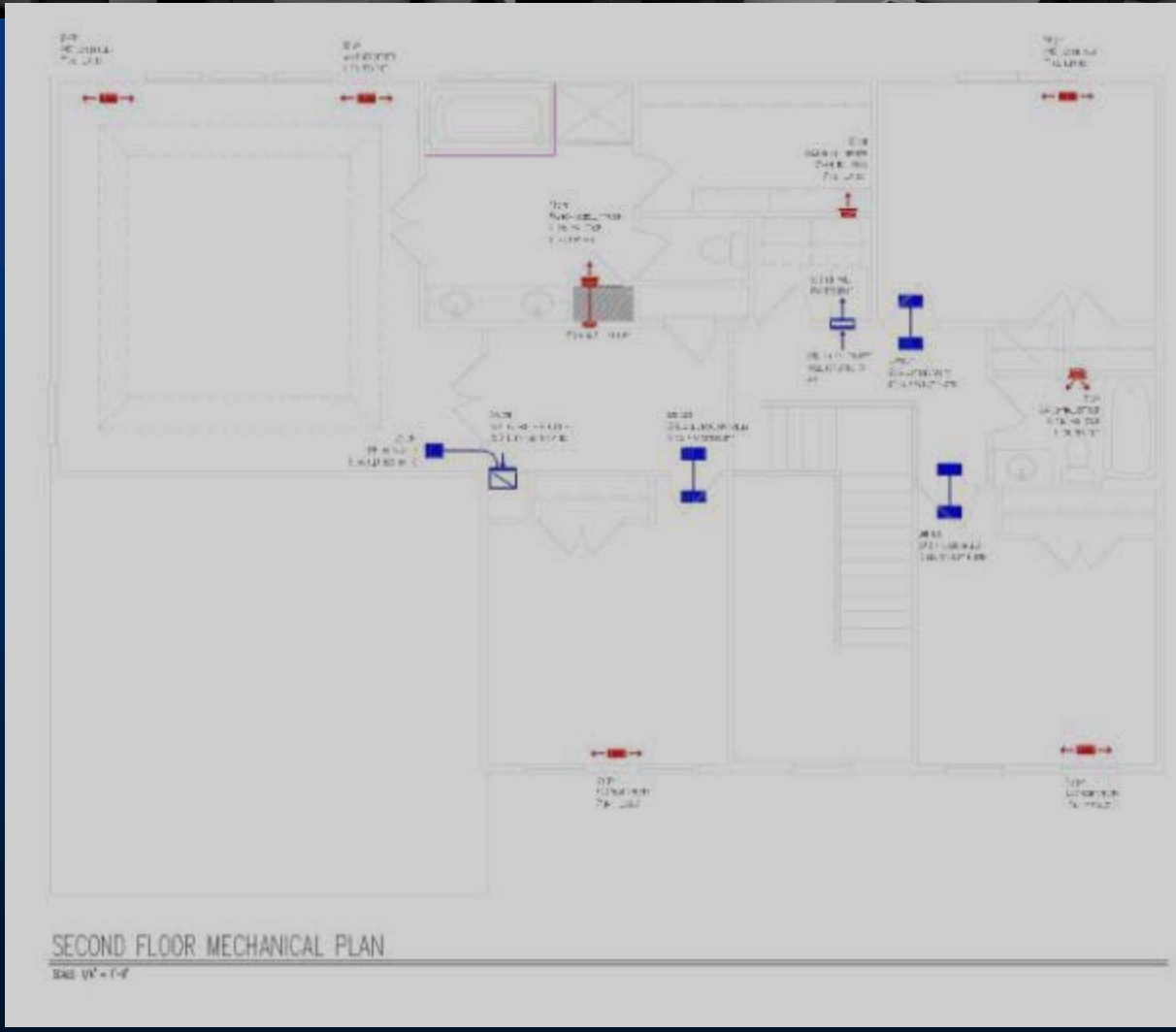
Conventional Air Distribution

- Supply diffusers are located in conventional locations around the perimeter of the thermal envelope
- Again, no adjustment for improved thermal envelope
- Central return with jump ducts
- These second floor supply diffusers could not get much further away from the unit

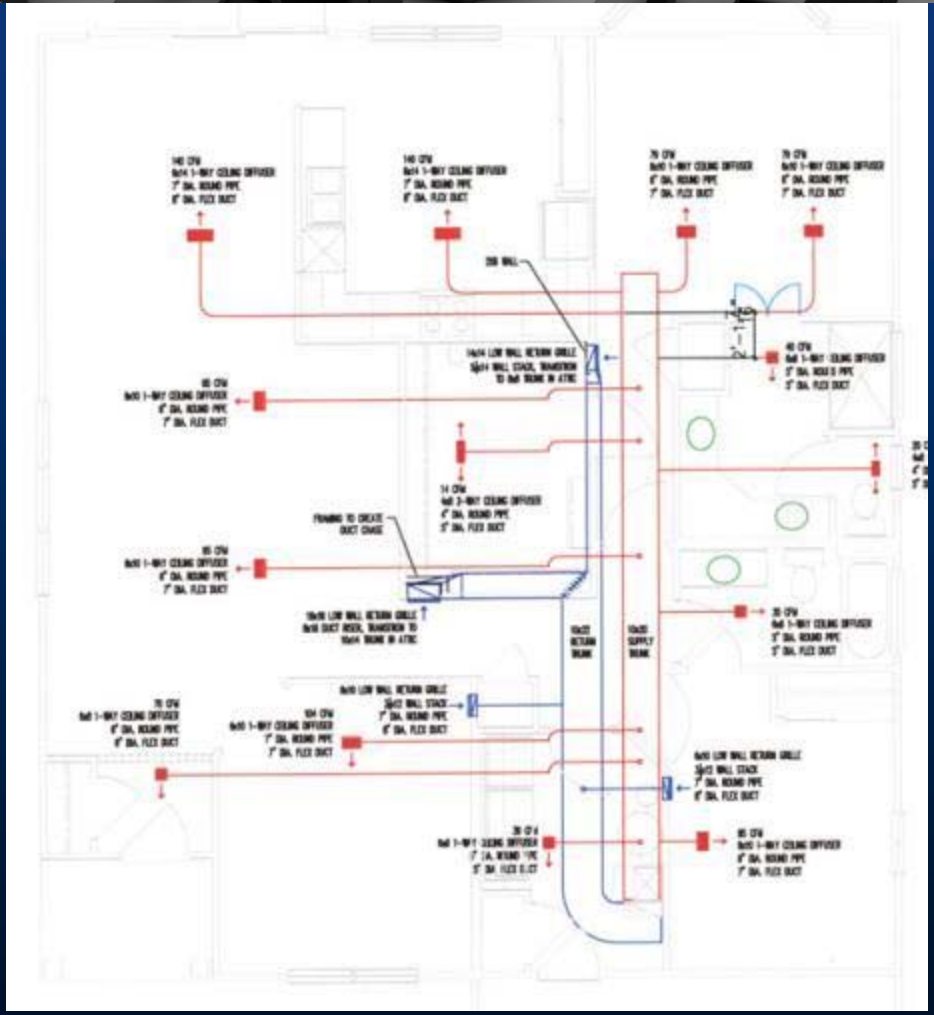


High-Efficiency Air Distribution

- The improvements to the thermal envelope need to be passed on to the air distribution system
- Old rules of thumb no longer apply
- Right-sized equipment needs to equals right-sized air distribution system
- Standard to oversized ducts result in lower velocities
- Lower velocities at diffusers reduce throw and mixing

High-Efficiency Air Distribution

- Improved thermal envelope results in installation of a 2 ton system
- Easily placed air distribution system located in the cathedralized attic
- Short and efficient supply locations
- Central returns
- Reduced total equivalent length
- Right-sized ducts deliver air at needed velocities



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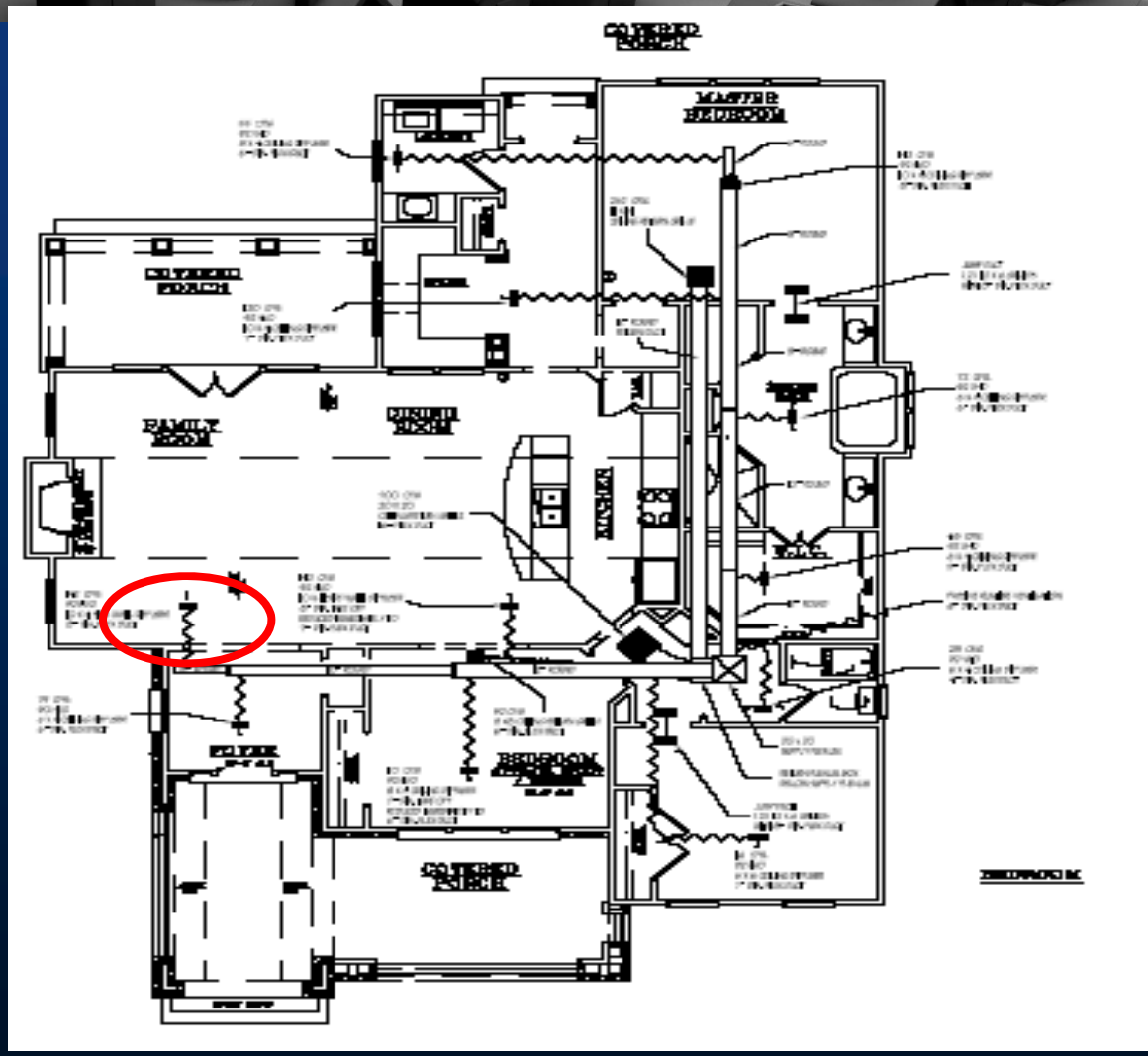
High-Efficiency Air Distribution

- Lower Supply Air Temps
- Longer Run Times
- High Sidewall Diffusers
- Duct Location
- Diffuser Selection



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Thank You

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IBACOS Advanced Space Conditioning Strategies

Brad Oberg, Chief Technology Officer,
IBACOS

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Building America
U.S. Department of Energy
Research Toward Zero Energy Homes

Pittsburgh Lab Home

- Inaugural Zero Energy house
- Cobblestone Estates, Ohio Township, Pittsburgh, PA
- 2,188 sq ft, 2-story home
- Construction beginning in March 2010
- Construction complete fall 2010
- Research, educational and marketing resource for 3+ years

- Maximize performance of ground source heat pump
- Reduce cost of installation
- Alternative Space Conditioning strategies

2x8 Double Stud Wall

Windows and inside corners

Looks simple, but what about the drainage plane?

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Furring adapted to siding needs

Pneumatic gun application

Custom groove to match frame

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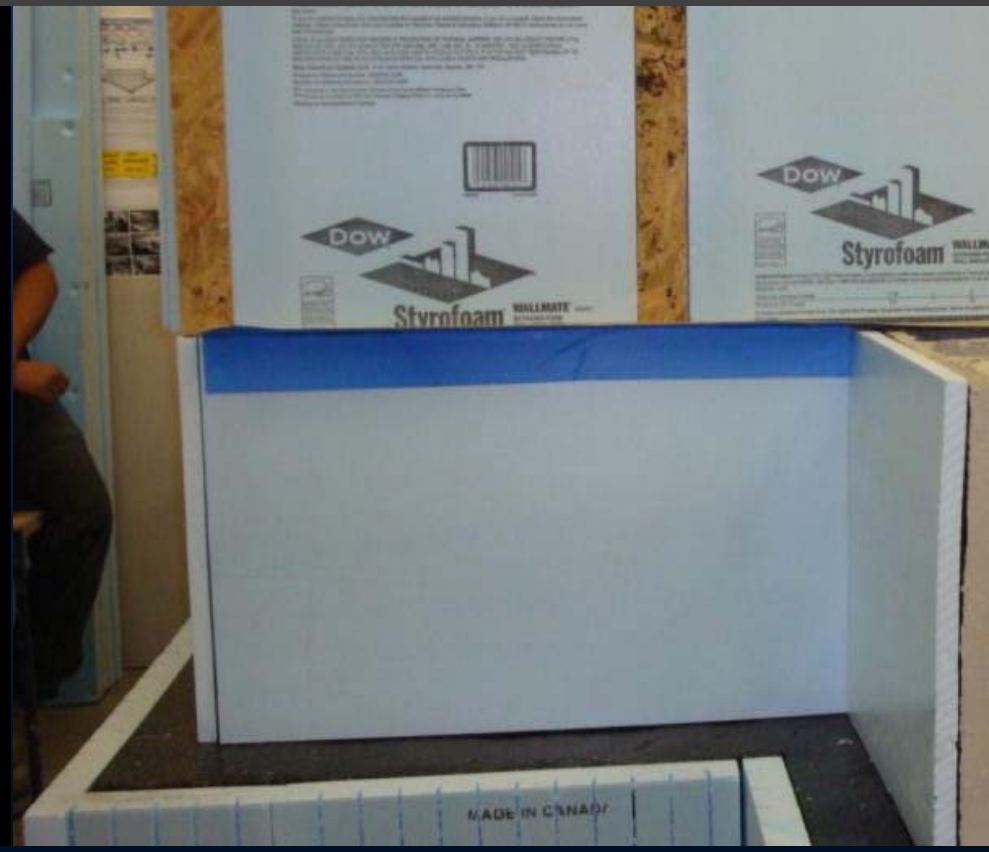
Foundations need care too!

Waterproofing and below grade drainage provide protection

Drainage plane transitions behind brick to grade



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Building America U.S. Department of Energy
Research Toward Zero Energy Homes

More Foundation Details

Through-wall flashing and mortar net maintains drainage

Insulation and drainage plane extend over brick sill

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Airtightness is critical to energy efficiency

Housewrap transitions to drywall

Closed cell foam completes the transition and picks up details

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Building America U.S. Department of Energy

Research Toward Zero Energy Homes

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Completing the R-value story

2” exterior foam sheathing allows R-28 interior cavity fill

Grade 1 cavity insulation at R-3.8 per inch

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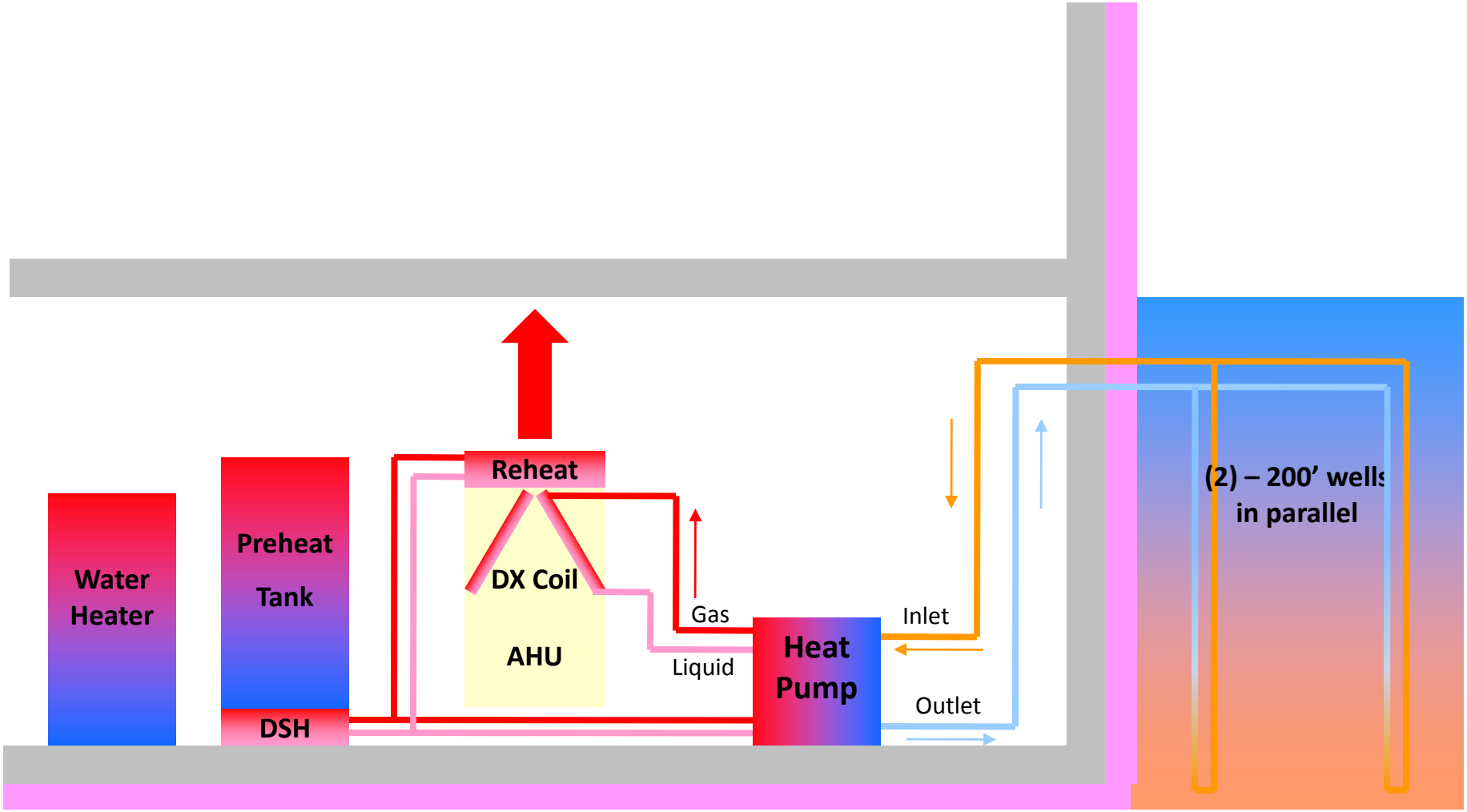
Building America U.S. Department of Energy

Research Toward Zero Energy Homes

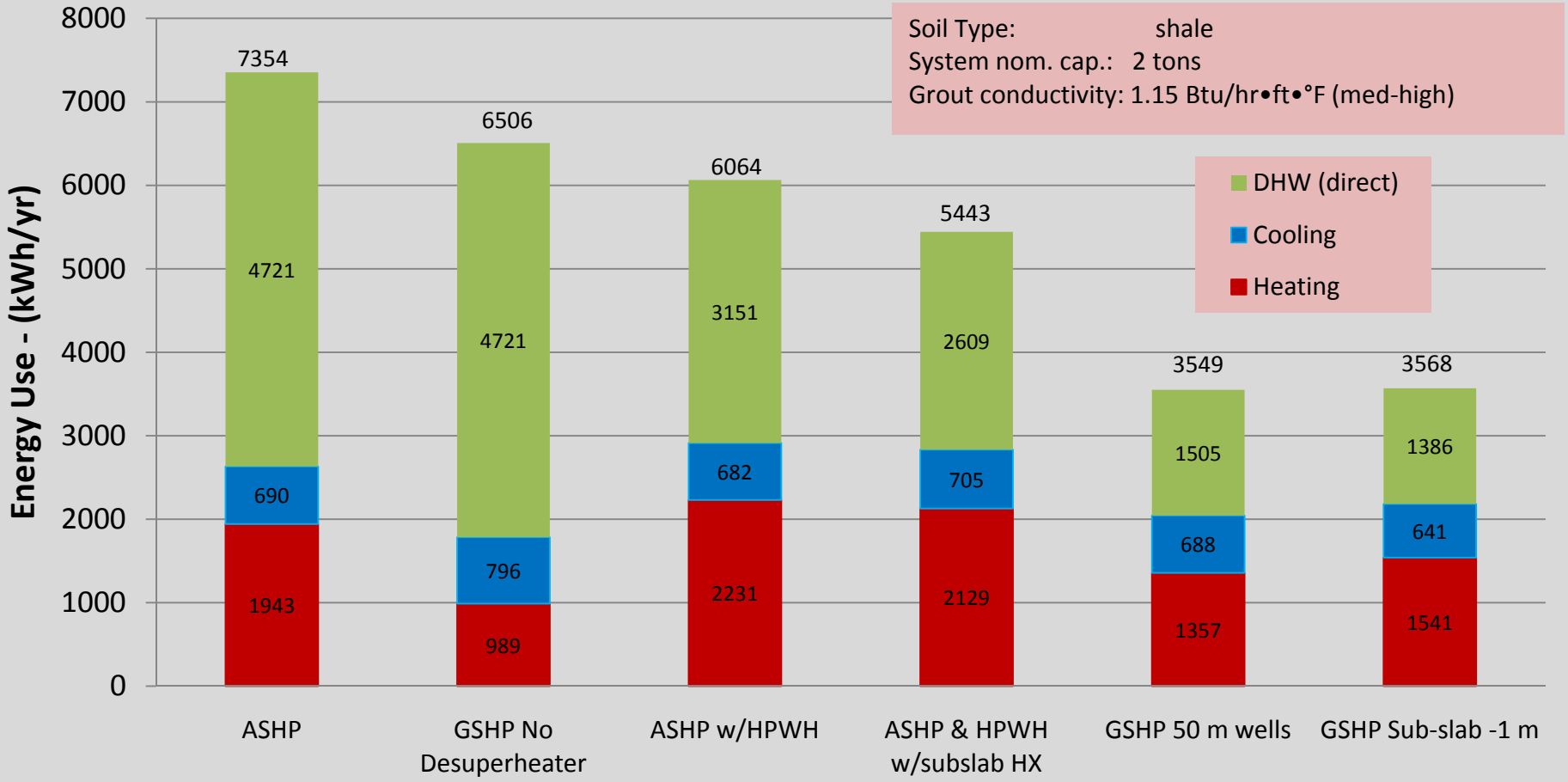
Lab Home Research



Lab Home Research

Lab House HVAC System Options

4 Bedrooms



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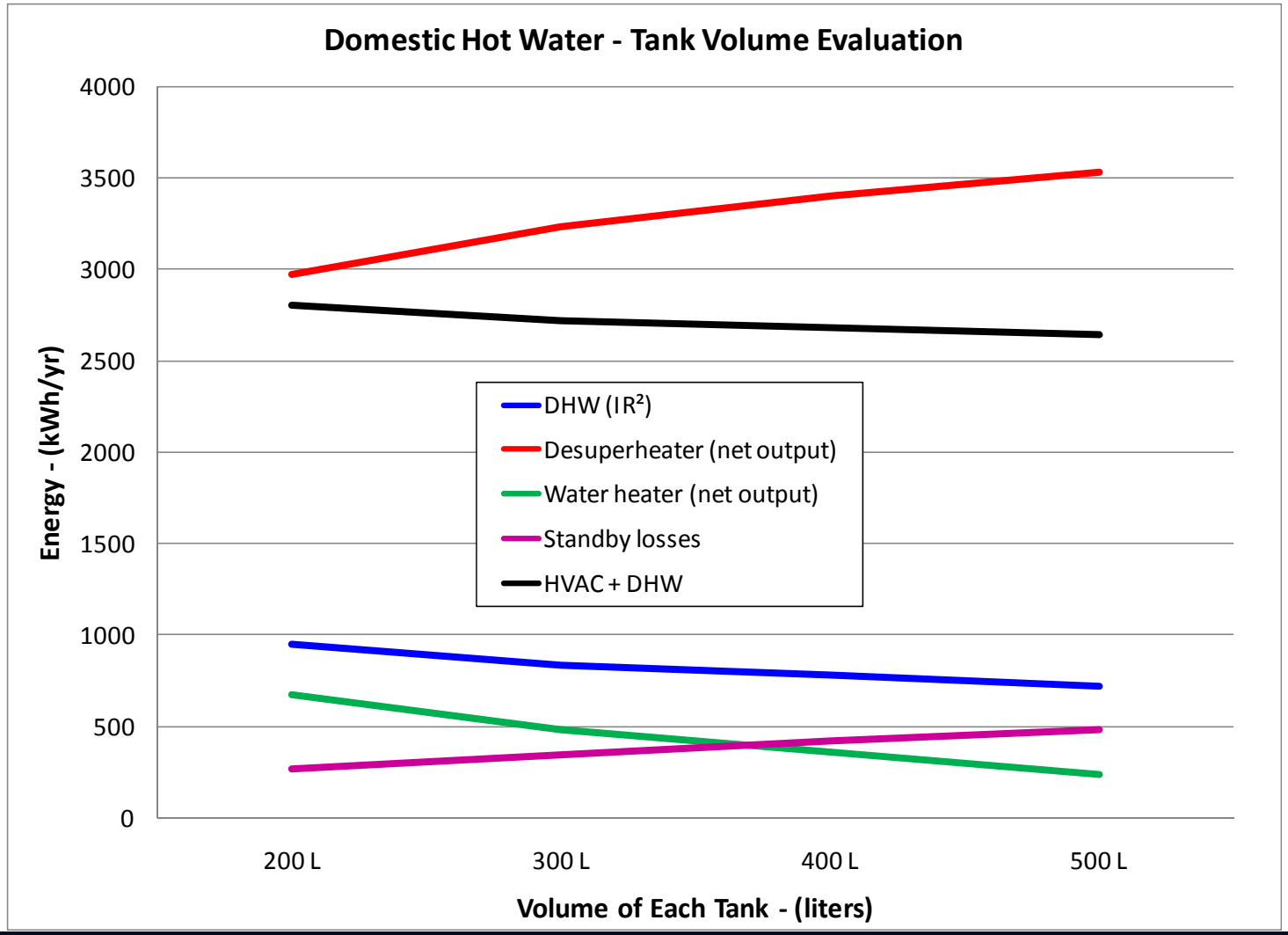


Lab Home Research

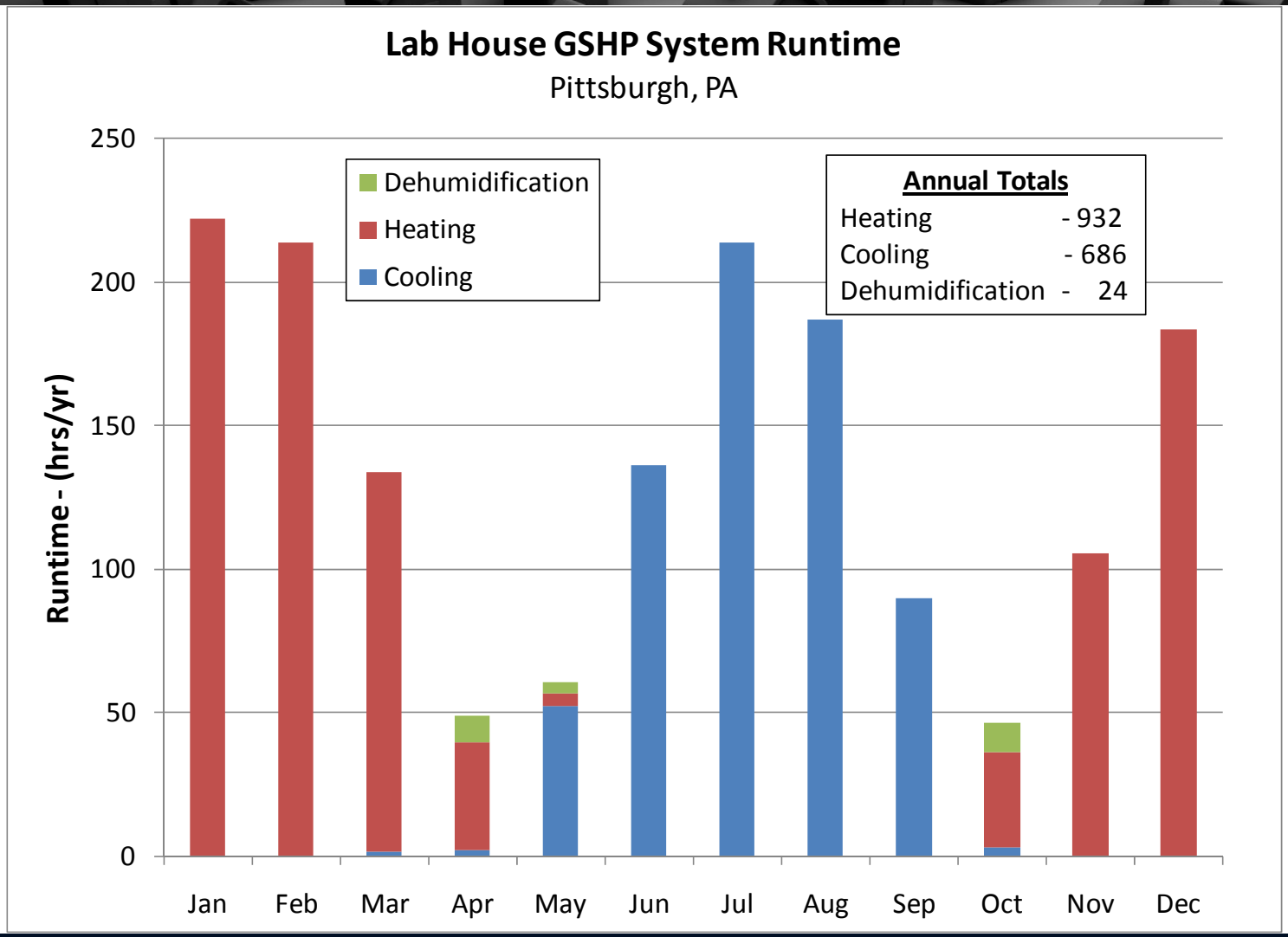
			Efficiency		with pump		Pumping	
Loop_in °F	Loop_out °F	Delta Δ°F	Heating COP	Cooling EER	Heating COP	Cooling EER	Heating kWh	Cooling kWh
45.7	**48.8**	-3.2	3.30		3.29		31	0
46.1	49.0	-2.9	3.15		3.15		26	0
47.8	50.5	-2.7	3.11	24.21	3.11	24.21	12	1
52.8	54.4	-1.5	3.06	23.20	3.06	23.20	5	2
72.5	69.0	3.5	3.55	21.82	3.55	21.82	0	10
78.8	74.0	4.8		20.12		20.12	0	18
79.4	74.7	4.7		19.85		19.85	0	20
80.1	**75.3**	4.8		19.68		19.68	0	20
76.2	72.3	3.9		20.92		20.92	0	11
60.9	60.8	0.0	3.19	22.14	3.19	22.14	3	3
49.3	52.1	-2.8	3.04	25.40	3.04	25.40	13	0
46.3	49.5	-3.2	3.32		3.32		24	0
			3.21	**20.38**	**3.21**	**20.38**	**115**	**83**

Lab Home Research

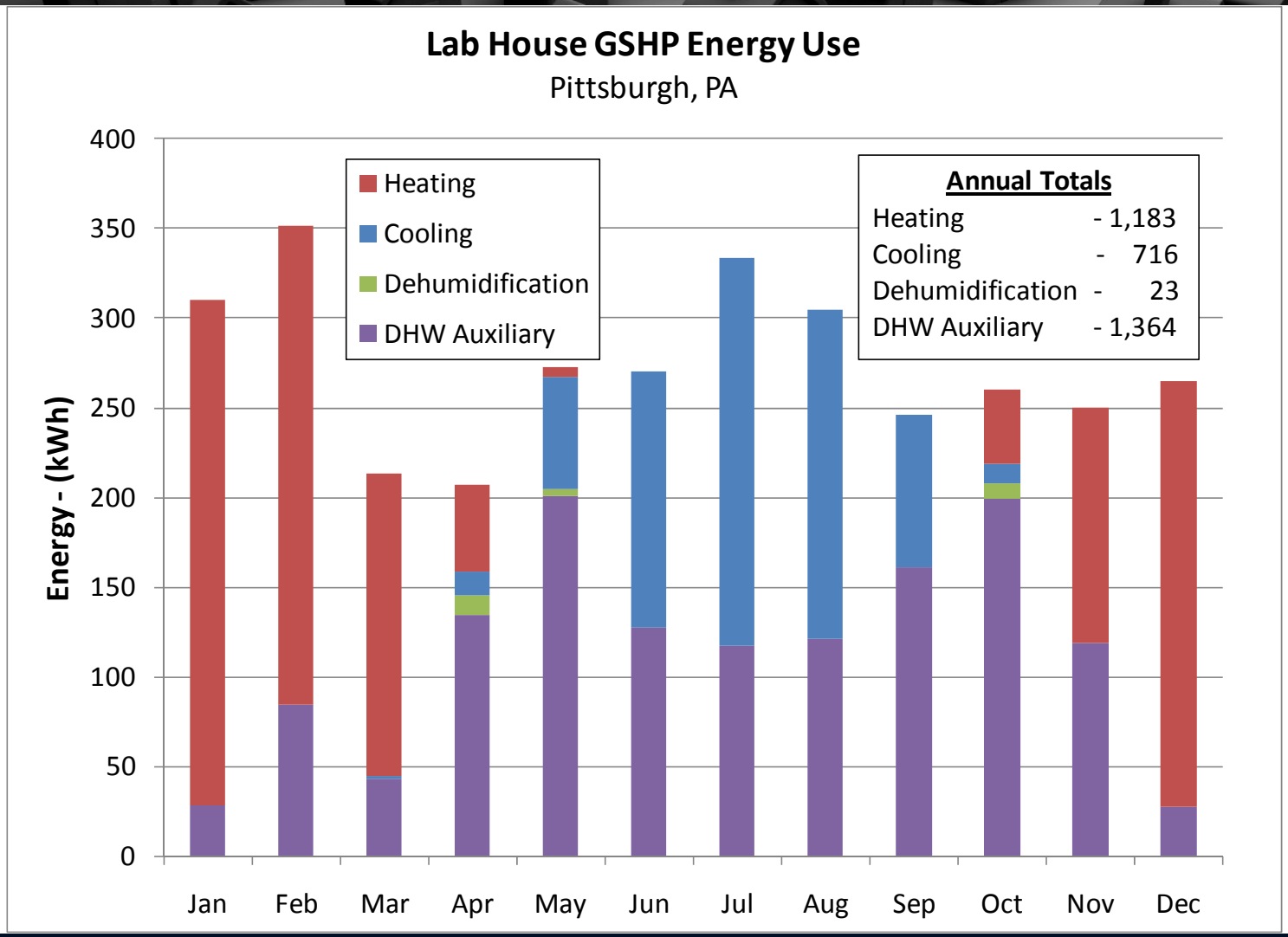
Loop_in °F	Loop_out °F	Delta Δ°F	Efficiency Heating COP	Efficiency Cooling EER	with pump Heating COP	with pump Cooling EER	Pumping Heating kWh	Pumping Cooling kWh
38.2	41.0	-2.8	3.05		3.05		36	0
35.7	**38.1**	-2.4	2.81		2.81		32	0
37.5	39.7	-2.3	2.79	32.34	2.79	32.34	15	0
41.8	43.4	-1.6	2.72	31.15	2.72	31.15	7	1
55.4	51.9	3.6	3.29	29.17	3.29	29.17	0	9
65.6	60.6	5.0		25.49		25.49	0	18
71.8	66.9	4.9		22.87		22.87	0	21
76.4	**71.3**	5.0		21.21		21.21	0	22
75.2	71.1	4.1		21.37		21.37	0	12
62.8	62.3	0.5	3.24	23.96	3.24	23.95	3	3
51.0	53.9	-2.9	3.11	26.29	3.11	26.29	13	0
43.7	46.8	-3.0	3.25		3.25		26	0
			3.00	**23.42**	**3.00**	**23.42**	**131**	**86**

Sub-slab HX

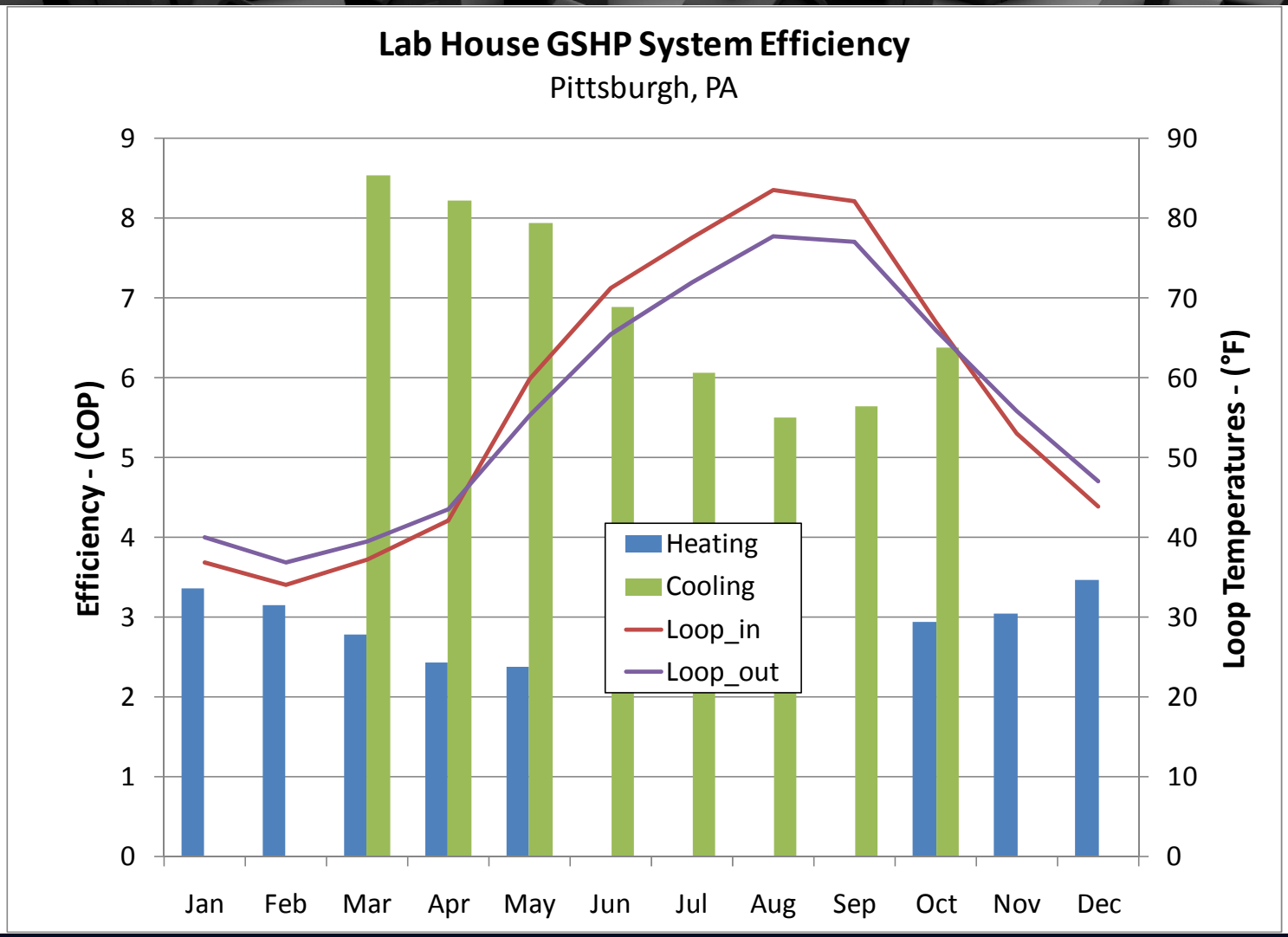
Lab Home Research



Lab Home Research



Lab Home Research



Research Questions

- Can alternative air distribution systems provide the same level of comfort when applied in a well insulated, airtight house?
  - How does the TCPI of this system compare? What were the influential factors?
  - How does the system respond to extreme load conditions?
  - Do over the door transfer grills influence the distribution of heated or cooled air in the house? How?
  - Does distribution locations dominate depending on the season?
  - If there are shortfalls in comfort, can they be made up by delivering the remainder of the design load to a single point?

- Systems approaches:
  1. Reduced distribution locations
  2. Undersized distribution

2010 HVAC Research Initiatives

- 70% Lab Home
  - Cold climate (refine test plan, construct house, prepare for testing)
  - Mixed-Humid climate (model systems performance)
- Part Load Modeling
- Air Flow Testing
  - Proprietary Infinity system findings
- Alternate Control Strategies

Lab Home Research

Thermal Comfort Performance Index

	Basement						Zone 1 - Dining						Zone 2 - Kitchen					Zone 8 - Bedroom 2						Zone 9 - Master Bedroom						Whole House	Whole House w/o Basement
	Daily Time Periods						Daily Time Periods						Daily Time Periods					Daily Time Periods						Daily Time Periods						
Months	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	1	2	3	4	5	6	1	2	3	4	5	6		
Jan	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.68	0.91	0.99	0.96	0.83	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.95	0.89	0.98	1.00	0.98	0.98	0.86	0.73	0.80	0.96	0.86	0.95
Feb	0.00	0.01	0.00	0.00	0.00	0.00	0.82	0.73	0.92	1.00	0.97	0.90	1.00	1.00	1.00	0.98	0.99	1.00	1.00	0.97	0.89	0.97	1.00	0.98	0.99	0.88	0.80	0.81	0.94	0.86	0.95
Mar	0.00	0.00	0.00	0.00	0.00	0.00	0.98	0.97	1.00	0.98	0.99	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	1.00	0.89	0.99
Apr	0.21	0.41	0.30	0.11	0.03	0.03	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.92	1.00
May	0.25	0.53	0.43	0.19	0.15	0.14	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.93	1.00
Jun	0.11	0.31	0.20	0.05	0.00	0.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.91	1.00
Jul	0.90	1.00	0.95	0.59	0.24	0.31	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.97	1.00
Aug	0.99	1.00	0.99	0.78	0.54	0.63	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00
Sep	0.90	0.99	0.97	0.74	0.55	0.51	1.00	1.00	1.00	0.99	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.92	1.00	1.00	1.00	1.00	1.00	0.94	0.97	1.00	0.97	0.99
Oct	0.95	1.00	0.97	0.75	0.66	0.79	1.00	1.00	1.00	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	0.97	1.00	0.98	0.99
Nov	0.79	0.93	0.82	0.52	0.47	0.44	1.00	1.00	1.00	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.96	1.00
Dec	0.17	0.25	0.18	0.09	0.08	0.07	0.82	0.78	0.93	0.99	0.94	0.86	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.98
Average	0.44	0.54	0.48	0.32	0.23	0.24	0.95	0.93	0.98	0.99	0.99	0.96	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.97	1.00	1.00	1.00	1.00	0.97	0.94	0.96	0.99	0.93	0.99

Lab Home Research

Thermal Comfort Performance Index

Months	BSMT	Dining	Kitchen	Family	Foyer	Hall	Br 4	Br 3	Br 2	Mstr Br	Whole House
Jan	0.00	0.86	1.00	0.94	0.94	0.99	0.99	1.00	0.97	0.88	0.95
Feb	0.00	0.89	1.00	0.94	0.94	0.98	0.97	1.00	0.97	0.90	0.95
Mar	0.00	0.99	1.00	1.00	1.00	1.00	0.97	0.99	1.00	1.00	0.99
Apr	0.18	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00
May	0.28	1.00	1.00	1.00	1.00	1.00	1.00	0.98	1.00	1.00	1.00
Jun	0.11	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Jul	0.67	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00
Aug	0.82	1.00	1.00	1.00	1.00	1.00	1.00	0.99	1.00	1.00	1.00
Sep	0.78	1.00	1.00	1.00	1.00	1.00	0.98	0.98	0.99	0.99	0.99
Oct	0.85	0.98	1.00	1.00	1.00	1.00	0.93	1.00	1.00	0.99	0.99
Nov	0.66	1.00	1.00	1.00	1.00	1.00	0.97	1.00	1.00	1.00	1.00
Dec	0.14	0.89	1.00	0.99	0.99	1.00	0.99	1.00	1.00	0.96	0.98
Average	0.37	0.97	1.00	0.99	0.99	1.00	0.98	0.99	0.99	0.98	0.99

Lab Home Research

Average PMV Values

Zone 9 - Master Bedroom						
	Daily Time Periods					
Months	**1**	**2**	**3**	**4**	**5**	**6**
Jan	-0.38	-0.38	-0.41	-0.44	-0.43	-0.39
Feb	-0.36	-0.36	-0.40	-0.43	-0.42	-0.37
Mar	-0.24	-0.23	-0.25	-0.29	-0.30	-0.27
Apr	-0.14	-0.11	-0.14	-0.19	-0.23	-0.23
May	-0.10	-0.06	-0.10	-0.13	-0.15	-0.16
Jun	-0.04	-0.02	-0.04	-0.04	-0.04	-0.05
Jul	-0.05	-0.04	-0.02	-0.01	-0.03	-0.03
Aug	-0.07	-0.07	-0.05	-0.05	-0.06	-0.06
Sep	-0.15	-0.12	-0.18	-0.19	-0.17	-0.17
Oct	-0.21	-0.16	-0.20	-0.31	-0.34	-0.33
Nov	-0.20	-0.19	-0.21	-0.25	-0.27	-0.26
Dec	-0.32	-0.32	-0.35	-0.38	-0.37	-0.34
Annual	-0.19	-0.17	-0.20	-0.23	-0.23	-0.22

Air Distribution System

Research goal:

Determine if alternative space conditioning systems provide the same level of comfort as Standard System when applied in a well insulated, airtight house.

Standard System (Experimental Control)

- Sizing by manual J and D
- High sidewall outlets
- Low-mass ductwork (i.e. Ductboard and insulated flex) sealed and within conditioned space
- What is the measured Thermal Comfort Performance Index (TCPI) of this system?
- How does the system respond to extreme load conditions?

Alternative System 1

Reduced Distribution Locations

Two supply locations (zoned independently): first floor in living area and second floor in hallway.

- How does the TCPI of this system compare to the Standard system? What were the influential factors?
- How does the system respond to extreme load conditions?
- Do the over the door transfer grills influence the distribution of heated or cooled air in the house? How?
- Does one location dominate depending on the season?

Alternative System 2

Undersized

Distribute only the amount of Heating/Cooling energy that can be supplied using small diameter PVC ductwork (6” diameter main trunk, 3” branch lines to each room)

- How does the TCPI of this system compare to the Standard system? What were the influential factors?
- How does the system respond to extreme load conditions?
- If there are shortfalls in comfort, can they be made up by delivering the remainder of the design load to a single point?

Research Impacts

- Reduced distribution locations
  - Dramatically minimized space conditioning systems such as mini-split heat pumps are sufficient to meet needs of future houses
  - First cost HVAC cost reductions to help compensate for increased thermal enclosure costs
- Undersized distribution
  - Substantially reduced ductwork sizing is possible in future houses
  - Standard space conditioning system sizing equations do not accurately account for superior thermal enclosure performance

Energy Efficient Lighting Strategies

Sharing a vision on High Performance Lighting in the Pursuit of Zero Energy

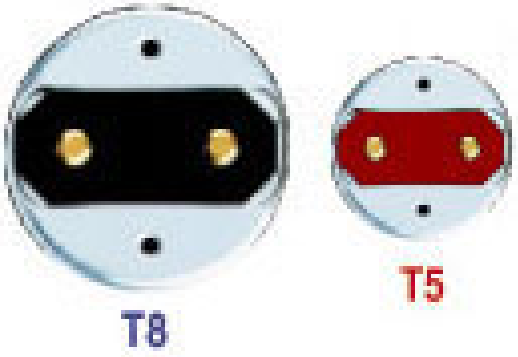
Brad Oberg, Chief Technology Officer, IBACOS

IBACOS | Home Quality + Performance |

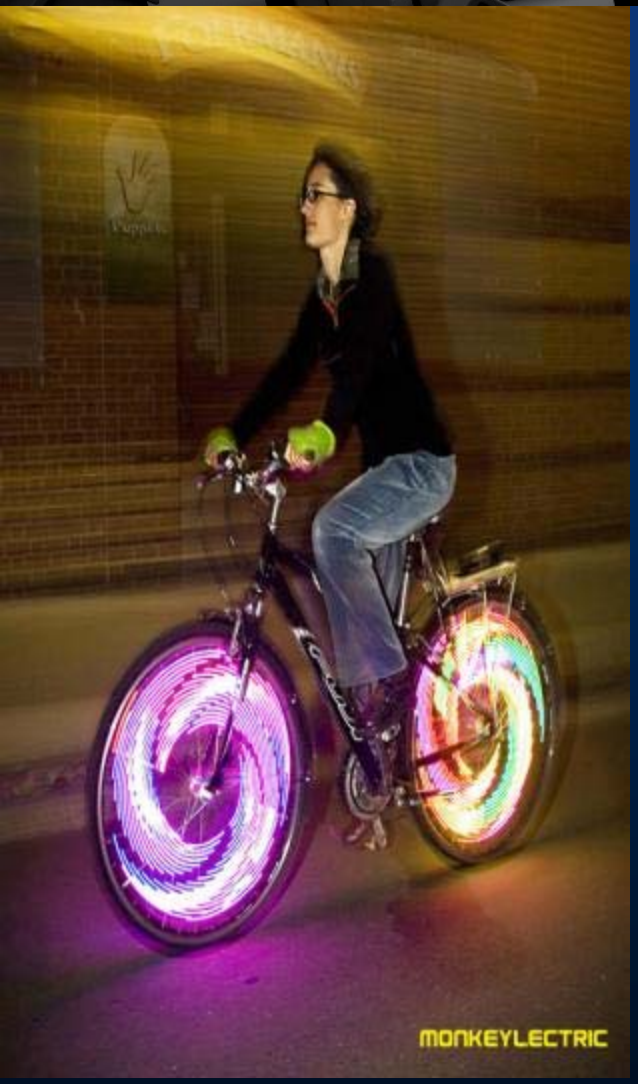
Best Practices Research Alliance®

Big Picture

- We are about creating the confidence for builders to make energy efficient lighting choices
- Codes and incentive programs create an interest
- Lighting historically has been an underutilized design feature and many times is relegated to an allowance and a showroom sales person.
- It wouldn't take much to include good lighting design in more homes
- An integrated design-build-sell process is needed


T8
T5

Lighting in the High Performance Home



- LED lighting has become a major medium for art, because of its vibrant color and low energy demands
- Battery powered displays are used in point of sale through safety and more!
- Energy efficient lighting may soon become the norm in homes as well

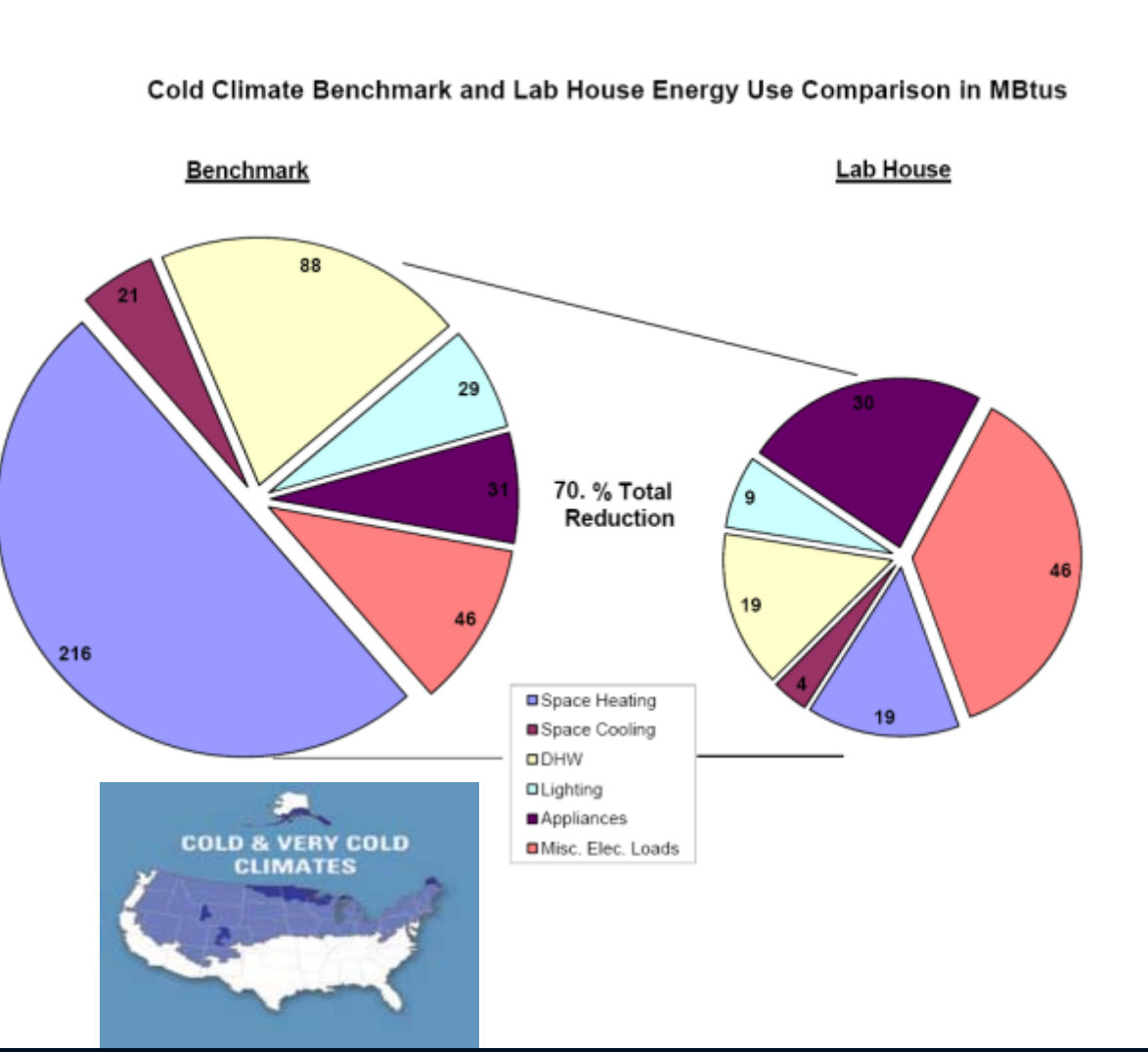
LAMEL

Lighting, **A**ppliances, and **M**iscellaneous **E**lectric **L**oads

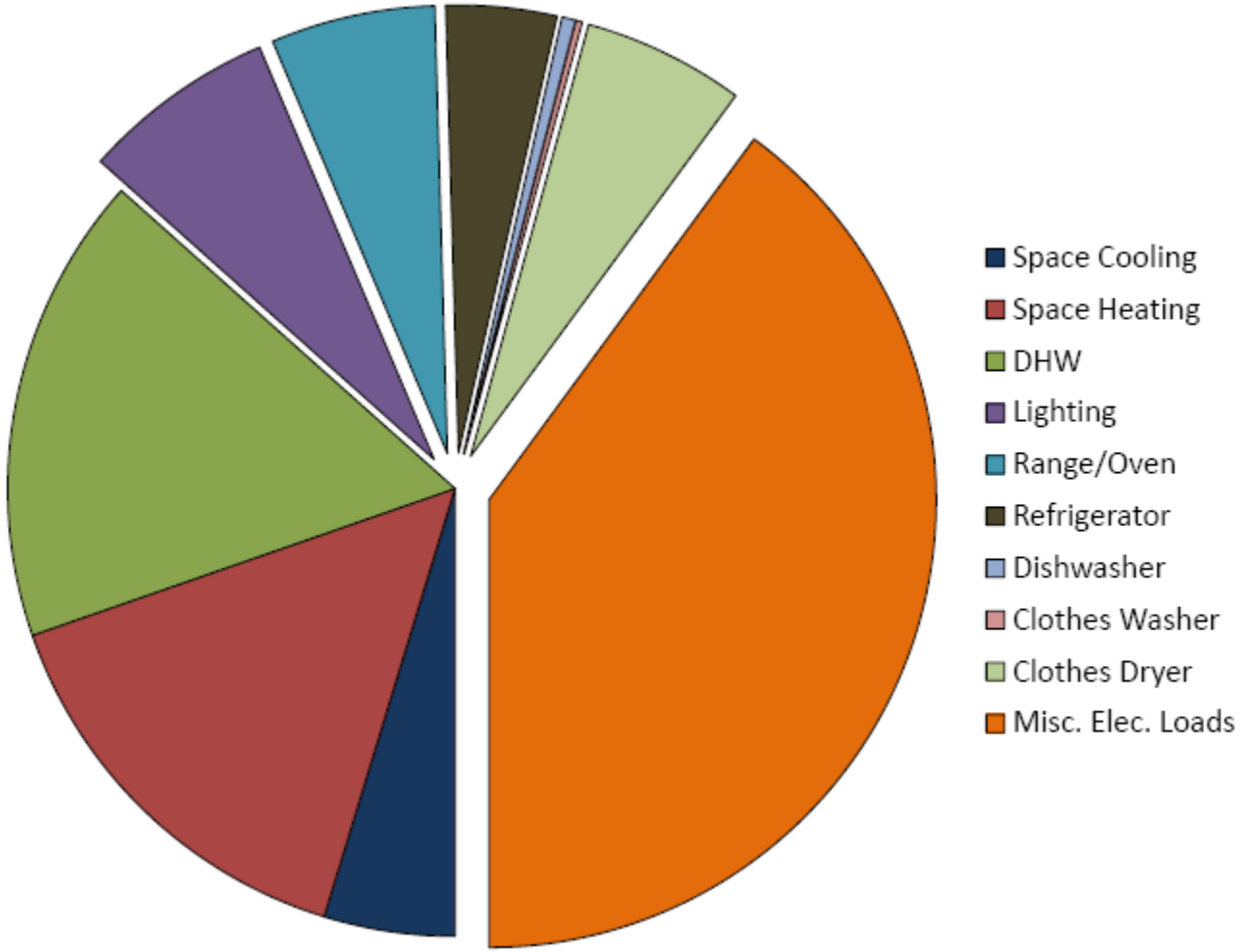
- Lighting: hardwired and plug-in
- Appliances: big 5 major appliances
- MELs: plugged in equipment and other loads

Cold Climate

- Large variances of rain, temperature & geography
- Lots of basements and crawl spaces
- Lots of moisture stresses
- Forced air systems – metal ductwork
- Chicago, Denver, Minneapolis, Pittsburgh, Indianapolis

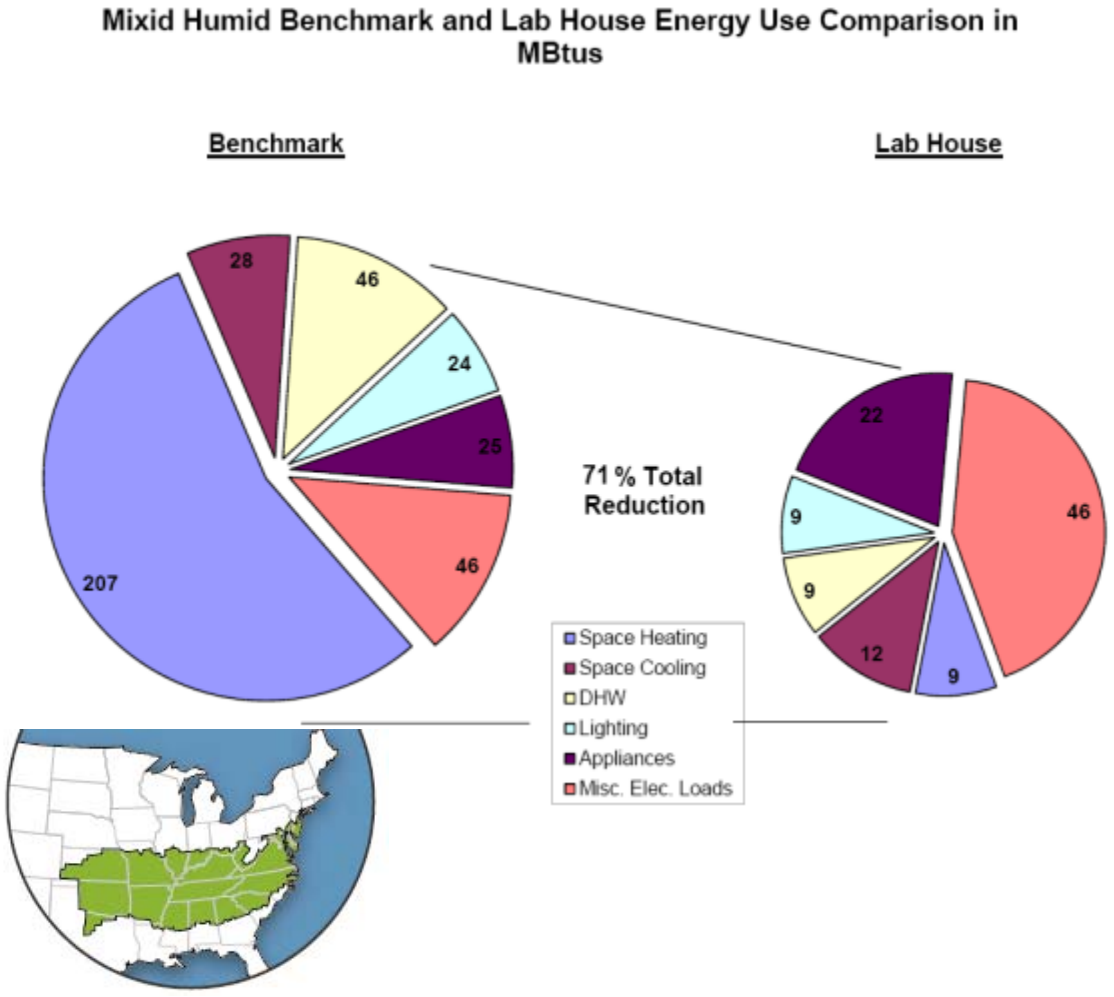


LAMEL


Space Cooling
Space Heating
DHW
Lighting
Range/Oven
Refrigerator
Dishwasher
Clothes Washer
Clothes Dryer
Misc. Elec. Loads

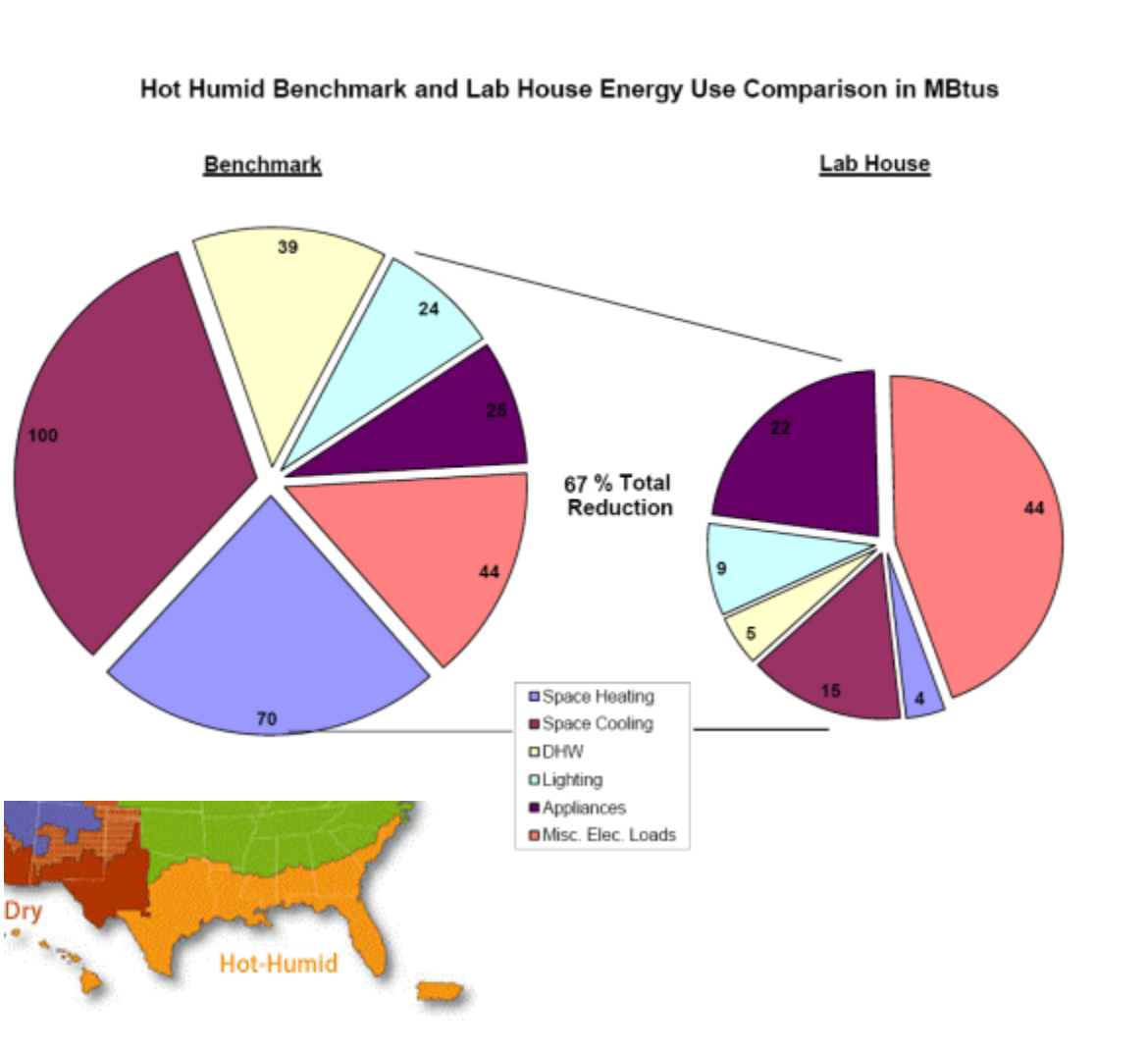
Mixed Humid

- Similar variances of rain & temperature
- Large variances of elevation
- Basements and crawl spaces
- Lots of moisture stresses
- Heat Pumps - Forced air systems – flex duct
- Charlotte, Atlanta, Louisville, Dallas



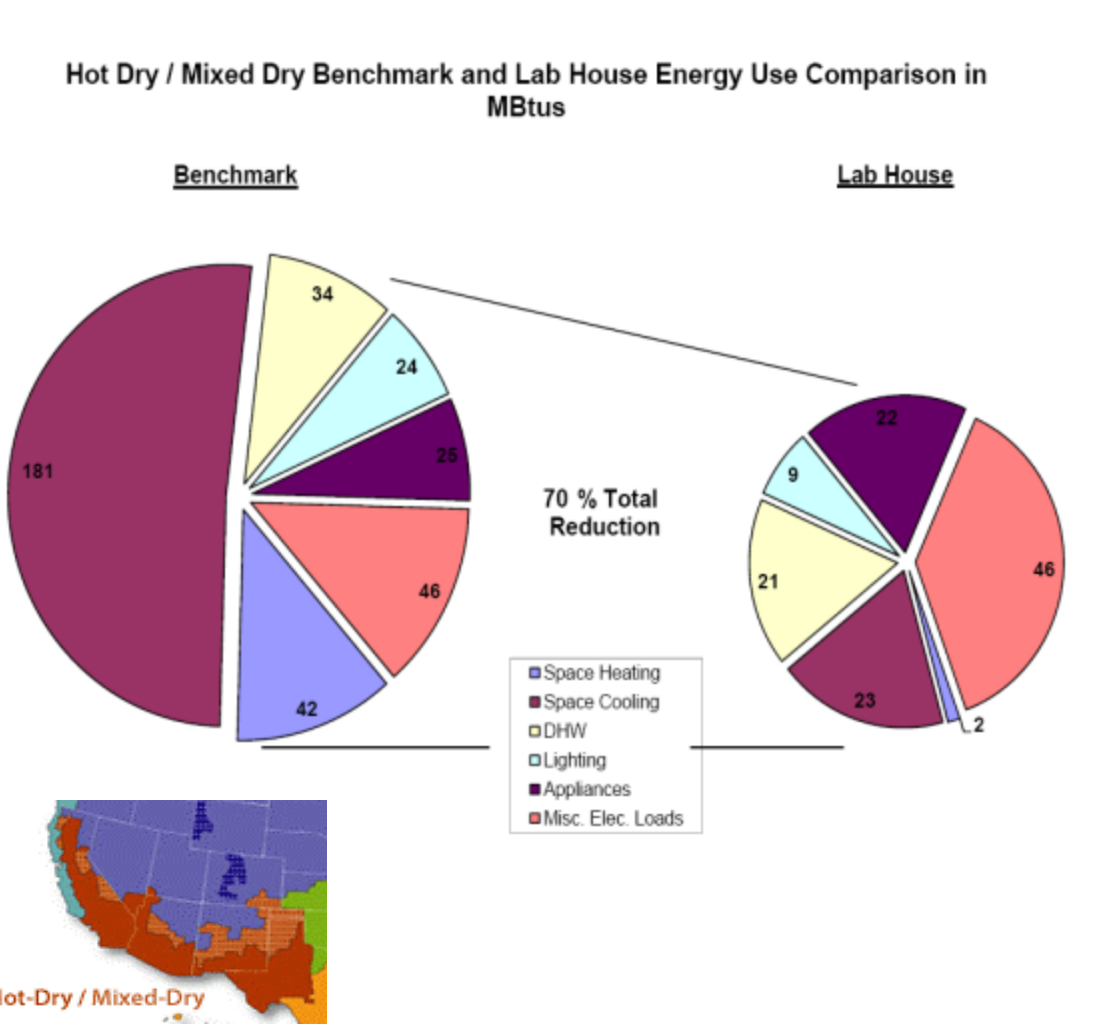
Hot Humid

- Intense solar load
- Moisture a challenge
- House types and styles vary greatly
- AC almost always installed
- Heat pumps - forced air systems, flex duct
- Houston, Orlando, West Palm, Atlanta, New Orleans



Hot Dry/ Mixed Dry

- Intense solar radiation
- Avg. rainfall of <20”/yr, but can receive large quick rain amounts
- Improper irrigation techniques can lead to moisture problems
- Slab on grade construction
- Mixture of exterior finish products – stucco predominate
- Tucson, Sacramento



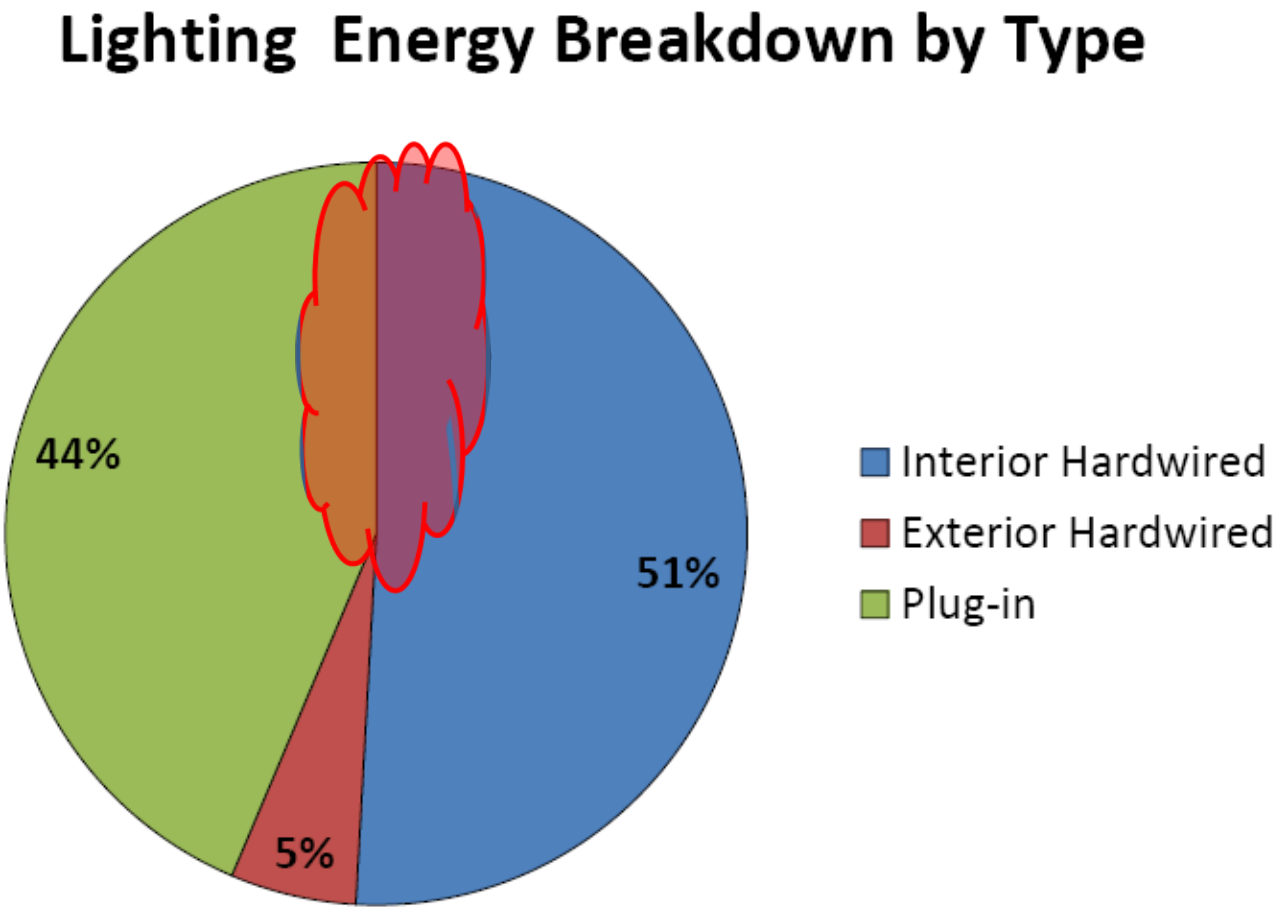
Lighting

Interior Hardwired

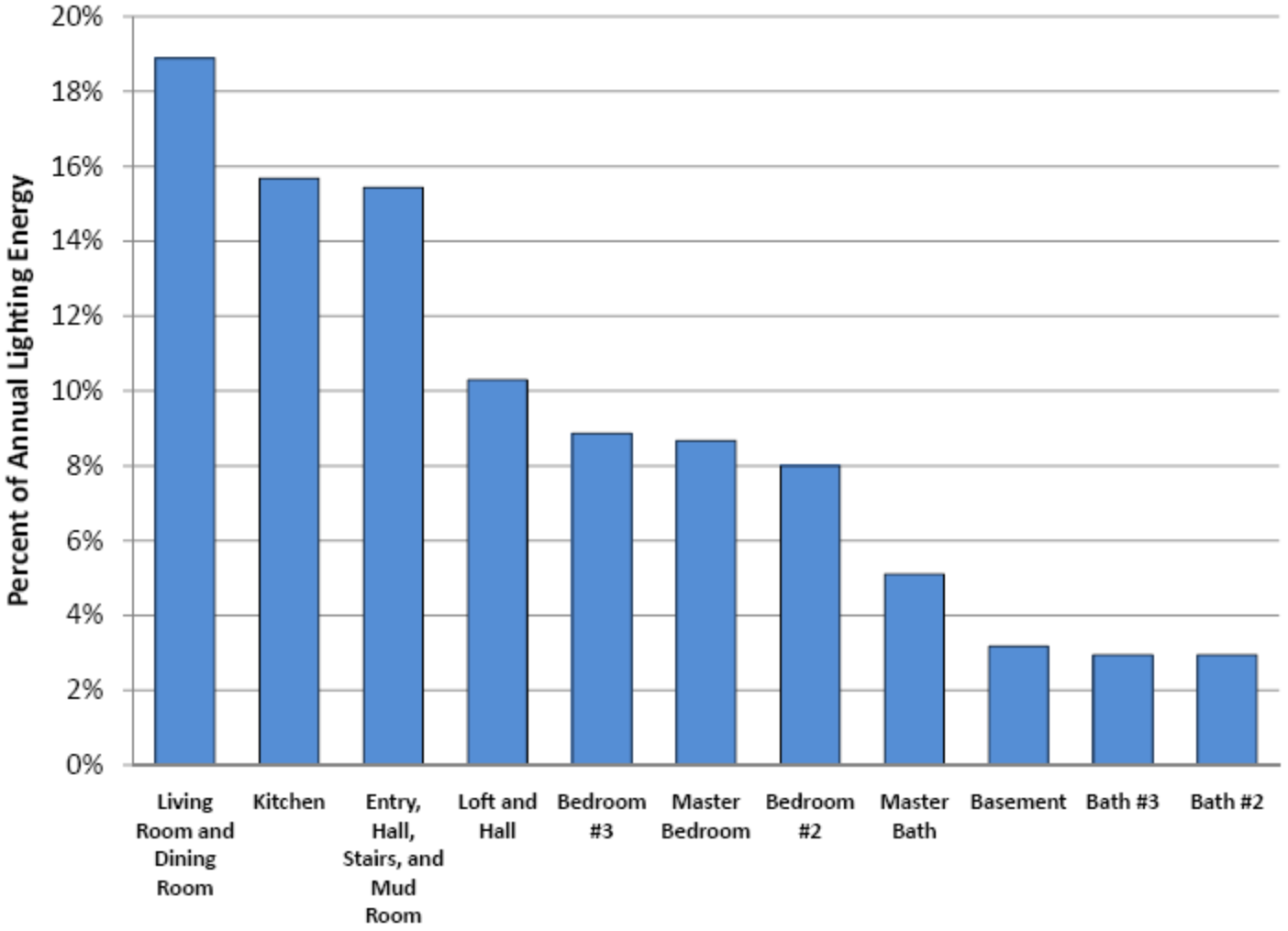
Exterior Hardwired

Plug-in Lights

Lighting


Lighting Energy Breakdown by Type
44%
51%
5%
Interior Hardwired
Exterior Hardwired
Plug-in

Lighting: Interior Hardwired Distribution



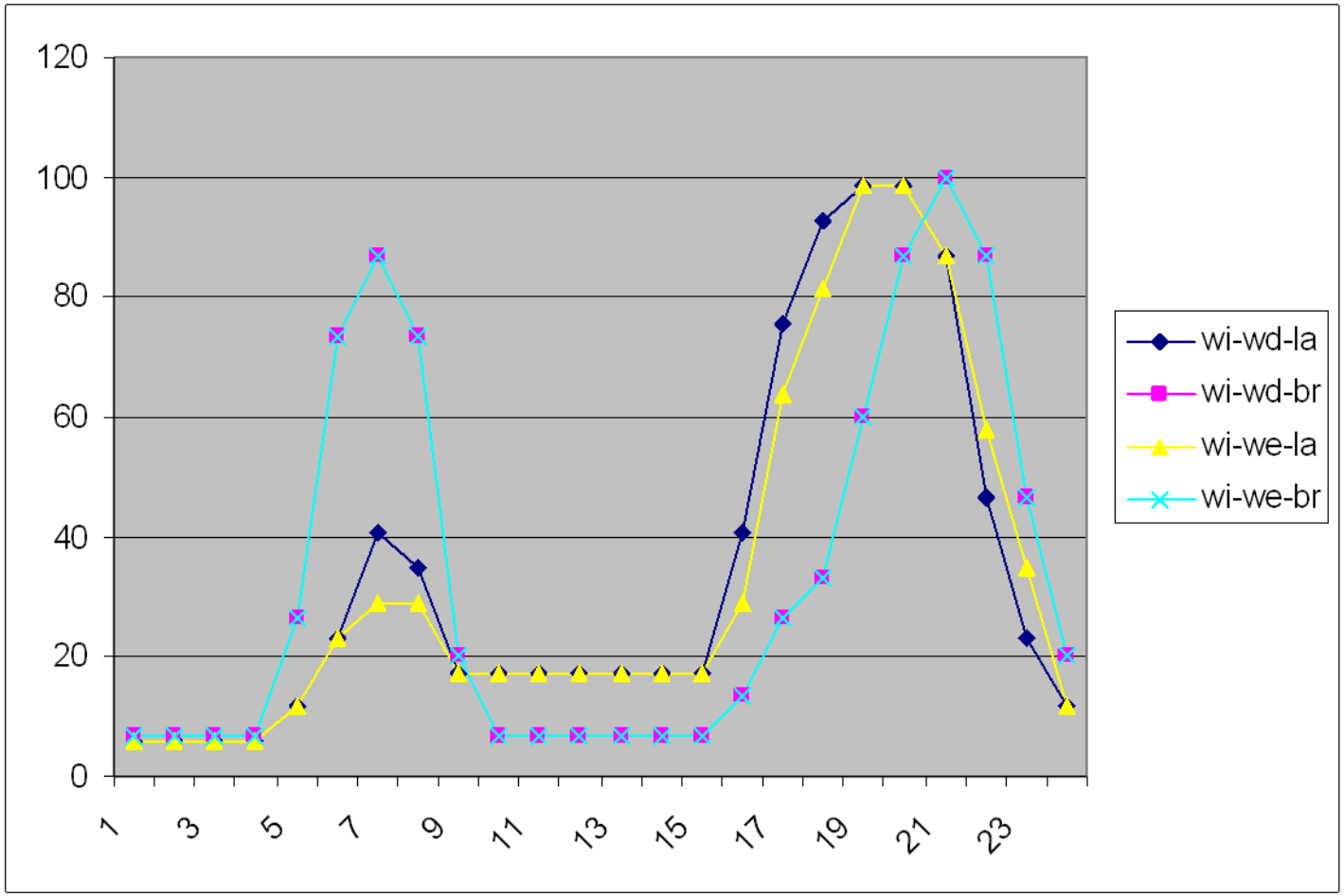
Whole House Model

Lighting Power Densities

	Areas	Base Lighting	Efficient Lighting
0-Basement	1191	0.6	0.2
1-Dining	242	2.4	1
1-Family	245	1.8	0.4
1-Hall	141	1.28	0.26
1-Kitchen	251	2.7	1.3
1-Laundry	75	1.6	0.7
1-Library	148	2.7	0.7
1-Powder	30	4.8	1
1-Stair	60	1.2	0.2
1-Garage	442	0.4	0.2
2-Bath 2	45	2.5	0.9
2-Bedroom 2	167	1.6	0.4
2-Bedroom 3	161	1.6	0.7
2-Bedroom 4	149	1.8	0.8
2-Closet	65	1.2	0.6
2-Foyer	81	1.9	0.5
2-Hall	112	1.5	0.3
2-Master Bath	124	2.1	0.9
2-Master Suite	228	1.2	0.6
2-Stair	60	0	0
Attic	1191	0	0

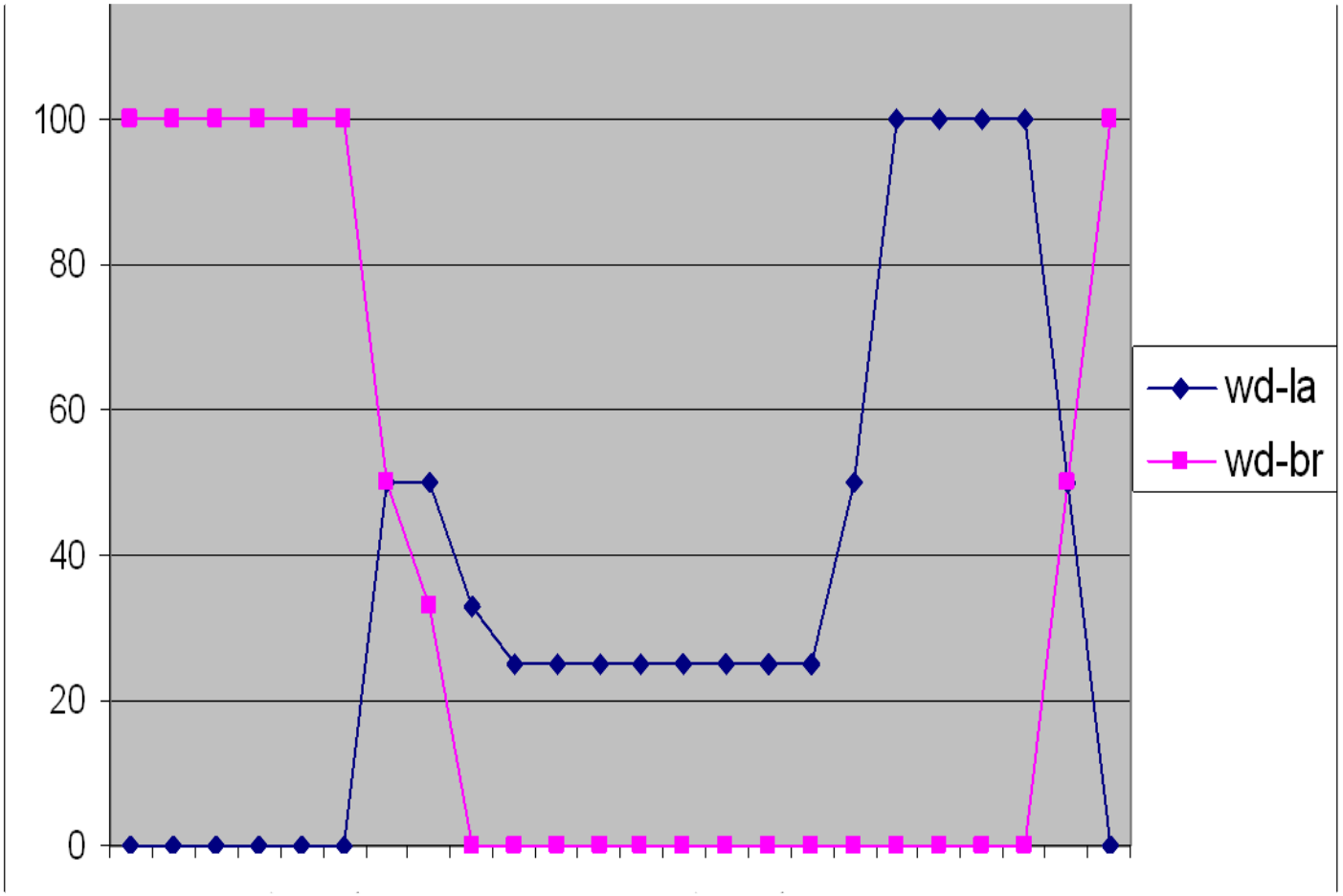
(Note: 1 indicates first floor; 2 indicates second floor.)

Whole House Model



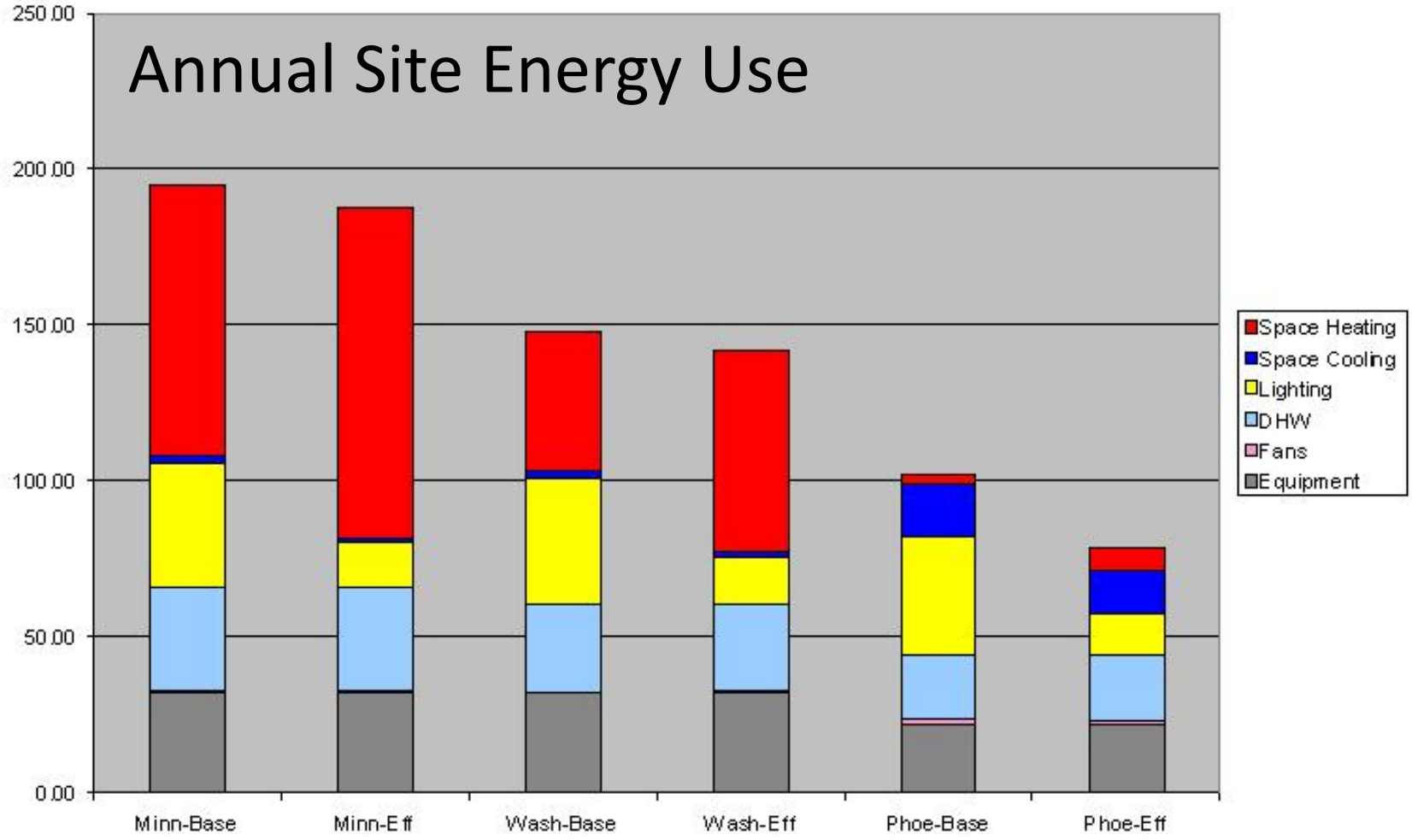
Schedules - Lighting

Whole House Model

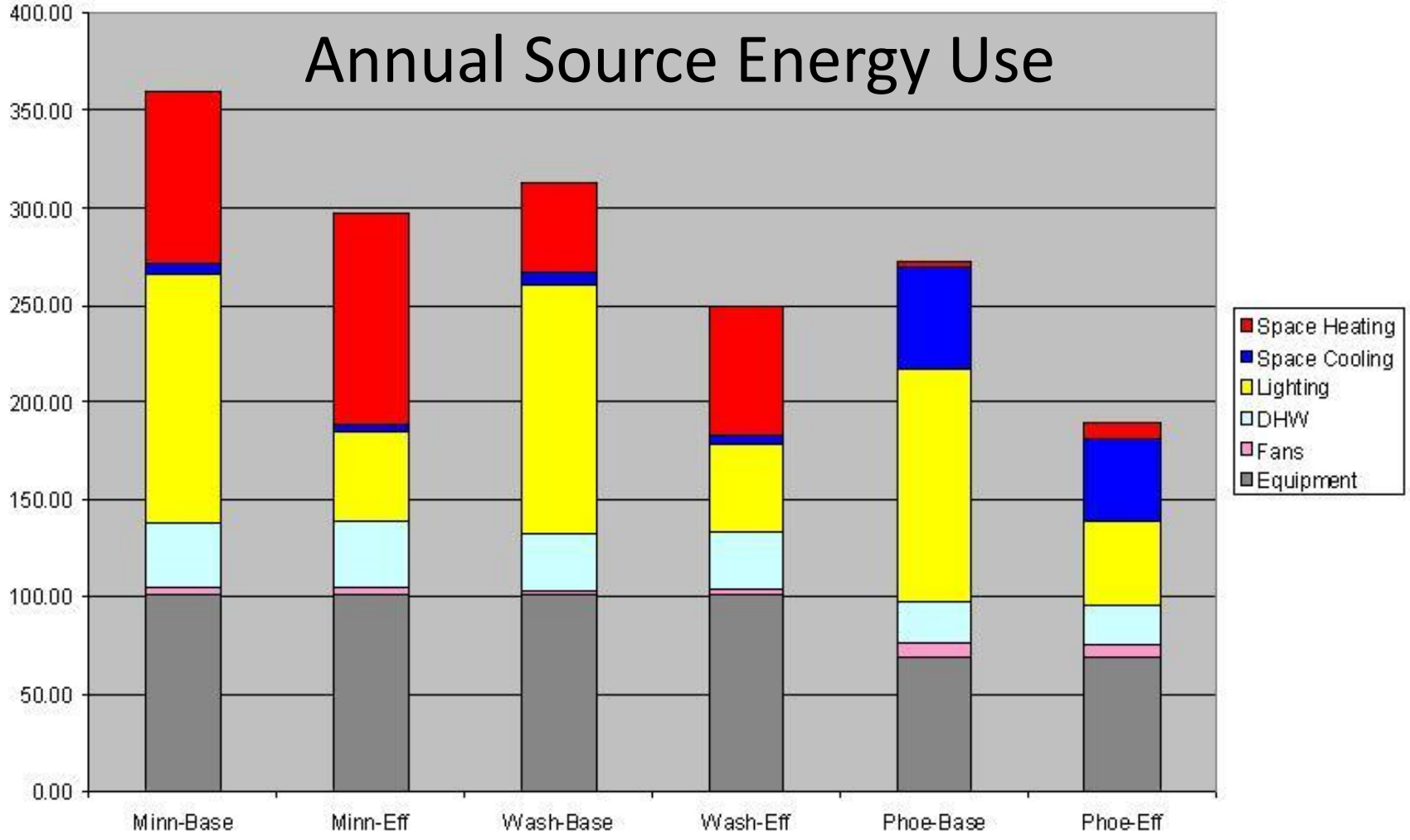


Schedules - Occupancy

Whole House Model



Whole House Model



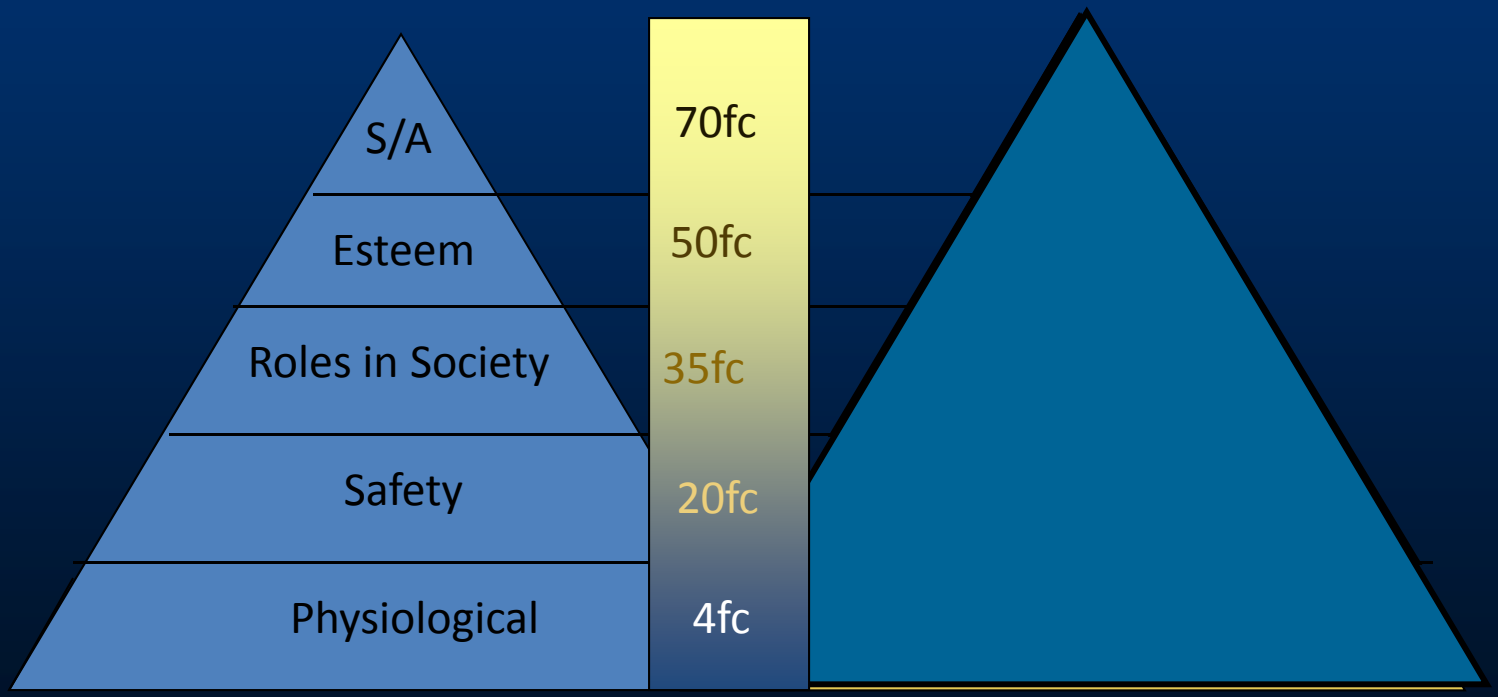
Why is lighting so personal?

Vision is a partnership between the brain and the eyes

We have been conditioned since pre-history to manage that partnership for survival

Big Picture

Lighting quality is measured subjectively by our reaction based on deeply trained responses



DESIGN CONSIDERATIONS : COLOR

Fluorescent: Energy Star QC Test

Color shift and short life issues plagued the CFL market in the last 2000's

ENERGY STAR "Durability" Testing
Work ongoing at Lighting Research Center

Source: US EPA

Fluorescent : New fixture and design choices

Fixture Inventory on Website

Strip Light in Cove

Recessed Downlight

Wall Washer

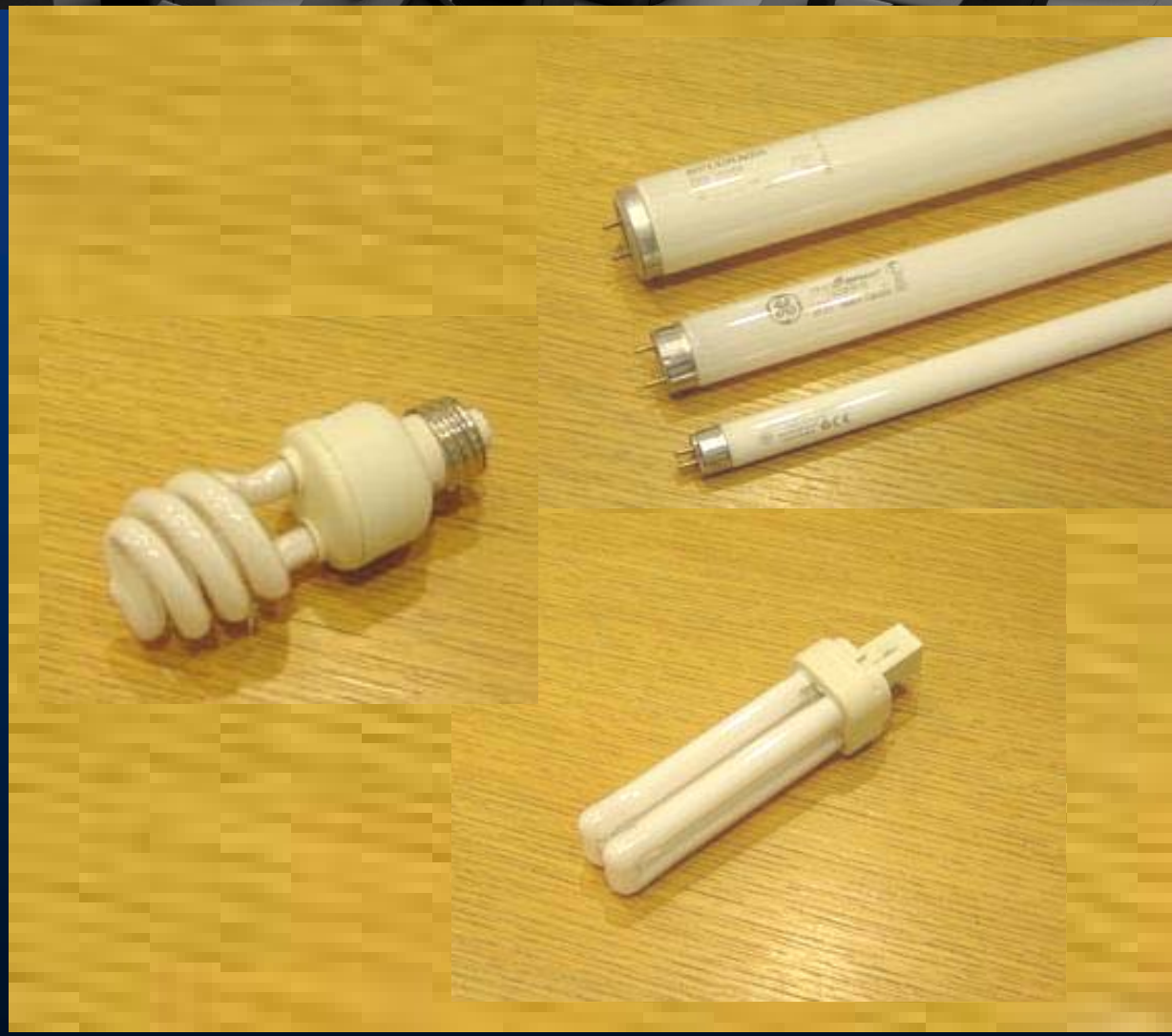
Under-Cabinet Light

Ceiling Surface Light

Fluorescent

Light Sources and Options

- Change Bulb
- Change Fixture
- Change Design



LED

Model E27-WLX3
3 Watt Luxeon (3 x 1 Watt)
LED Medium Base Spot
Light - 120 VAC

light output comparable to
25~30 watt incandescent

50,000 Hours Life Time
Warm White (3400K) –
49 lumens

Available with 10 or 30
degree beam pattern
Housing Material:
Aluminum and ABS Plastic

UL listed

LED

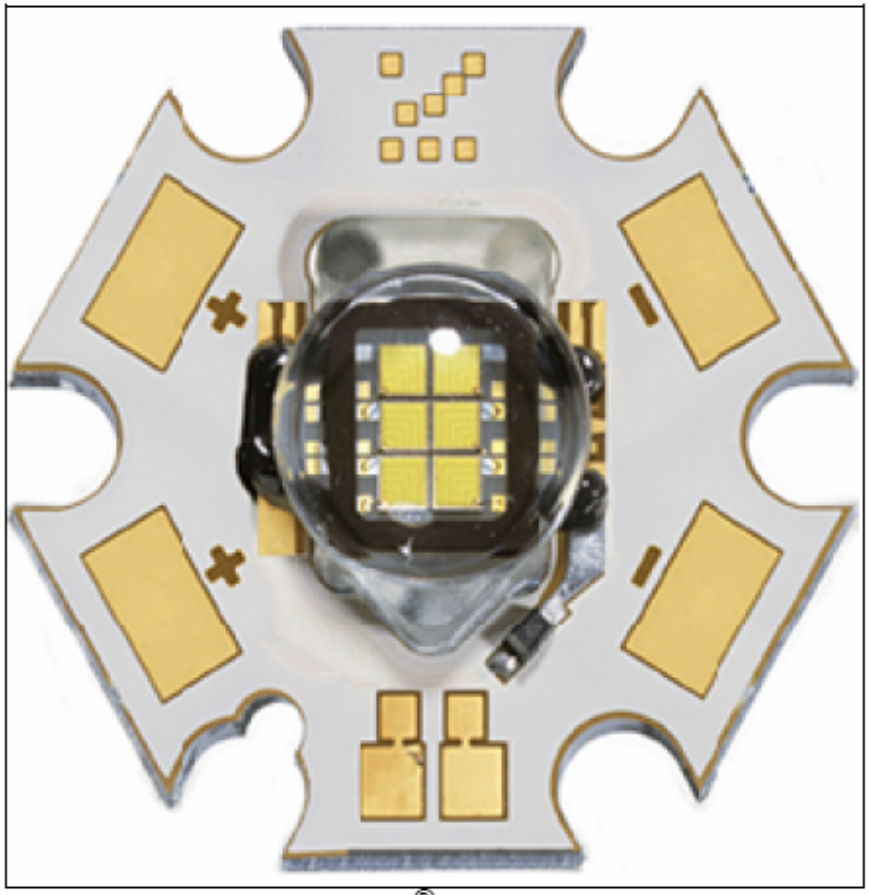


Figure 2: OSTAR®-Lighting with lens (LEW E3B)

OSTAR®-Lighting LED Light Source

The OSTAR®-Lighting LED light source was developed with an emphasis on the areas of general lighting such as:

- Room Lighting
- Architectural/Effect Lighting
- Industrial Lighting
- Radiators and Spot Lighting
- Flashlights

However, it is also suitable for special applications such as:

- Microscope Lighting
- High-quality Flash Lamps
- Traffic Signs
- Operation Lighting in Medical Technology

LED

The advantage of the chip coating is that the converter can be applied to the chip surface in a homogeneous layer with uniform concentration. This causes the converted light to be nearly constant across the entire chip surface.

Typically, the color temperature of the OSTAR®-Lighting lies in the range of 4500 to 7000 K (daylight white), with a color reproduction index (CRI) of 80.

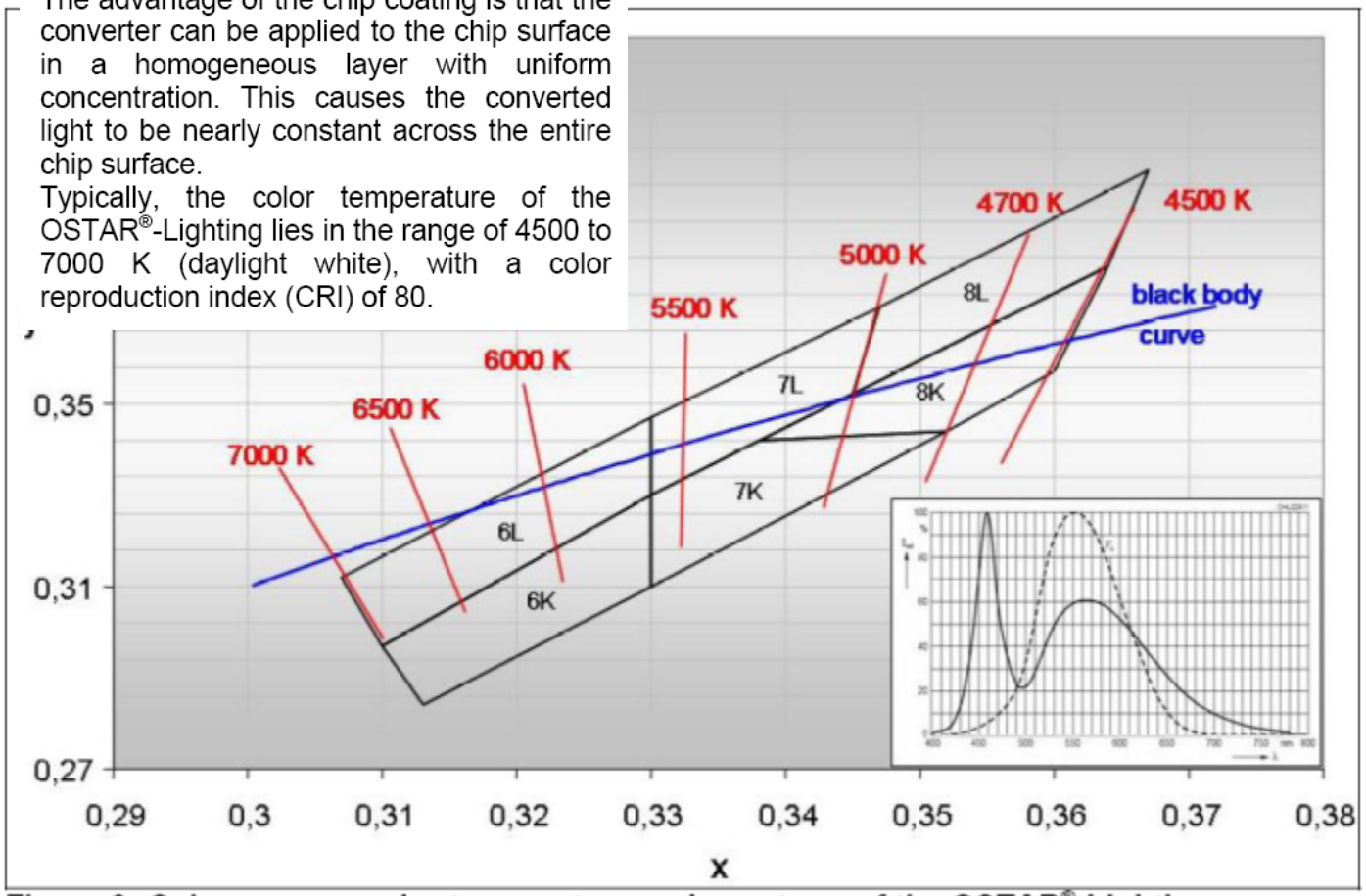


Figure 3: Color groups, color temperature and spectrum of the OSTAR®-Lighting

Color Rendition Is a Barrier

Color Temperature

- Not consistent in market
- Leads to consumer dissatisfaction
- Murky yellow at 2700K
- Greenish cast at 4100K

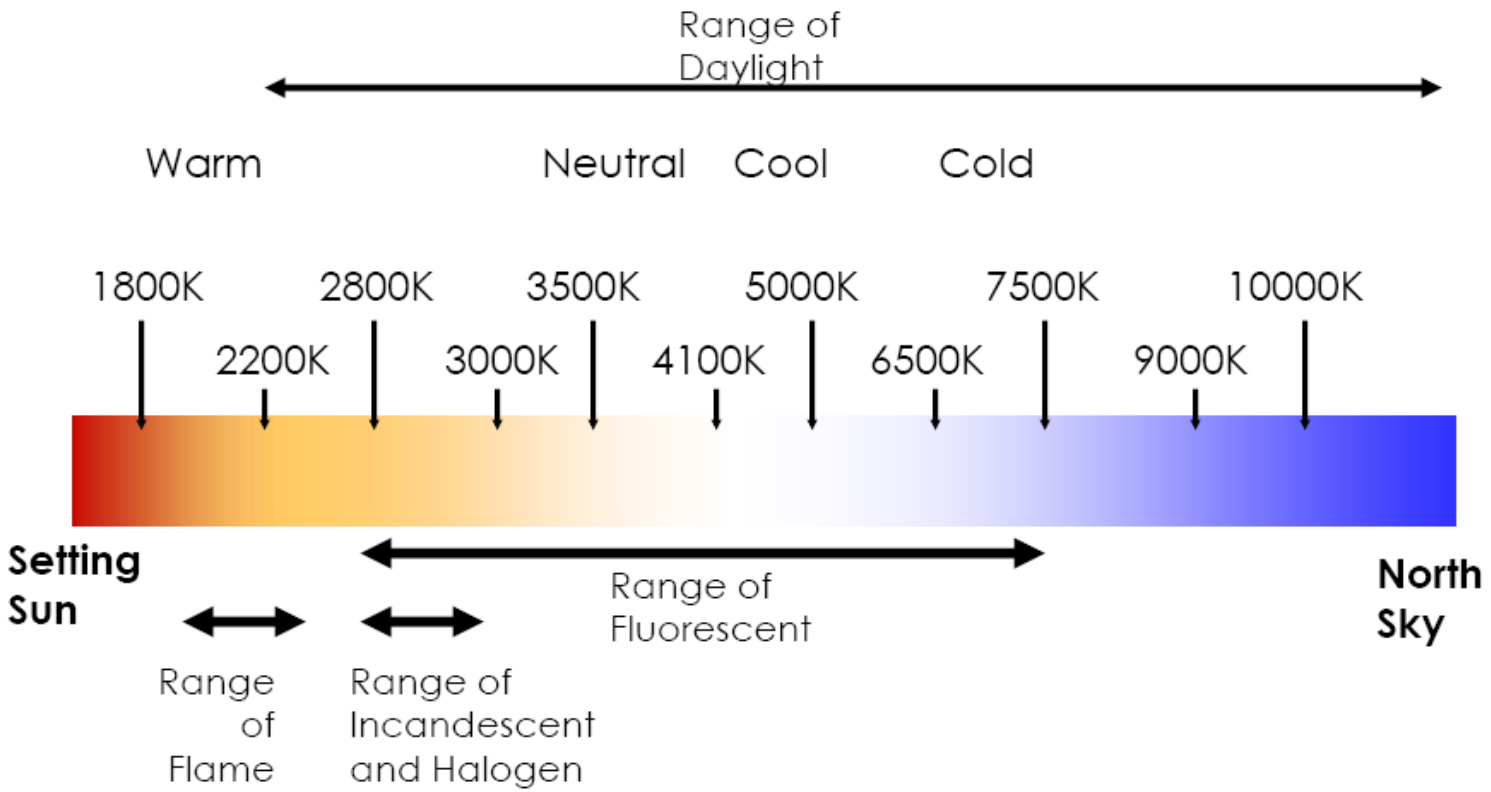
2700K

4100K

3000K

Color Temperature

Color temperature



Know the lamp code

Recommended Fluorescent Lamps for Common Use

Desired Lamp Color	Lamp Color Designation
• Warm 2700K	• "827"
• Warm 3000K	• "830" or "930"
• Neutral 3500K	• "835"
• Cool 4100K	• "841"
• Cold 5000K	• "850" or "950"

Example: F32T8/830 is a 3000K, 32 watt tubular fluorescent lamp 8/8" in diameter

Note the diminished power at the purple end of the spectrum

UV is absorbed by the longer path through the atmosphere

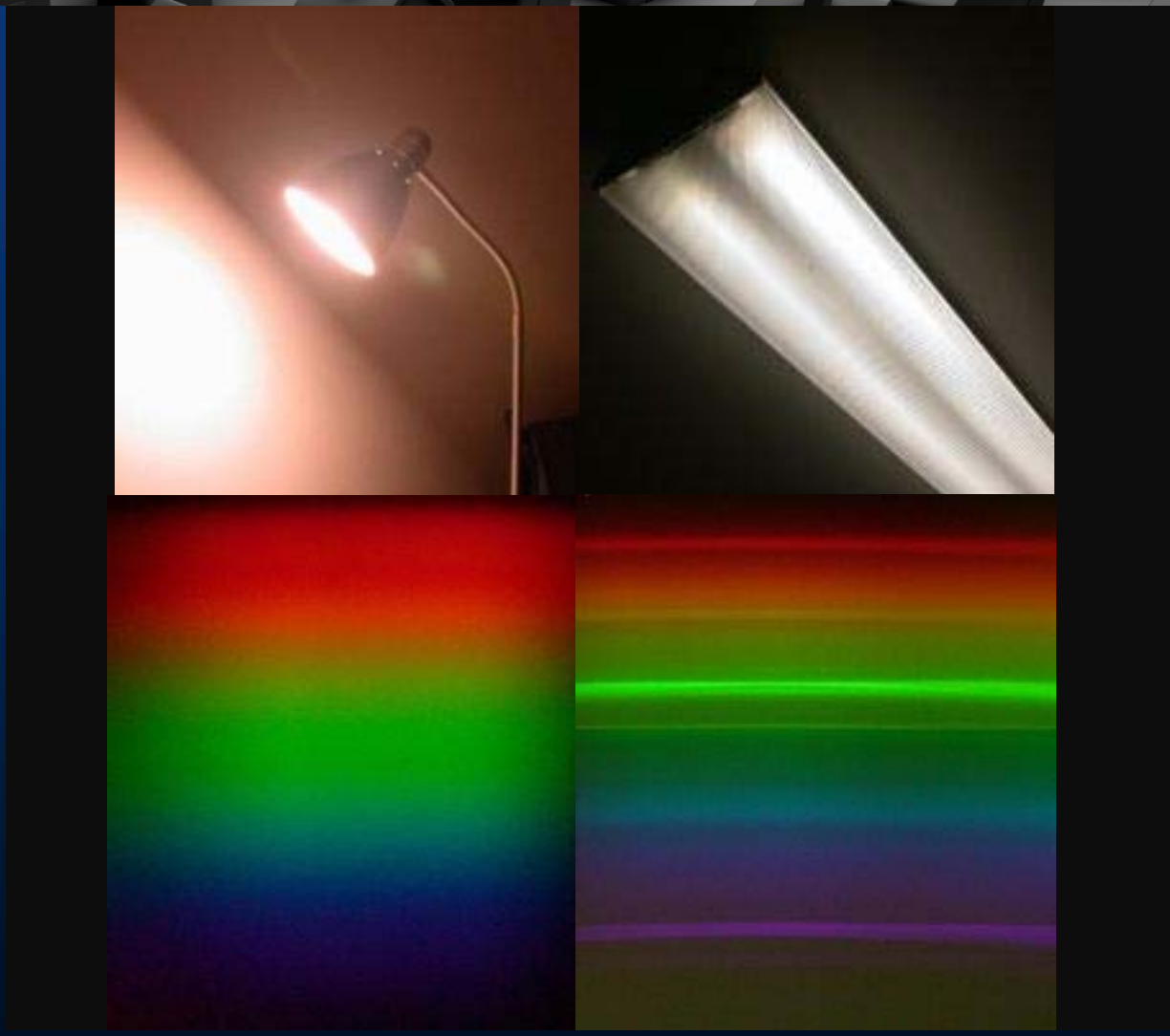
afternoon sun, altitude 24 degrees

setting sun, altitude 0.5 degree

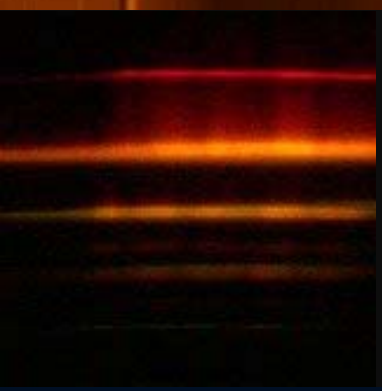
Color Temperature

Incandescent spectrum is continuous with an emphasis at the red end

Fluorescent spectrum is dominated by the phosphors used as the coating on the tube. Some fluorescent lamps have three or four phosphors, creating different results when viewing an object



High Pressure Sodium Light Source



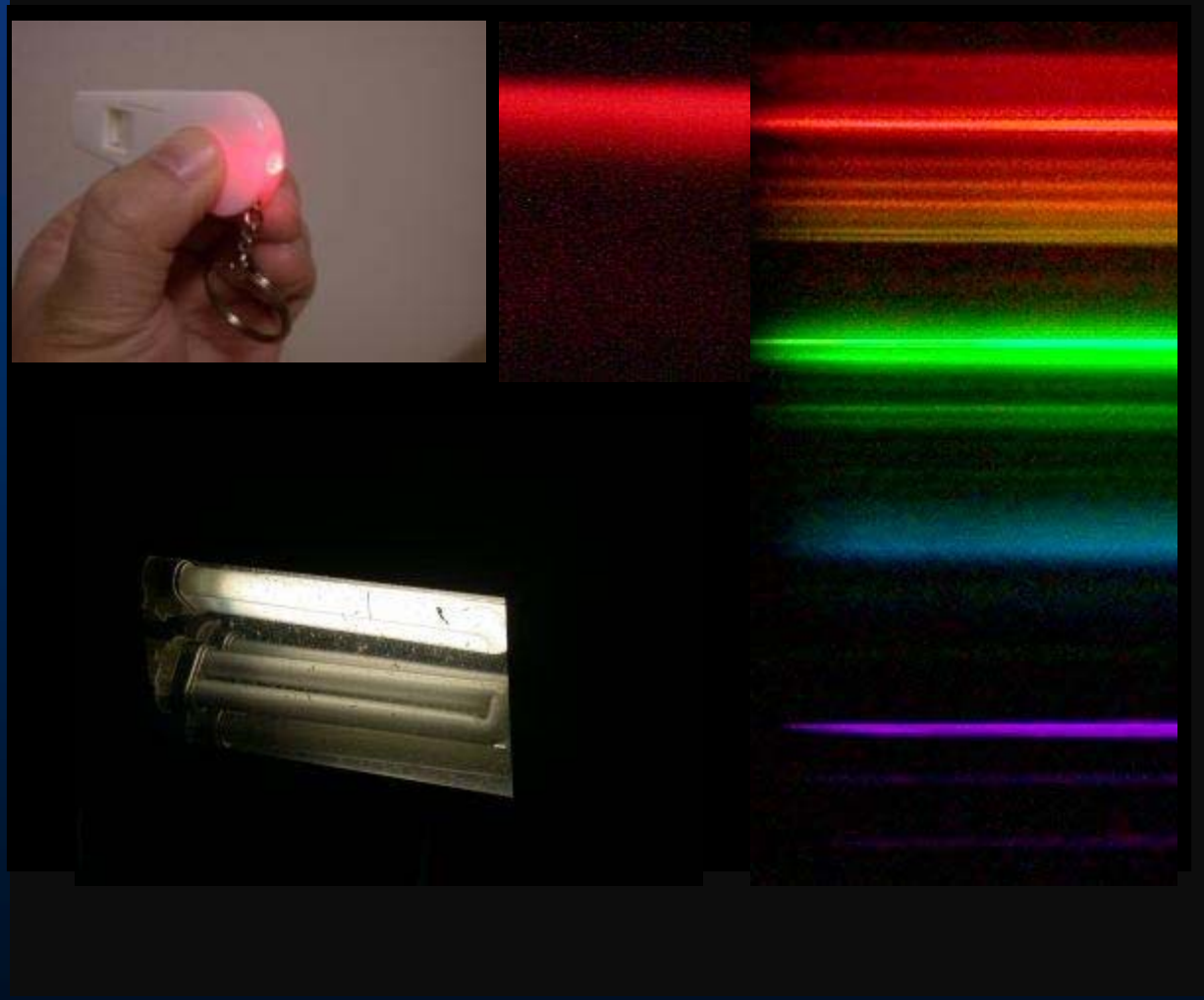
Color shift during warm up

Intro to LED light source

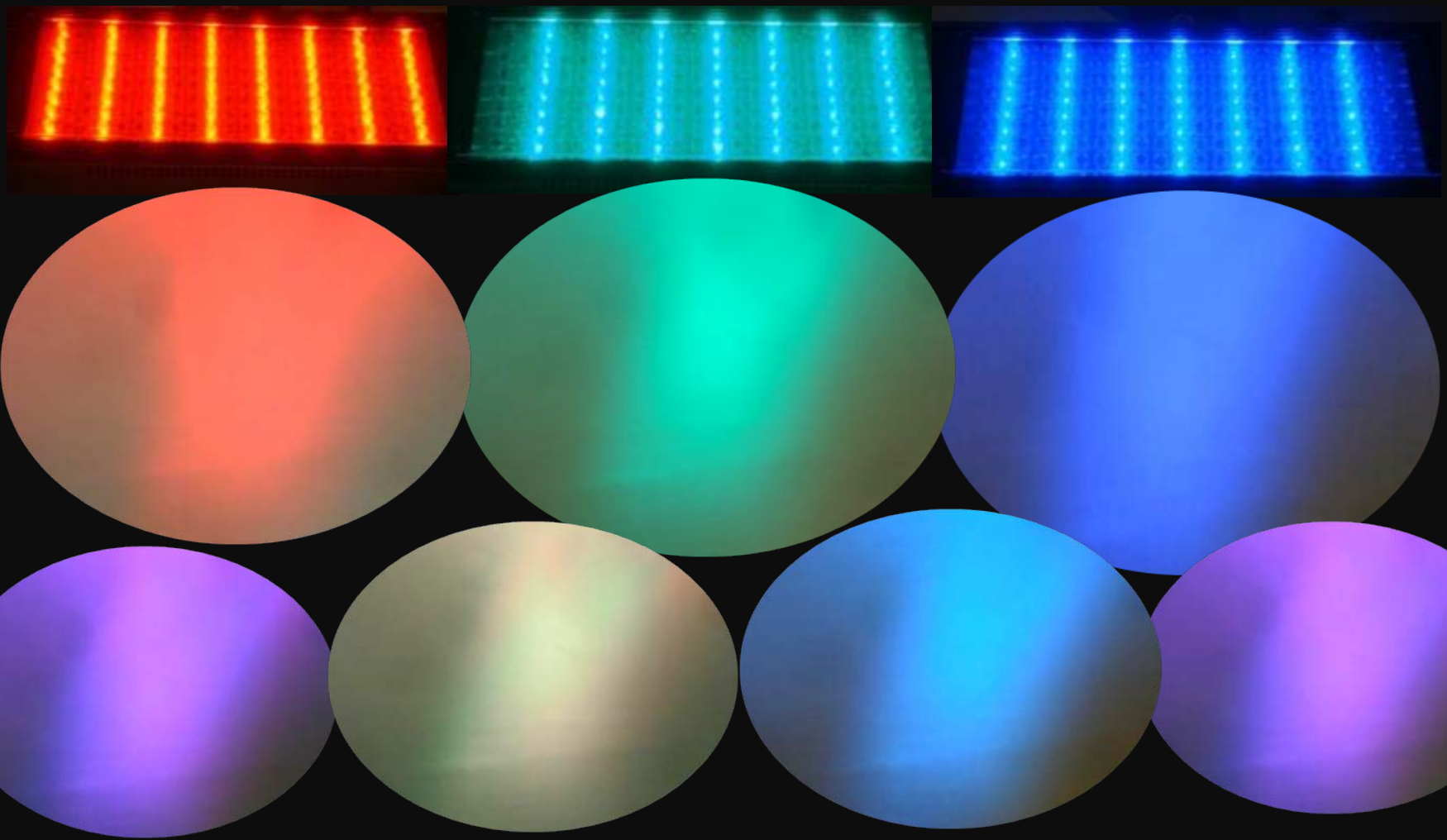
Early LED's are one color chip. CFL is a tri-phosphour source with multiple bands

Newer LED's can excite different base chip to form white light

Best to date is a white chip at 130 lumens per watt



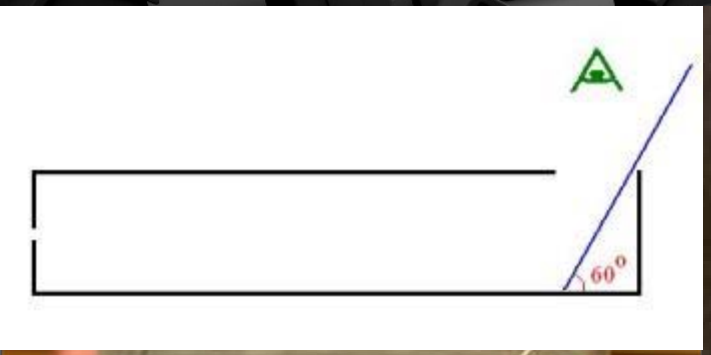
LED Color

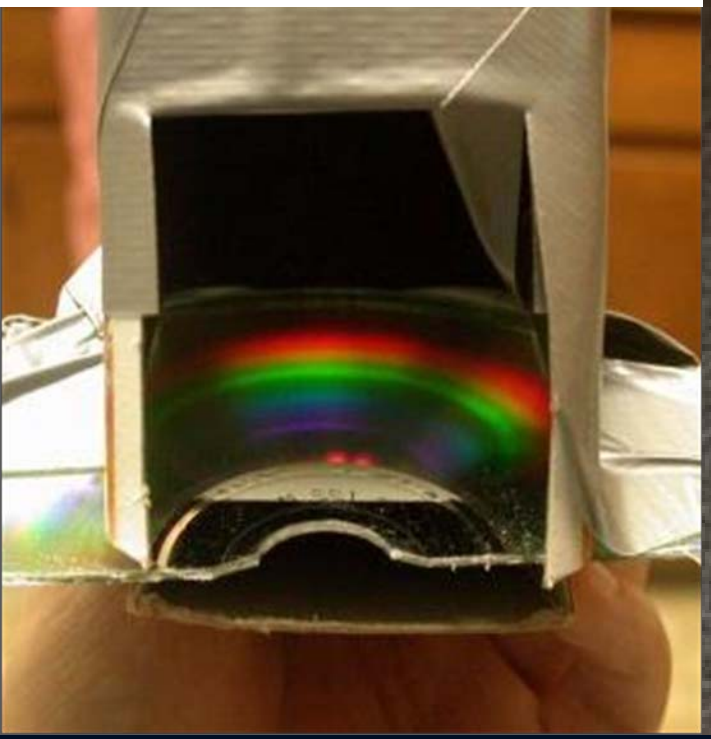


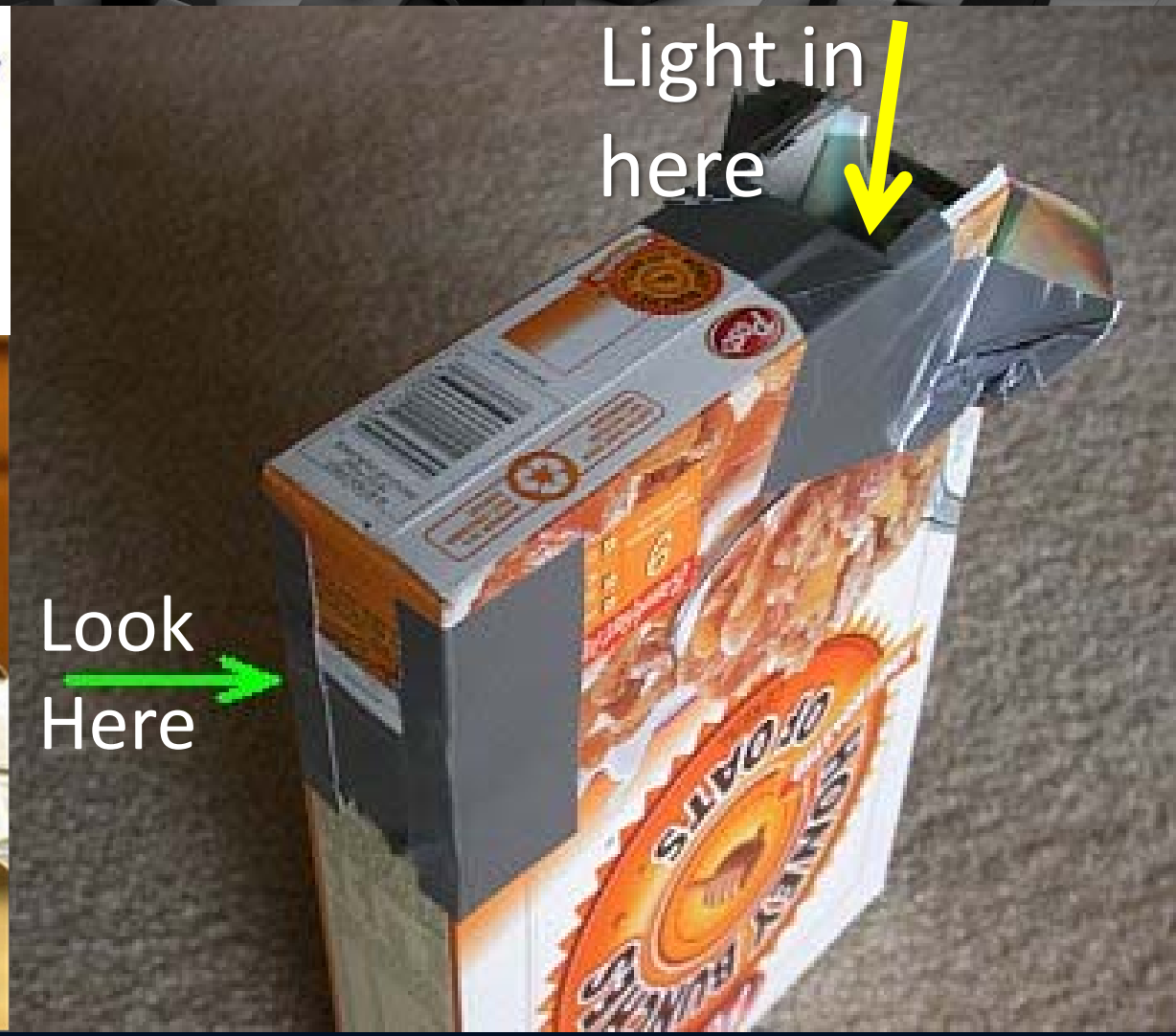
Metal Halide

Metal Halide is a broad spectrum based on the base metal materials

You can see the spectral distribution too!



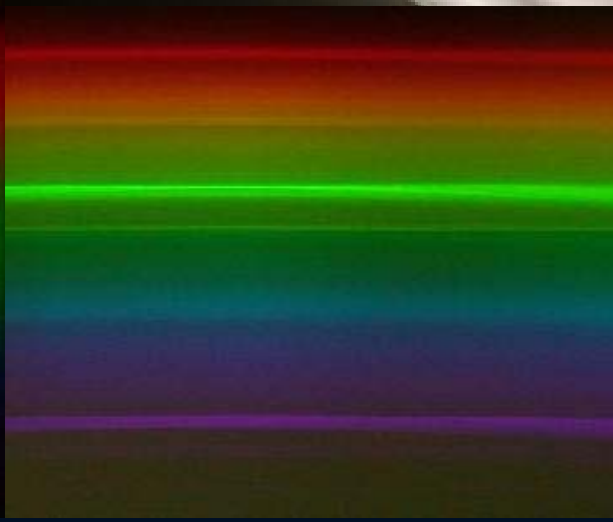




Color Rendition

Incandescent spectrum is continuous with an emphasis at the red end

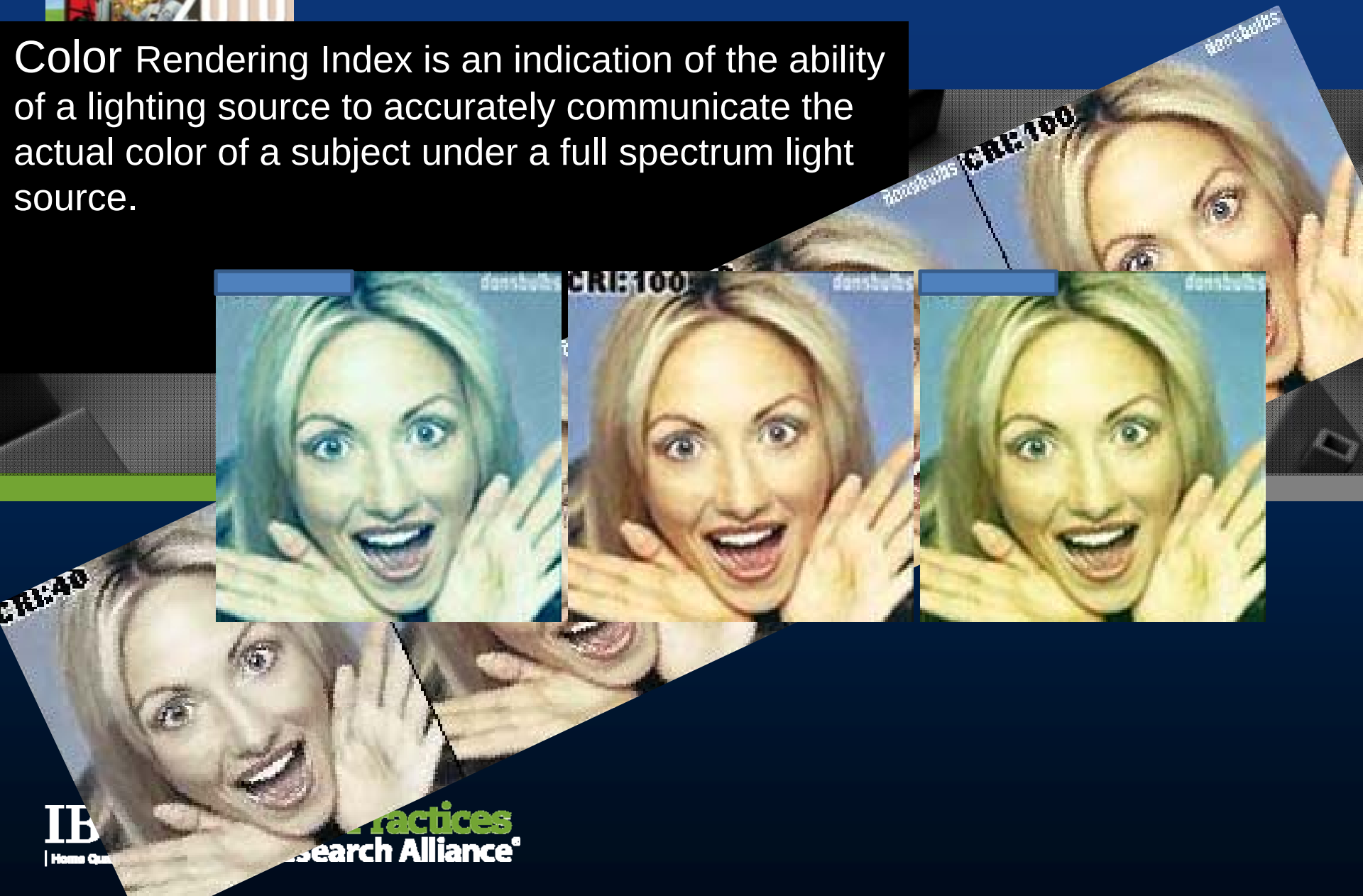
Fluorescent spectrum is dominated by the phosphors used as the coating on the tube. Some fluorescent lamps have three or four phosphors, creating different results when viewing an object



Color Temperature

Color Temperature

Color Rendering Index is an indication of the ability of a lighting source to accurately communicate the actual color of a subject under a full spectrum light source.



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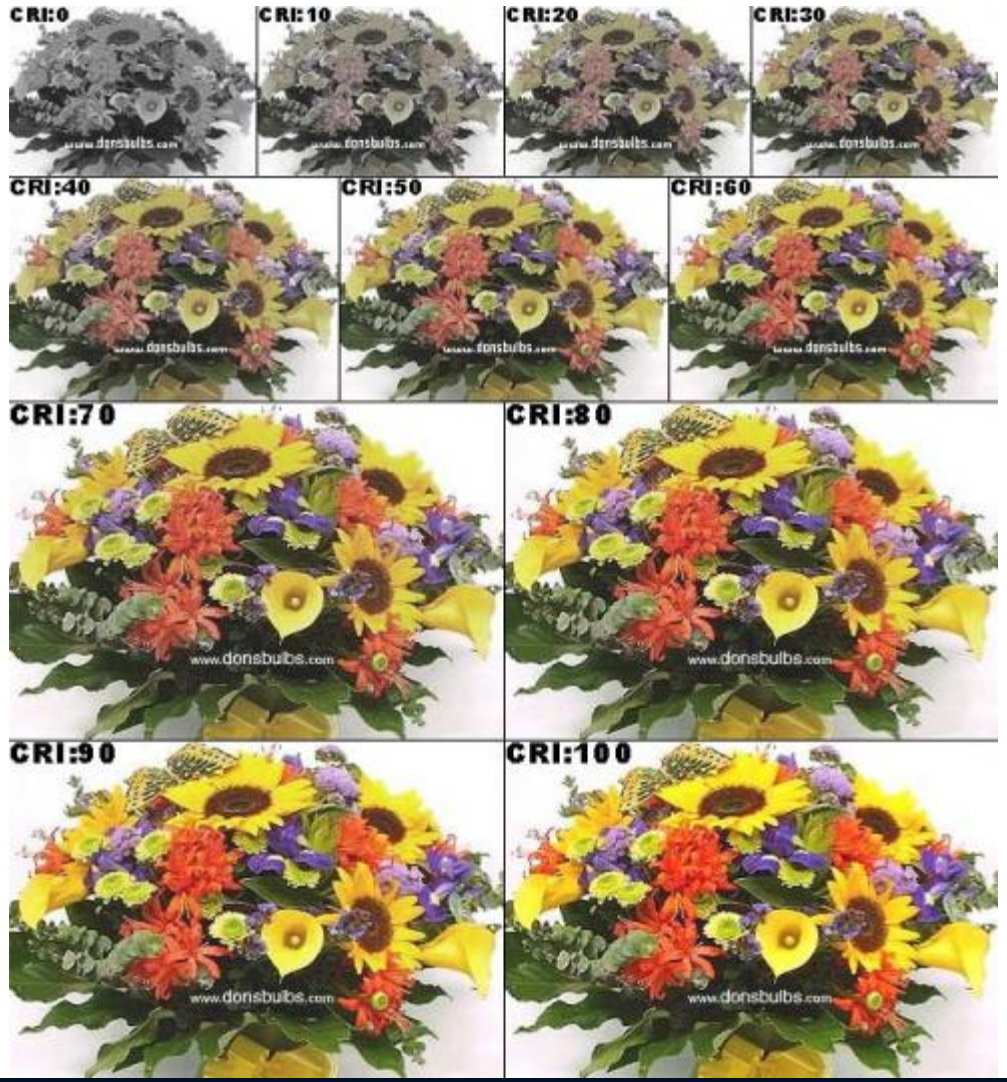
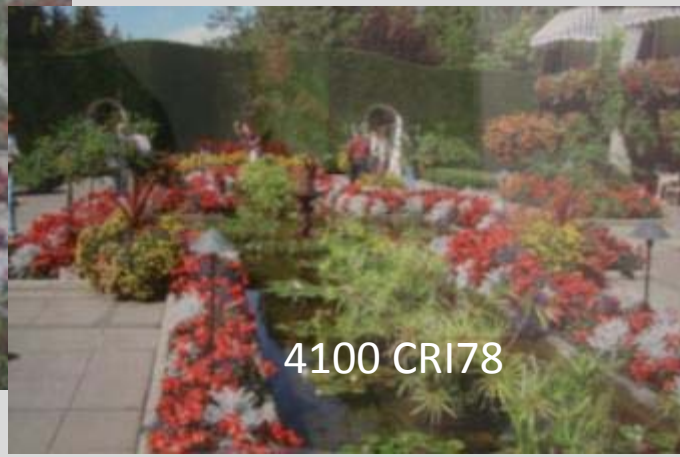
This image of Color Rendition Index is inaccurate in that the image is uniformly de-saturated.

Alternative lighting sources more correctly are of non-uniform saturation, emphasizing only a few colors

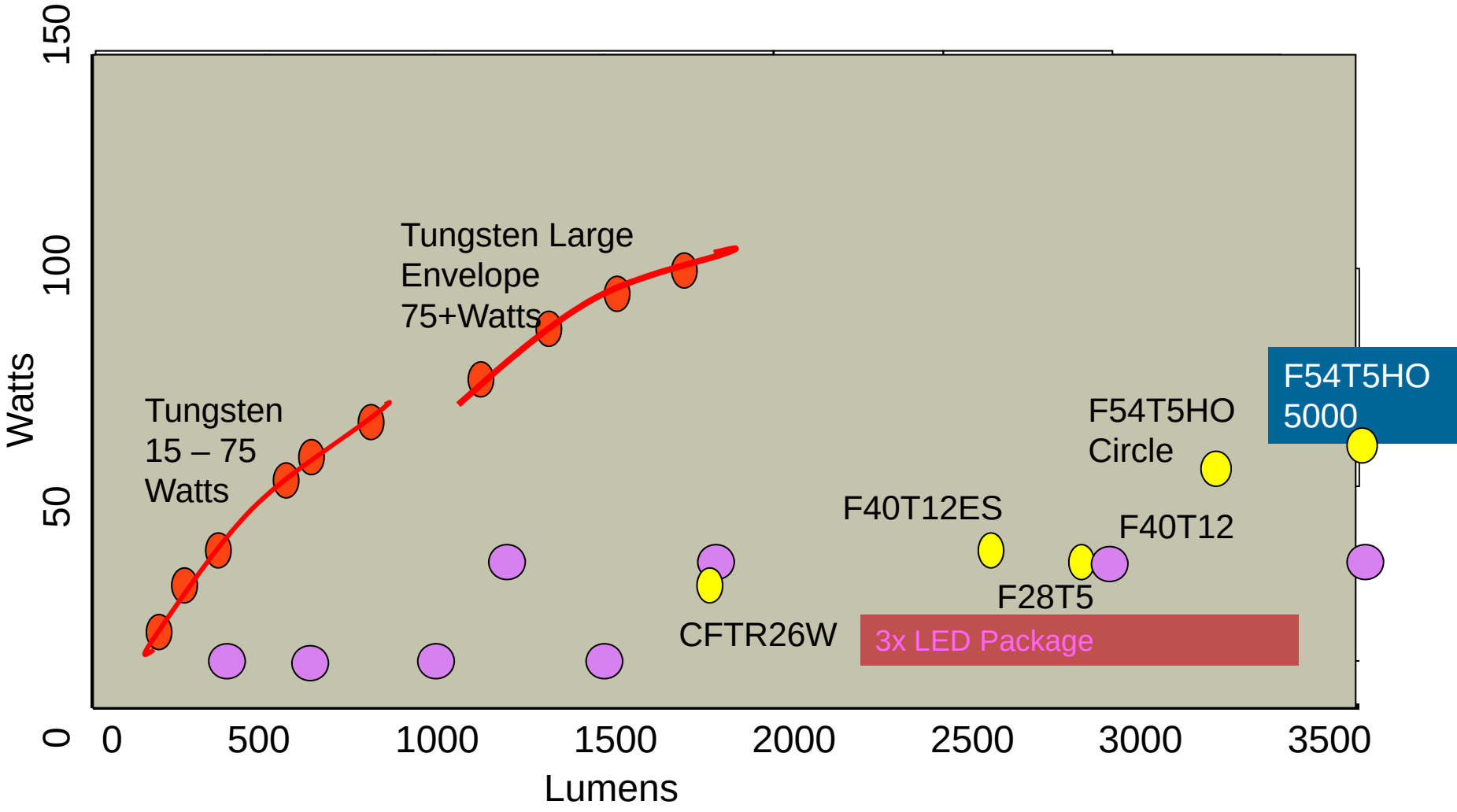


Change in primary color saturation

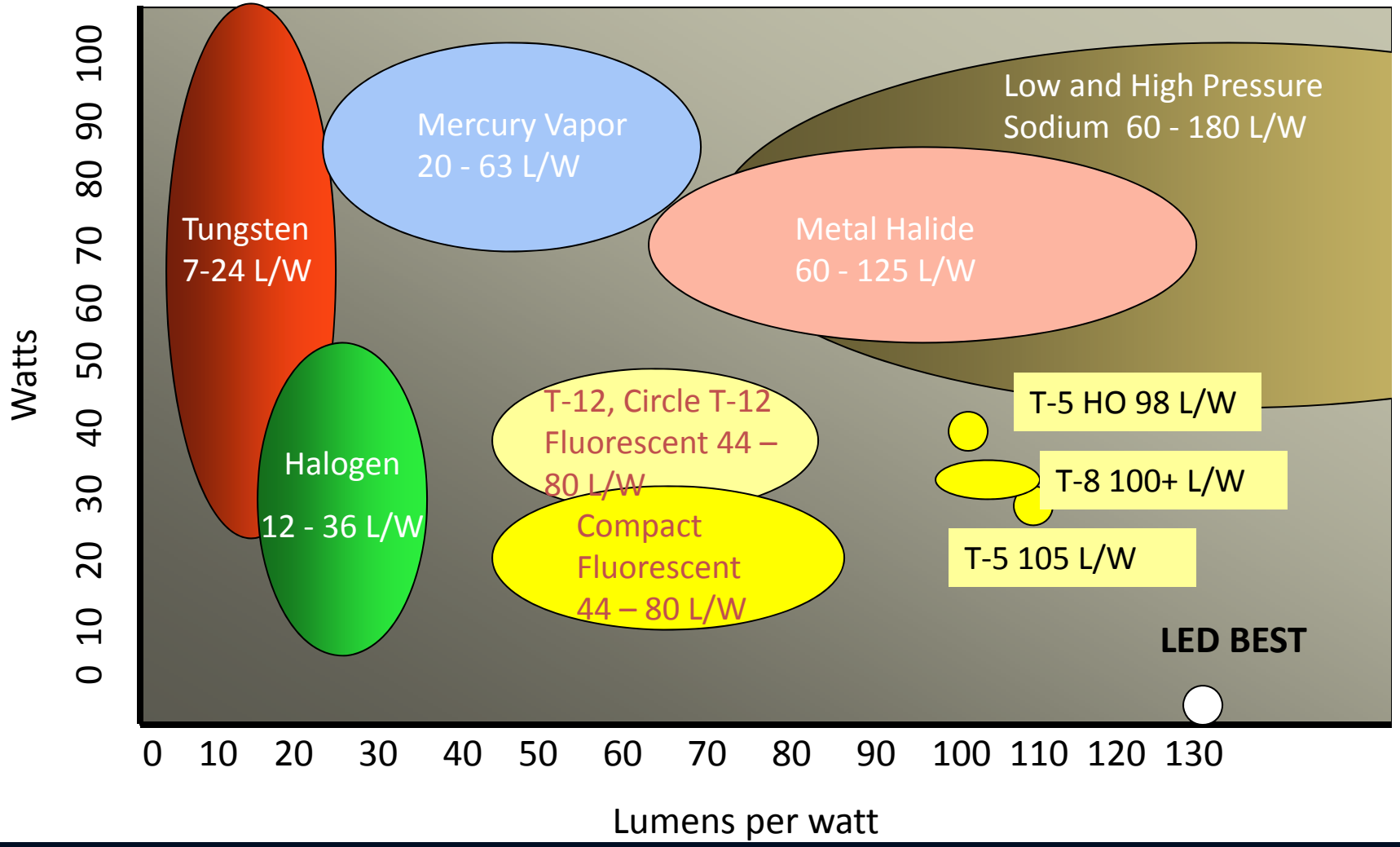
Color rendition



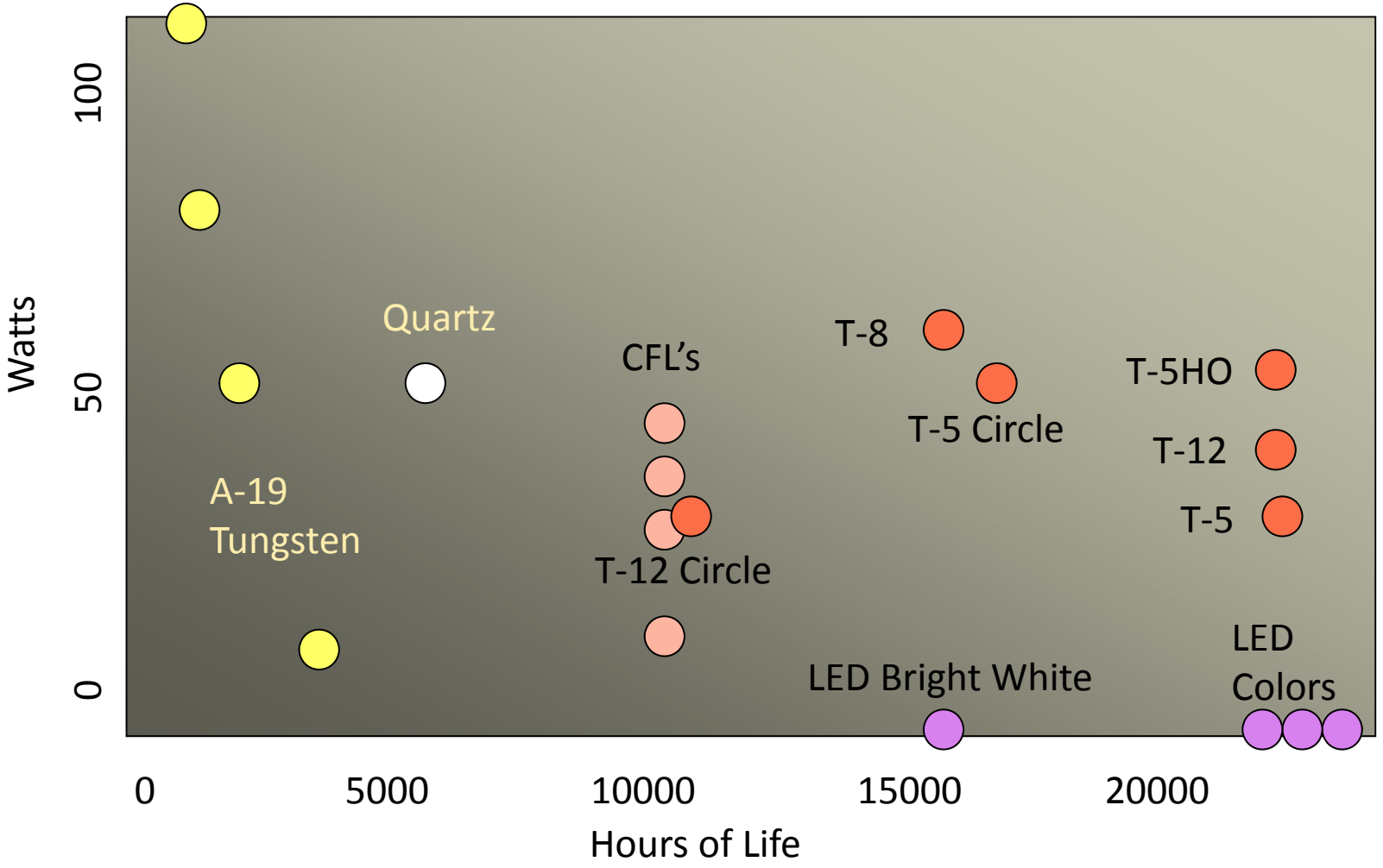
Light Output



Efficiency


Watts
0 10 20 30 40 50 60 70 80 90 100
Tungsten
7-24 L/W
Mercury Vapor
20 - 63 L/W
Low and High Pressure
Sodium 60 - 180 L/W
Metal Halide
60 - 125 L/W
Halogen
12 - 36 L/W
T-12, Circle T-12
Fluorescent 44 –
80 L/W
Compact
Fluorescent
44 – 80 L/W
T-5 HO 98 L/W
T-8 100+ L/W
T-5 105 L/W
LED BEST
0 10 20 30 40 50 60 70 80 90 100 110 120 130
Lumens per watt

Service Life



Lighting Examples

Let’s look at some real examples

But first,
The Top Ten Barriers

1. The lead time to get fixtures is unreasonable
2. My show room is not knowledgeable
3. The cost is too high
4. Heat has been and always will be a major contributor to short life
5. Design of fixtures don’t match my décor
6. Adapted light fixtures don’t use new light sources optimally
7. Light output is not the same level
8. Light output is not the same character
9. Light output is not the same color
10. My electrician doesn’t do/know about/care to install

Build in Test Homes

- Hedgewood - GA
- Tindall - NJ
- Kacin (Malky) - PA
- TNAH 05 - FL
- Aspen - CO
- Summerset Green - PA
- Southern Living Home - GA

Harvard Leading a market of voluntary standards

Stapleton Community:

All voluntary energy standards

Progression from Code plus to many builders building at 50% better than code

Harvard Communities

Builder is building high efficiency and experimenting with specifications that approach Zero Energy

Harvard Communities

Under Cabinet

Surfaces

Harvard Communities

Living Room Toward Deck

Living Room

Living Room Accents

Harvard Communities

Master Bedroom

Learning about Valences

Harvard Communities

Master Closet

Toilet Room

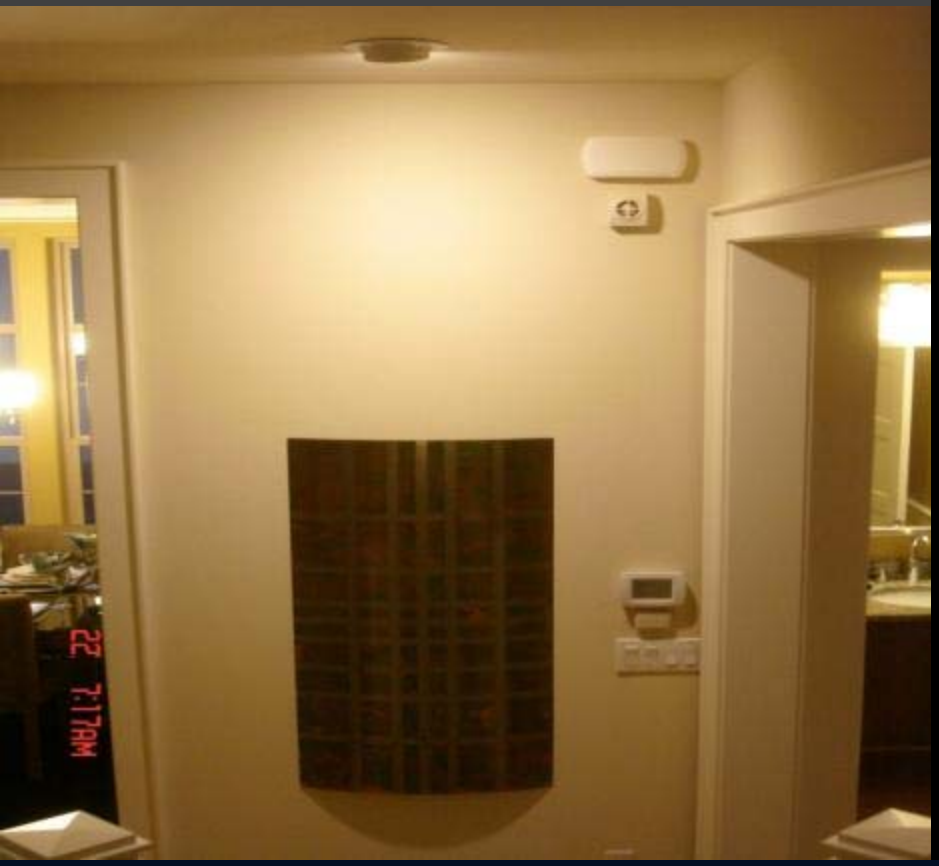
Harvard Communities

Vanity Lights

Master Bath Chandelier

Harvard Communities

Dual Purpose



Office Loft

Harvard Communities

Stairway Accents

Stairway Way-finding

Harvard Communities

Hallways

Stairs

Harvard Communities

CFL - Acceptable

LED - Unacceptable

studio26 homes

Small custom builder leading through energy efficiency and style

studio26 homes

All lighting energy efficient sources

CFL and Linear as well as some LED

studio26 homes

studio26 homes

Lighting Demonstration Area

Learning how to communicate the character and differences of lighting options to a builder

Making the need to make lighting choices more evident

Visualize the shape of the light

Create context settings

Compare various solutions

Kitchen and under cabinet lights generate a lot of interest

Measured Performance

Kitchen and under cabinet lights generate a lot of interest

Fixture Position

Lighting Inventory

Fixture Selection / Cost

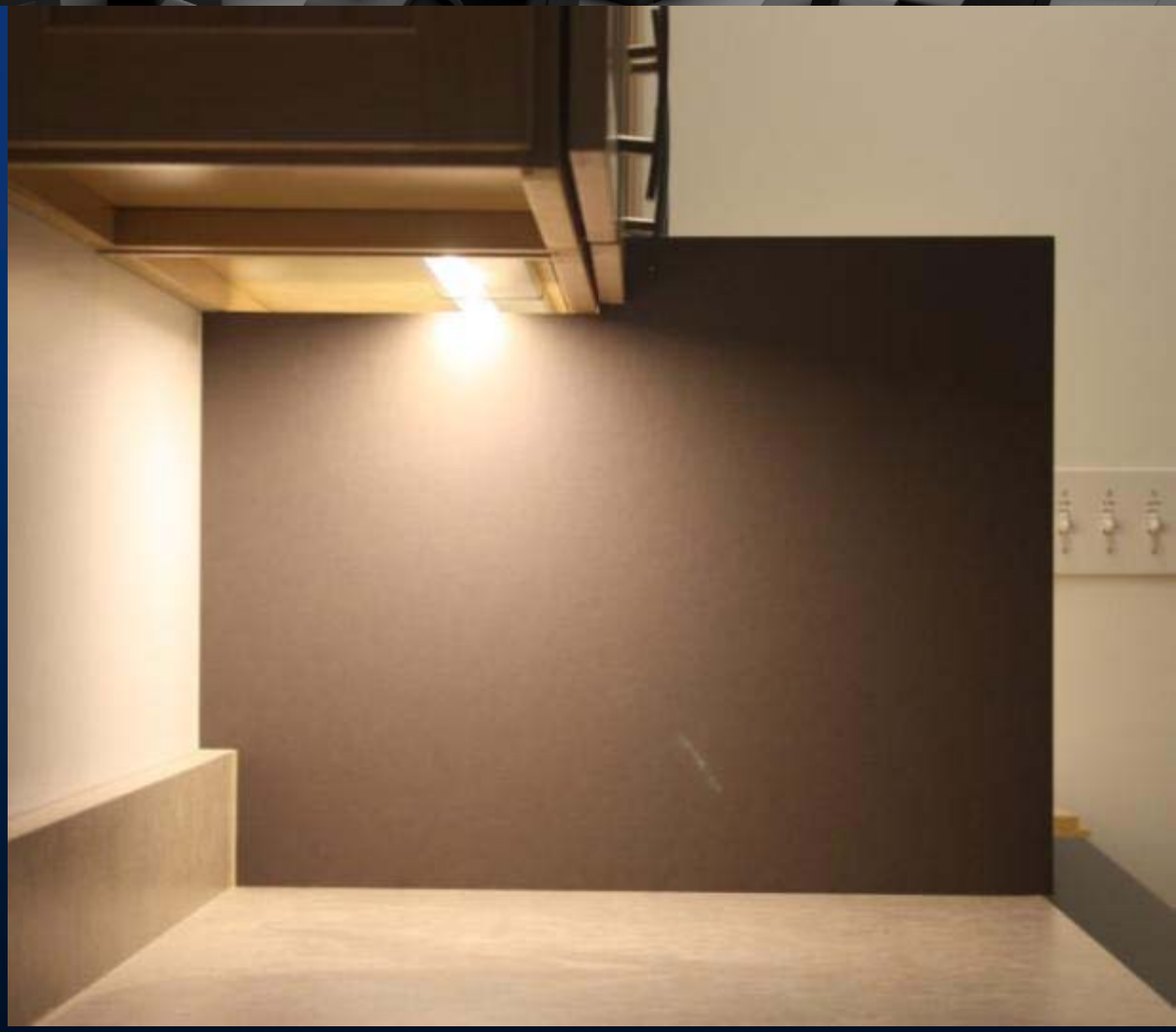
Is performance related to what you pay?

T-2 vs T-5 ?

LED ?

LED High end fixture

- Good light color
- Less light
- High cost



On IBACOS.com

Lighting Design Guide

Selecting Ducts and Registers for Comfort

Brad Oberg, Chief Technology Officer,
IBACOS

The High Performance Challenge

- Who would buy a Ferrari and put 4 for $100 tires on it?
- The ducts are the transaxle where power is transferred to the wheels
- The register is where we get traction between the Horsepower and the room
- Air is delivered at a real temperature and a real velocity with actual throw, buoyancy, and spread, for a specific time period

The High Performance Challenge

- Central system, Air based space conditioning systems are being “designed” at the boundaries of their ability to perform.

- At 400 CFM per ton, older homes (the 1970’s) required about 1 ton per 400 to 500 square feet
- Homes designed to “better than code” require just 1/2 ton for the same 400 square feet
- Homes we are designing to meet the Zero Energy Goal are between 1500 and 2000 sf/ton

Basic Assumptions

1. Outdoor heating and cooling loads are greatly reduced in the high performance house
2. Of greatest importance, radiant loss/gain from windows is greatly reduced with good glazing
3. Personal comfort starts from a better condition, air and radiant temperatures are moderated
4. Lower loads mean reduced air volumes
5. For furnishability, registers should not be located in the floor or baseboard

System Characteristics

	System size sf/ton	Air flow cfm/sf	Air exchange rate ACH
Historic Standard	400	1 cool	7.5
Base House, Austin TX	480	.82 cool	5.5
Lab C, Austin TX (HP)	580	.68 cool .74 heat	4.9
YPG House, Yuma AZ (HP)	580	.63 cool .63 heat	3.4
Civano, Tucson AZ	600-900	---	---
Lab House E, Pittsburgh PA	1000	.36 cool	2.4
IBACOS Demonstration House	1500	.25 cool	1.4

Exploring Solutions

This talk will focus on modifications to current air based distribution system to increase the comfort potential and utilize systems based on the 400 cfm per ton energy balance of current DX systems

In the future we'll need to:

- Heat with cooler air
- Cool with warmer air
- Not use central systems
- Have more thermostats

We'll need to think differently

Parts and Pieces of this talk

- Duct design overview
- IBACOS study of high performance home with zoned air based heating system
- Register and room mixing characterization study
- Guidance for selection and placement of registers
- NREL Modeling showing register engineering discovery

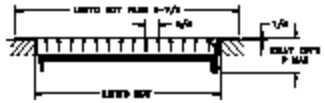
Air Distribution Design:
Potential Problems

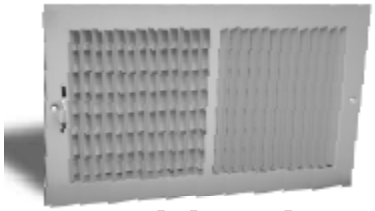
Poor Room Air Distribution

- Obstruction by furniture or draperies
- Poor throw due to low airflow

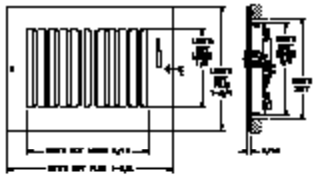
Air Distribution Design:
Room Air Distribution

900 Commercial





600 Residential



Register Selection Criteria

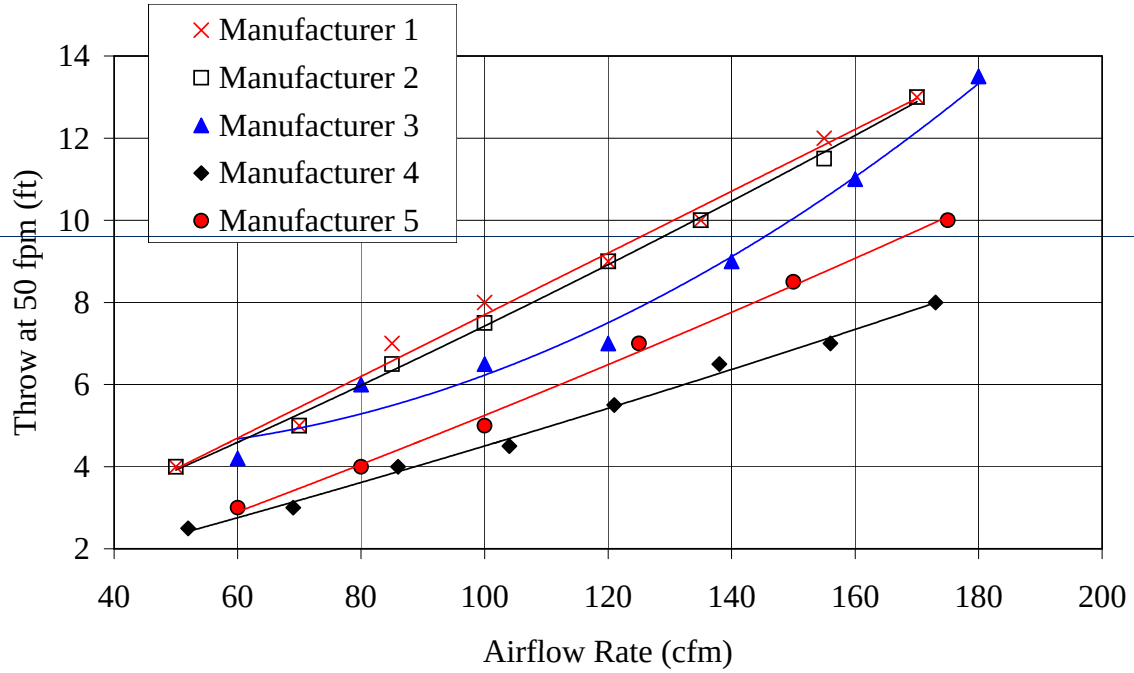
- Throw
- Pressure Drop
- Noise

Higher performance does not have to cost more

Air Distribution Design:
Room Air Distribution

Register Selection Criteria

- Throw
- Pressure Drop
- Noise



Floor Register Performance (4x10)

Floor Register Performance (4x10)

Convert Throw to 50 fpm

We consider a terminal velocity of 50 fpm as the desired residential limit to mixing effectiveness

We use this excel program to convert from published data to the 50 fpm

Key	
CFM	Cubic Feet / min
Ak	Effective Area
K	Throw Factor
Vt	Terminal Velocity
Throw	Typically 50'/min or 75'/min
Adjustment	Dervired from data input on the left
X	Distance from outlet to Centerline
H	Width of jet at outlet IE; Deflection A, B, C
Note:	For Slot Type Diffusers when calculating free area us X/H instead of X/

1. Calculate adjustment

CFM	100
Ak	0.16
K	4.4
Vt	75
Throw	10
Adjustment	0.603

2. Enter design parameters

CFM	100
K	4.4

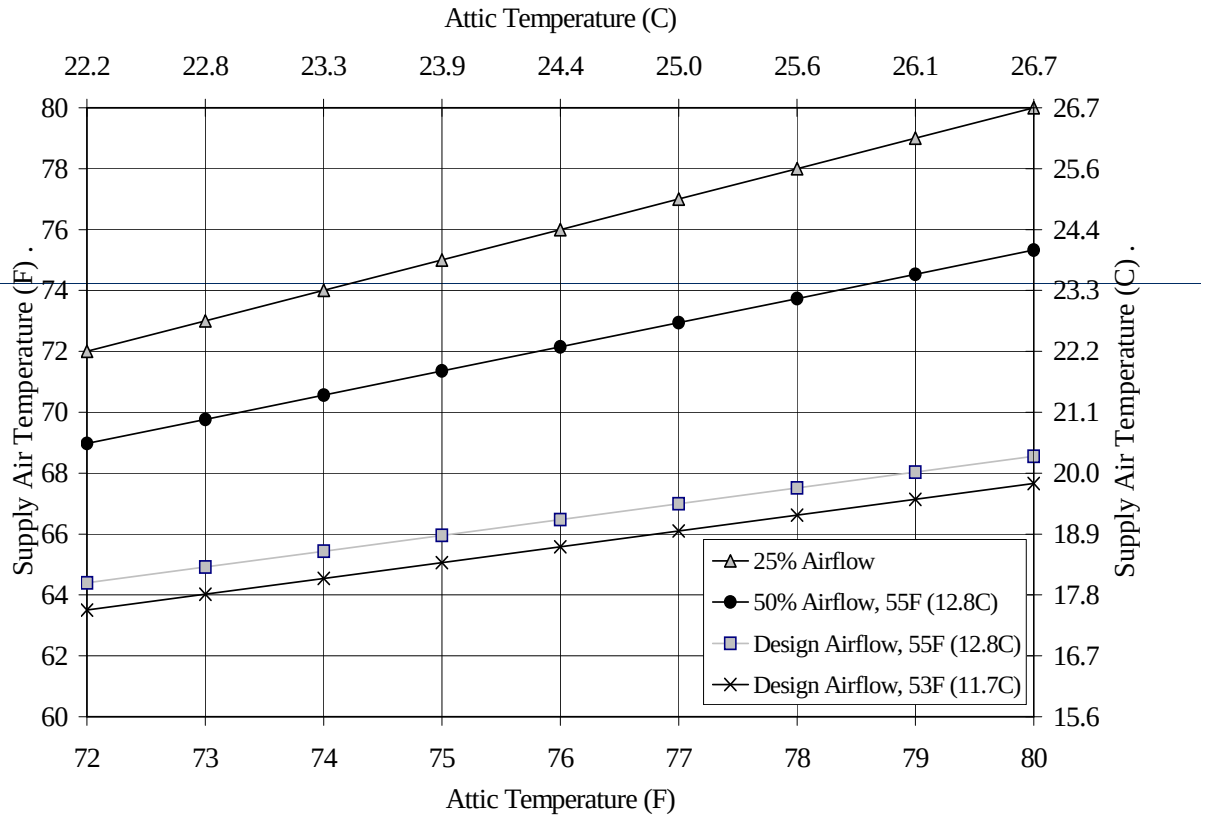
Terminal Velocity	Throw (feet)
50	12.0
100	7.5
150	5.0

Recommended K Values

Outlet Type	Discharge Pattern	K
High sidewall grille	0º deflection	5.0
High sidewall grille	wide deflection	3.7
High sidewall linear	core < 4" high	3.9
High sidewall linear	core > 4" high	4.4
Low sidewall	up wall, no spread	4.4
Low sidewall	wide spread	2.6
Baseboard	up wall, no spread	3.9
Baseboard	wide spread	1.8
Floor	no spread	4.1
Floor	wide spread	1.4
Ceiling circular	360º	1.0
Ceiling square	4-way, little spread	3.3
Ceiling square	1-way, little spread	4.4
Ceiling linear	1-way, horizontal	4.8

Change in Supply Temperature:
Un-insulated Ducts in Semi-conditioned Space

- Under constant flow
- Eliminating heat gain during stagnation
- Un-insulated ducts passing through attic space inside thermal envelope demonstrate poor efficacy based on flow percentage



Air Distribution Design:
Construction Concerns

- Provide return path
- Ducted return main
- Return path for each room

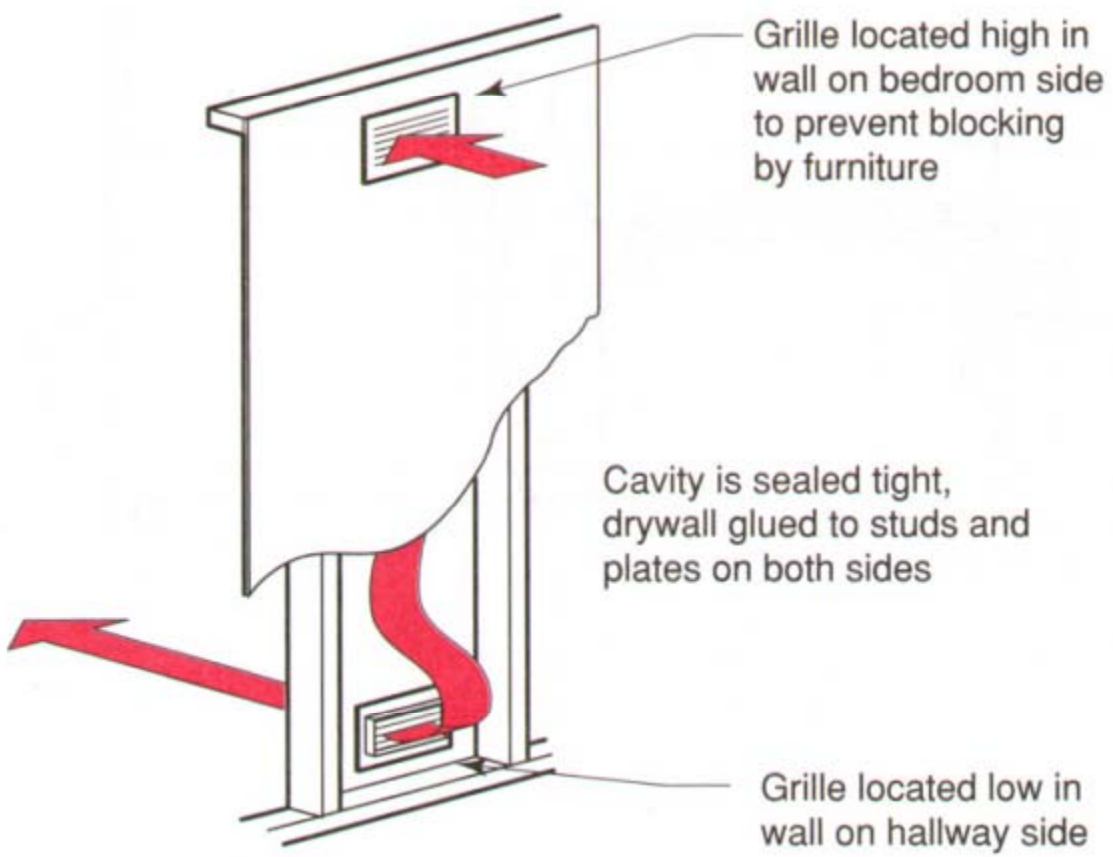
Air Distribution Design:
System Design Principles

Locate system in conditioned space or insulate well

- Basement
- Un-vented crawlspace
- Structure/ceiling space of main floors

Air Distribution Design:
System Design Principles

- Provide return path
- Ducted return main
- Return path for each room
-



Transfer Grille

Transfer Grille

Air Distribution Design:
System Design Principles

- Provide return path
- Ducted return main
- Return path for each room
- Design at 2x duct dimension

Jump Duct Above Door

Air Distribution Design:
Potential Problems

- Low system airflow – energy and comfort
- Wrong room airflow – comfort
- High pressure drop – energy
- Noise – comfort
- Poor room air distribution – comfort

Air Distribution Design:
Potential Problem #1

Low System Airflow

- High system pressure drop
- Wrong fittings
- Critical branch
- Poor fan performance

Many systems require return from both sides of the unit

Many systems require return from both sides of the unit

Potential Problem #1:
Low System Airflow

Convenient to build,
but not
to design

Potential Problem #1:
Low System Airflow

Air Distribution Design:
Potential Problem #2

Wrong Room Airflow

- Poor design (supply or return)
- Poor system balance
- Wrong fittings

Fitting selection is critical

Potential Problem #2:
Wrong Room Airflow

Air Distribution Design:
Potential Problem #3

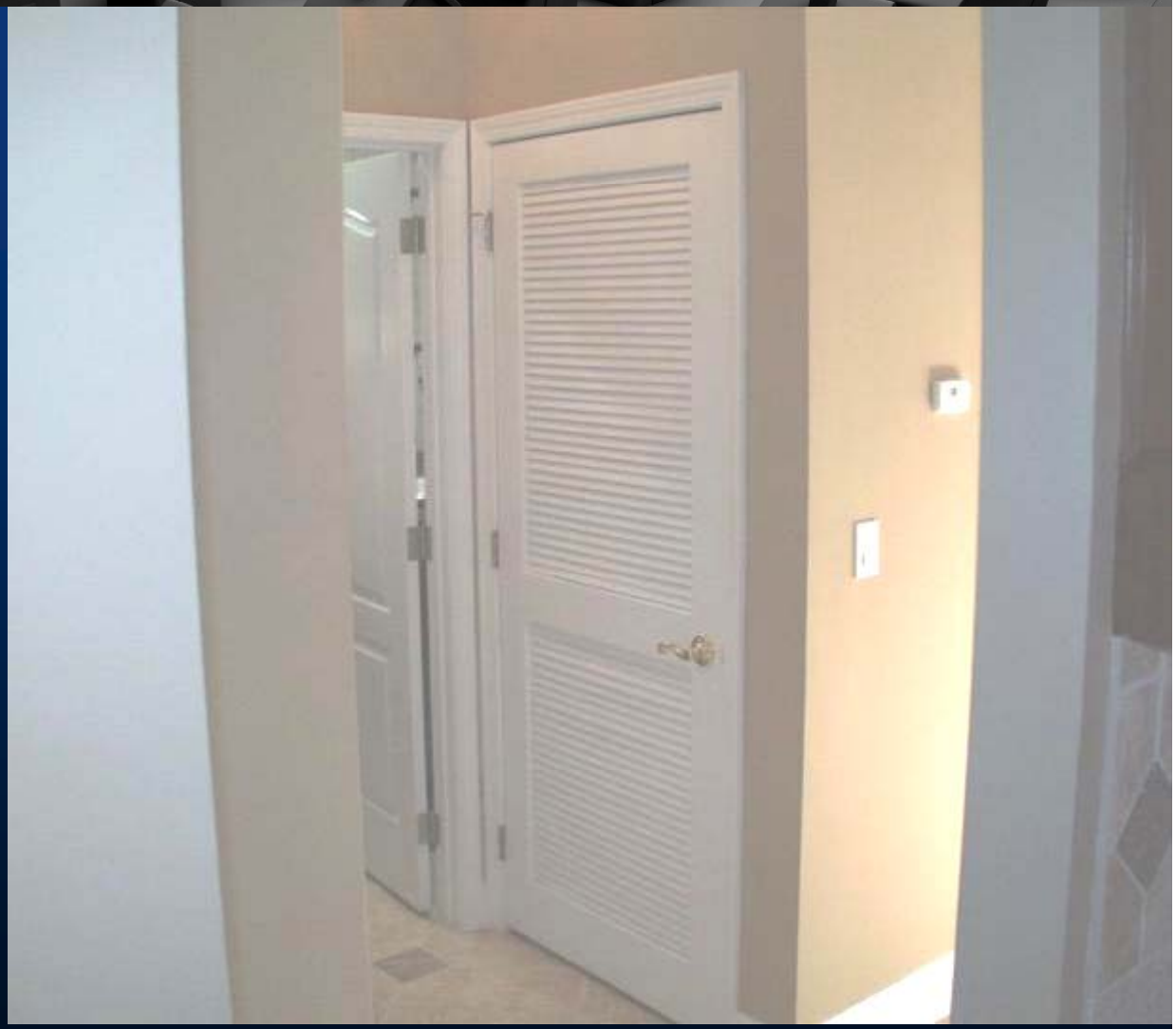
Noise

- High face velocity at register
- Poor fitting design
- No return duct system

Grills in doors and through walls restrict flow and do nothing to capture fan noise

Potential Problem #3: Noise

Door grills have less than 25% free area



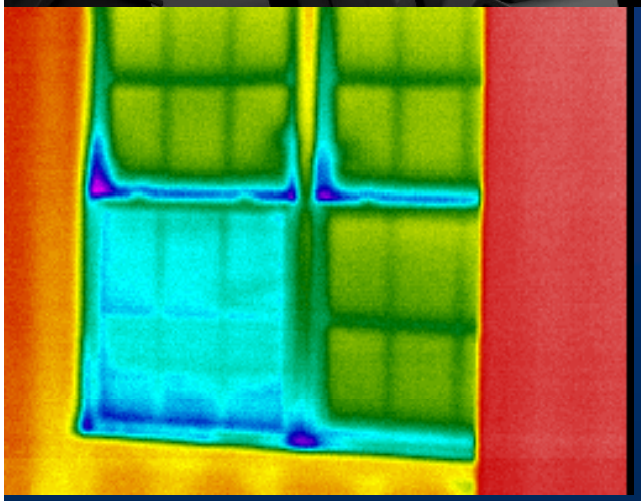
Air Distribution Design:
Potential Problems

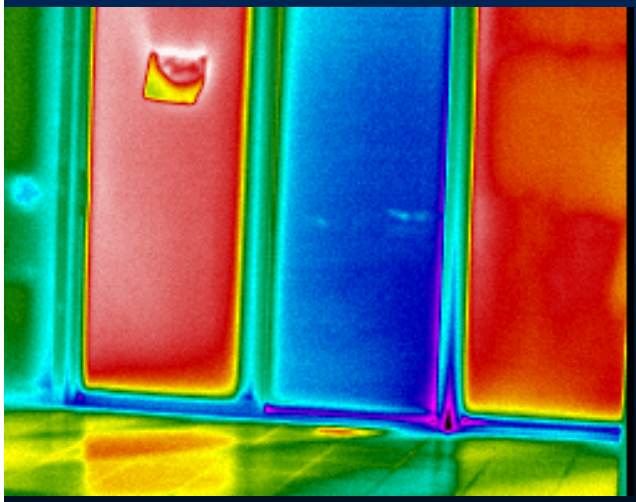
Short return path beneath air handler is a source of noise

Air Distribution Design:
System Design Principles

- Zone based on thermal loads
- Locate central supply and return mains
- Integrate distribution system into house
- Design fittings including plenums and boots
- Balance branch run-outs
- Locate ducts and equipment in conditioned space
- Provide delivery registers that mix well
- Provide return path
- Provide access to equipment

Air Distribution Design:
System Design Principles



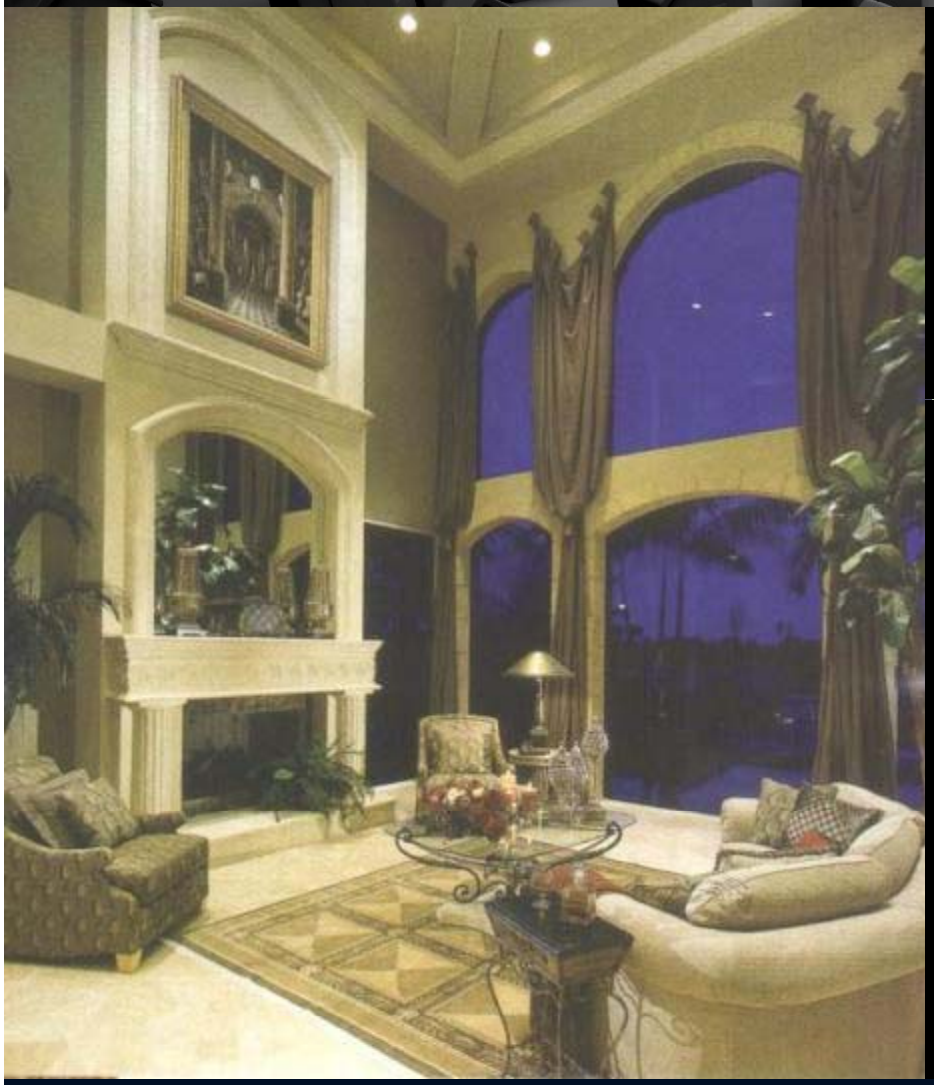


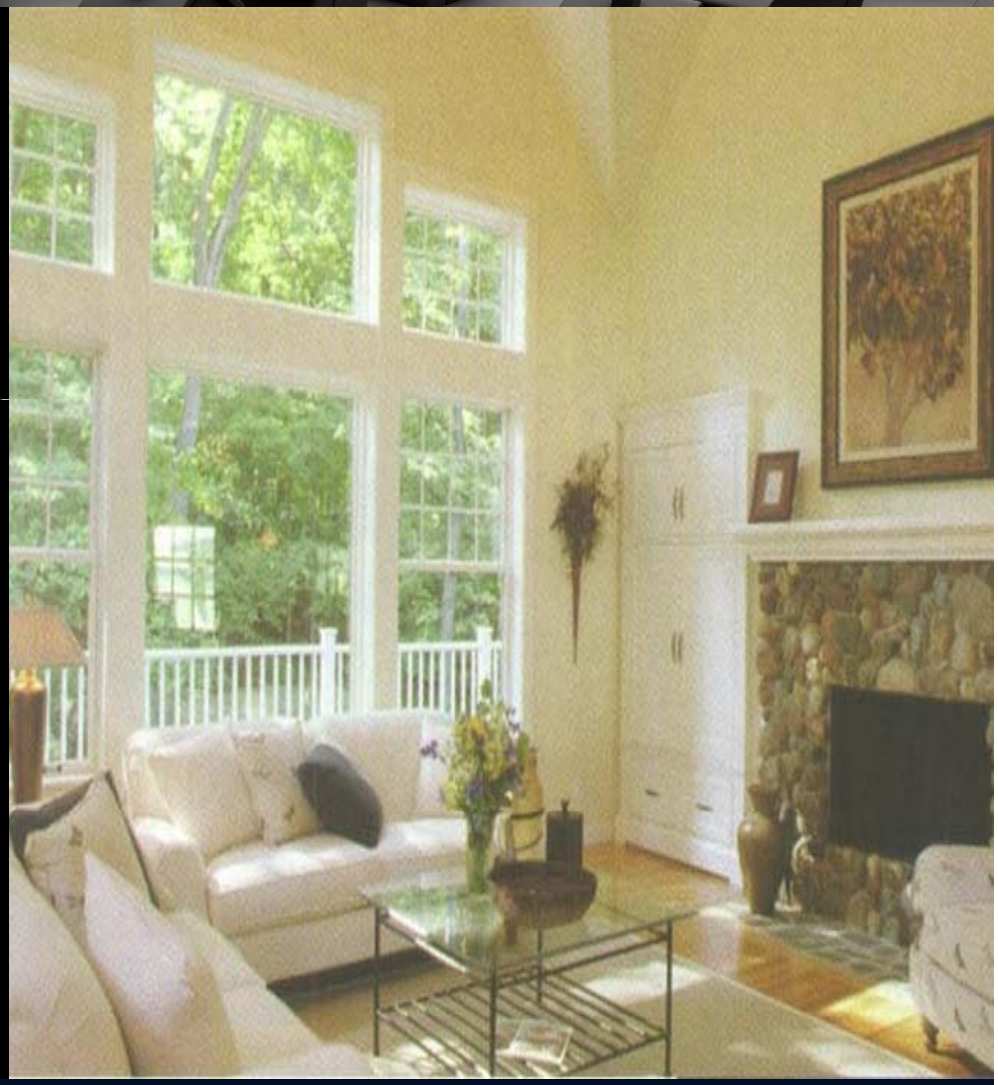
Zone Based on Thermal Loads

- Window performance
- Window sizes
- Window orientation

Low-e and reduced solar heat gain windows are useful tools in reducing peaks cooling loads

System Design Principle:
Zone Based on Thermal Loads





Air Distribution Design:
Construction Concerns

- Duct leakage
- Use of proper fittings
- Flex duct installation
- Commissioning

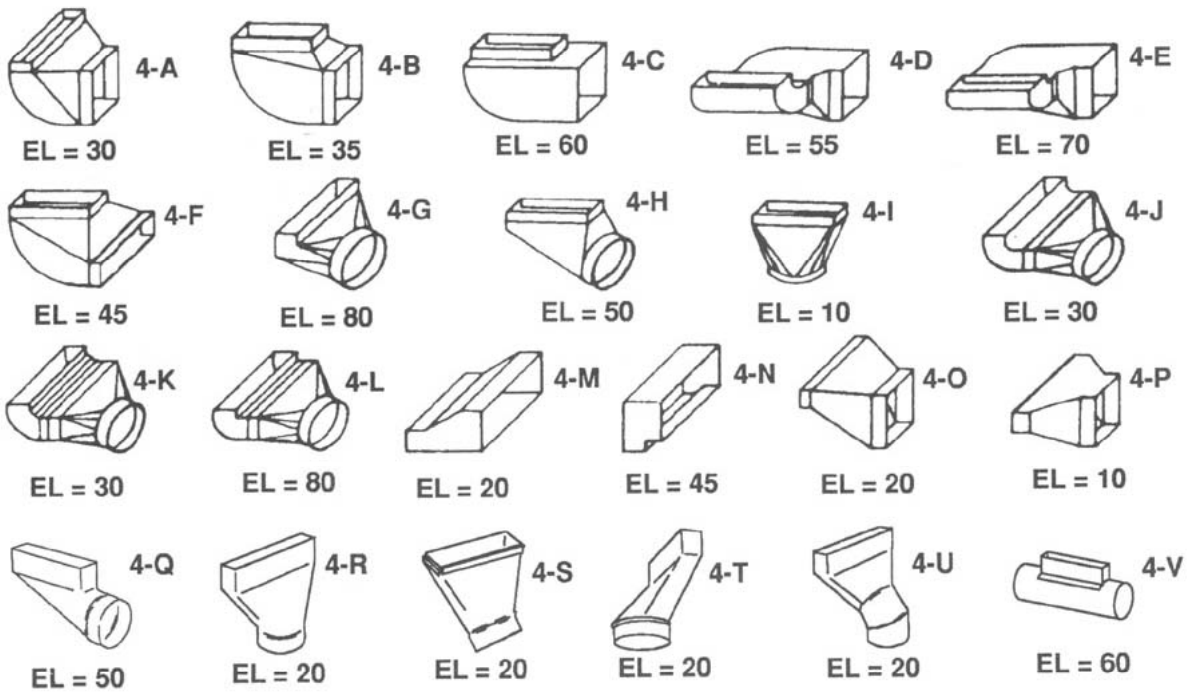
Air Distribution Design:
Design Guidance

- External static pressure is less for higher efficiency system!
- Balance distribution by fiction proportioned run-outs
- Shorter ducts with higher velocity
  - Allows pressure regain / balancing
  - Higher velocity comes from smaller ducts
  - Cost less and use fewer resources

Air Distribution Design:
System Design Principles

Design Fittings

- Plenum
- Branch takeoffs
- Elbows
- Boots

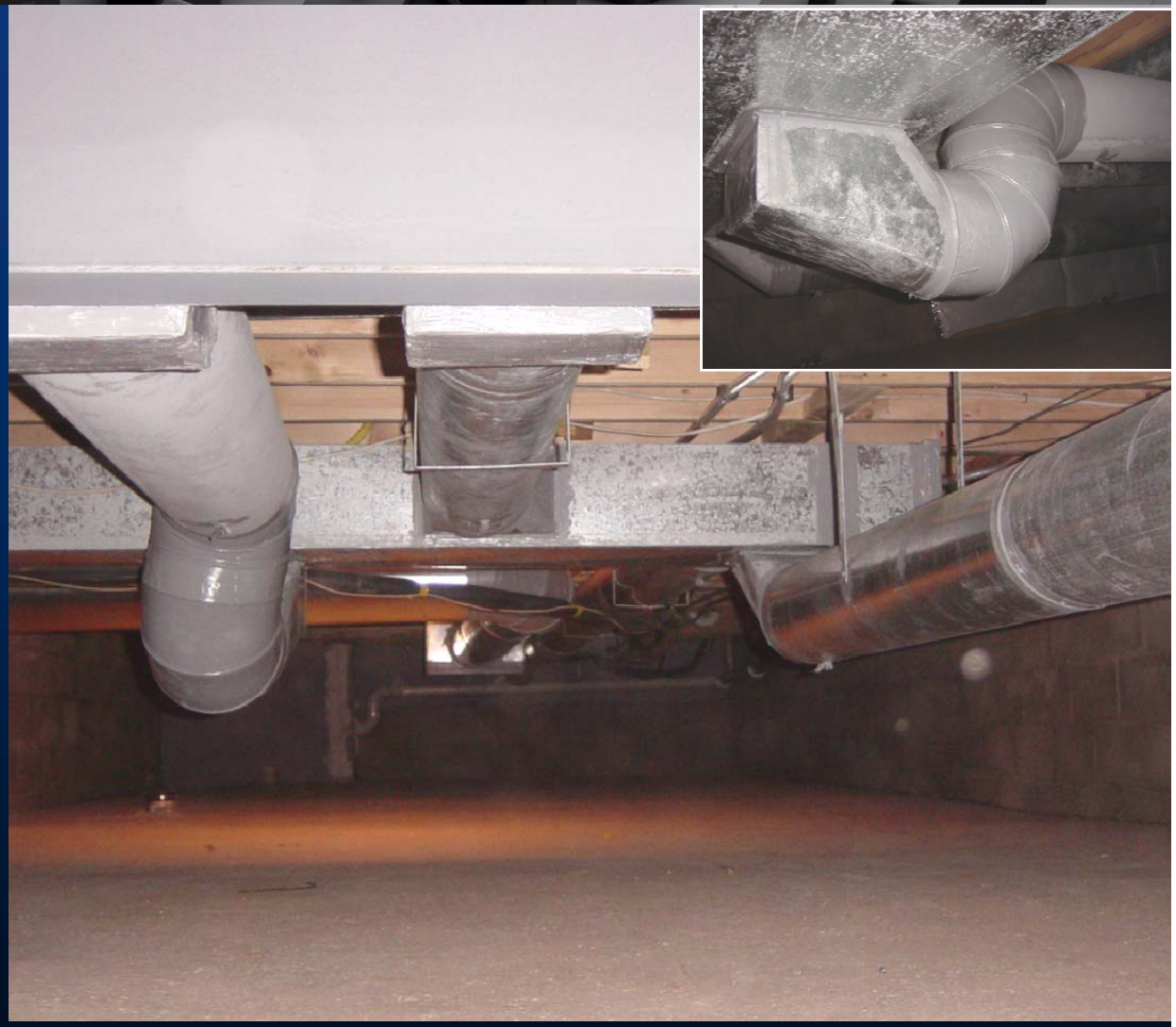


Each element contributes to loss in flow

Air Distribution Design: Construction Concerns

Improper Fittings

- Poor system balance
- Increased pressure drop

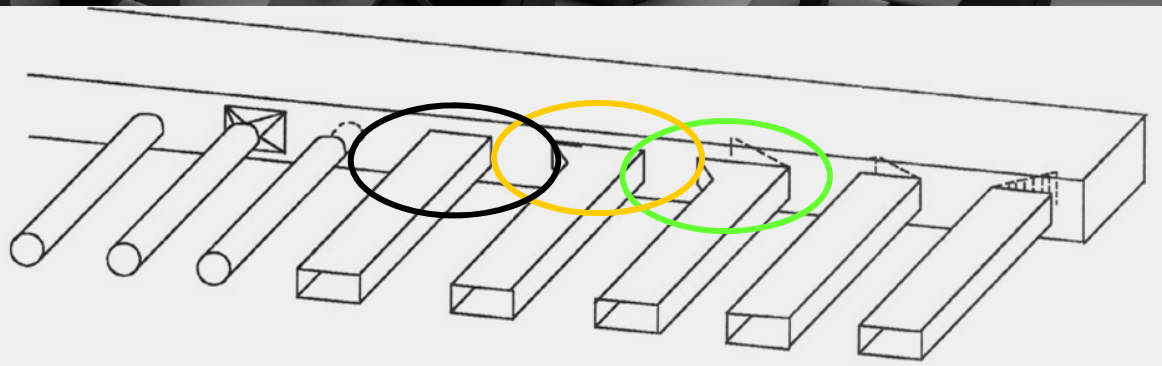


Supply Main in Crawl space with Branch Takeoffs

Air Distribution Design:
System Design Principles

Balance branch run-outs

- Convenience
- Tradition
- Performance



EL Values		Number of Downstream Branches to End of Trunk Duct or Number of Downstream Branches to a Trunk Reducer					
Fitting		0	1	2	3	4	5 or More
	2-A	35	45	55	65	70	80
	2-B	20	30	35	40	45	50
	2-C	65	65	65	65	70	80
	2-D	40	50	60	65	75	85
	2-E	25	30	35	40	45	50
	2-F	20	20	20	20	25	25
	2-G	65	65	65	70	80	90
	2-H	70	70	70	75	85	95

Note: If the trunk has a reducer, count down to the reducer; then begin counting (again) after the reducer

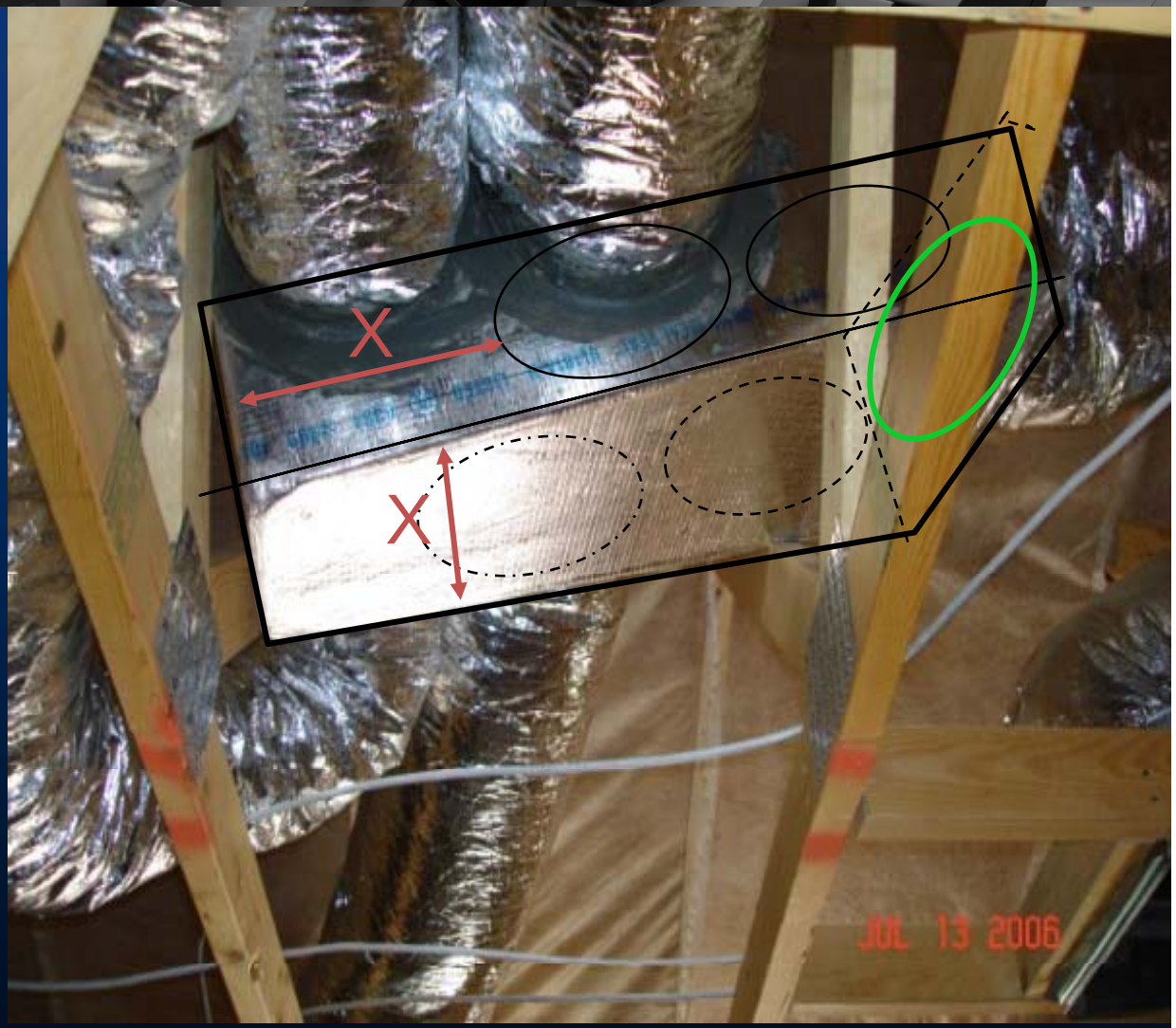
Pressure Regain Plenum

Round metal duct section at end of flex run out creates a plenum. The blank end converts velocity pressure to static pressure yielding relatively uniform pressure to all ducts.

Flow is proportioned by downstream friction and opening size

Pressure Regain Plenum

- Plenums must create equal pressure across openings to yield proportional flow
- Do not place outlets in last third of plenum. This section must convert velocity pressure to static pressure.
- Duct in NO Zone drain off distribution energy



Splitter Boxes

- Make splitter boxes as small as needed to just fit the supply duct
- For square splitter boxes, do not take a duct off opposite supply duct connection

Distribution Strategy

- These are very hard to balance.
- Equal size ducts on opposite sides of inlet/outlet, create no or little static pressure to force distribution to side branches
- In Round duct, two takeoffs on same side shadow each other and reduce flow to second duct

Air Distribution Design:
Construction Concerns

- Remember
  - These are technologies for balancing
  - Balancing is done to improve room-to-room comfort

Air Distribution Design:
System Design Principles

Locate system in conditioned space or insulate well

- Basement
- Unvented crawlspace
- Structure/ceiling space of main floors

Air Distribution Design:
System Design Principles

Integrate system into house

- Structure
- Other systems
- Code compatibility

Air Distribution Design:
Construction Concerns

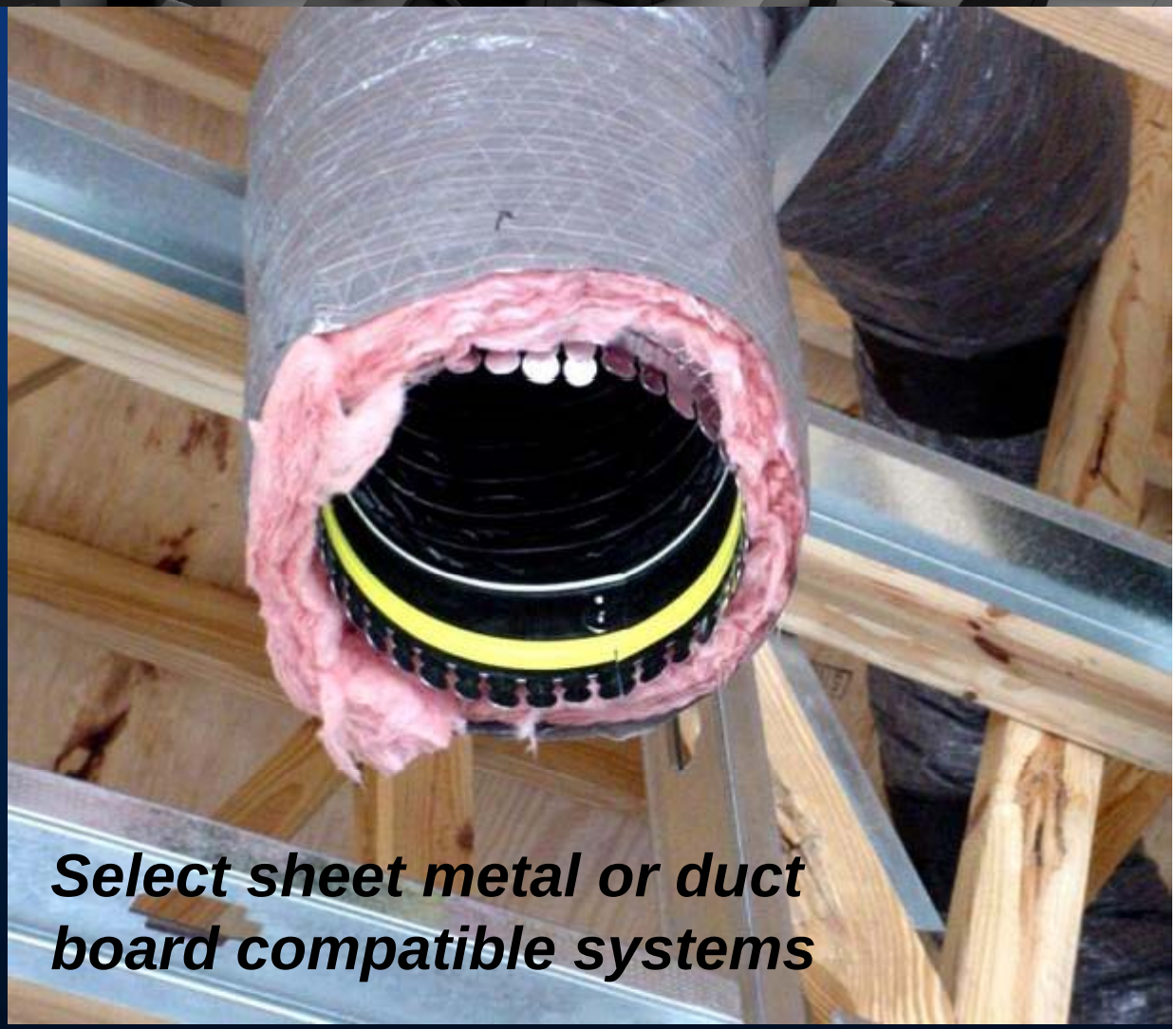
Duct Leakage

- Seal all fittings and seams
- Use UL181 systems
- Don’t assume manufactured means sealed

Air Distribution Design:
Construction Concerns

Duct Leakage

- Quality of the connection
- Quality of the materials
- Quality of the execution



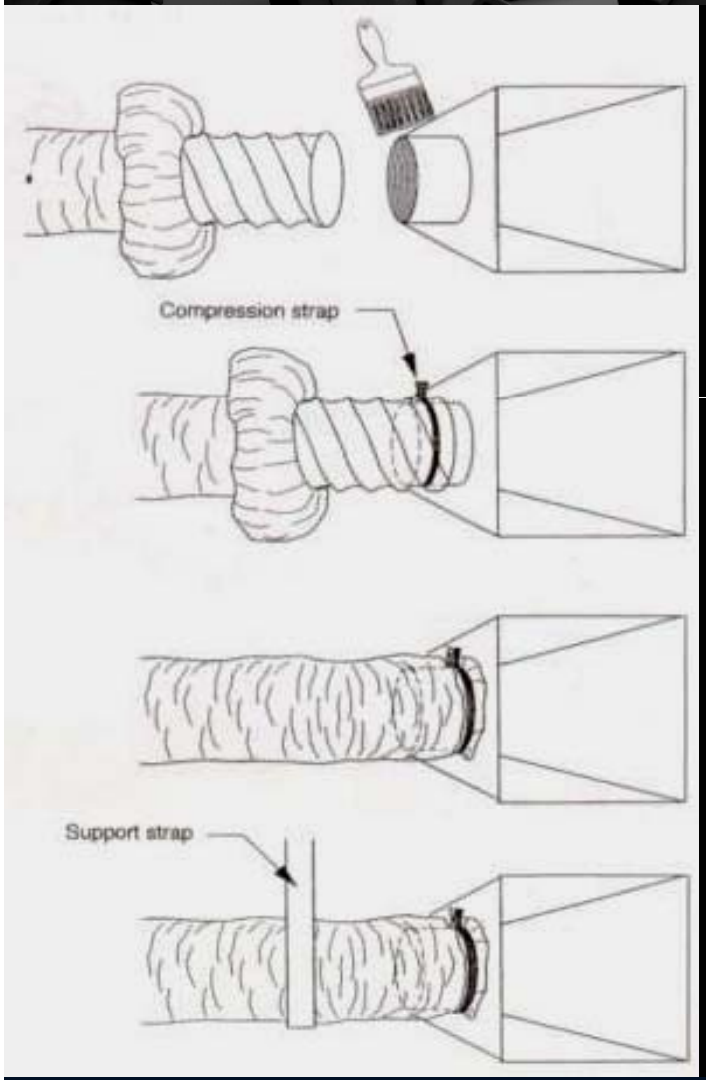
Air Distribution Design:
Construction Concerns

Condensation Control

- Insulation levels
- Vapor retarder continuity
- Installed condition

Control surface and internal condensation

Air Distribution Design:
Construction Concerns



Sealant and mechanical fastening is needed

Air Distribution Design:
Construction Concerns

Duct Leakage

- Factory
- Field
- Physics

Air Distribution Design:
Construction Concerns

Duct Leakage

- Avoid use of duct tape
- Properly install mastic

Air Distribution Design:
Construction Concerns

Commissioning

- System airflow
- Room airflows
- Supply registers

Leakage of the system should be less than 5% of fan capacity

Air Distribution Design:
Construction Concerns

Verify fan performance and system flows

Air Distribution Design:
Construction Concerns

Use flow hood measurements to balance, based of measured total flow

Air Distribution Design:
Construction Concerns

50 FPM is the boundary of throw. Understand performance of your registers

Air Distribution Design:
Construction Concerns

Measure temperatures at supply and room discharge to determine impact of duct location

Air Distribution Design:
Construction Concerns

Measure adequacy of pressure balancing and return strategy

Air Distribution Design

- Envelope improvements are implemented for control of loads and for durability
- The mechanical system is engineered for performance
- Quality execution and materials assure performance
- Application of design principals further reduces system size and cost and efficiently delivers comfort

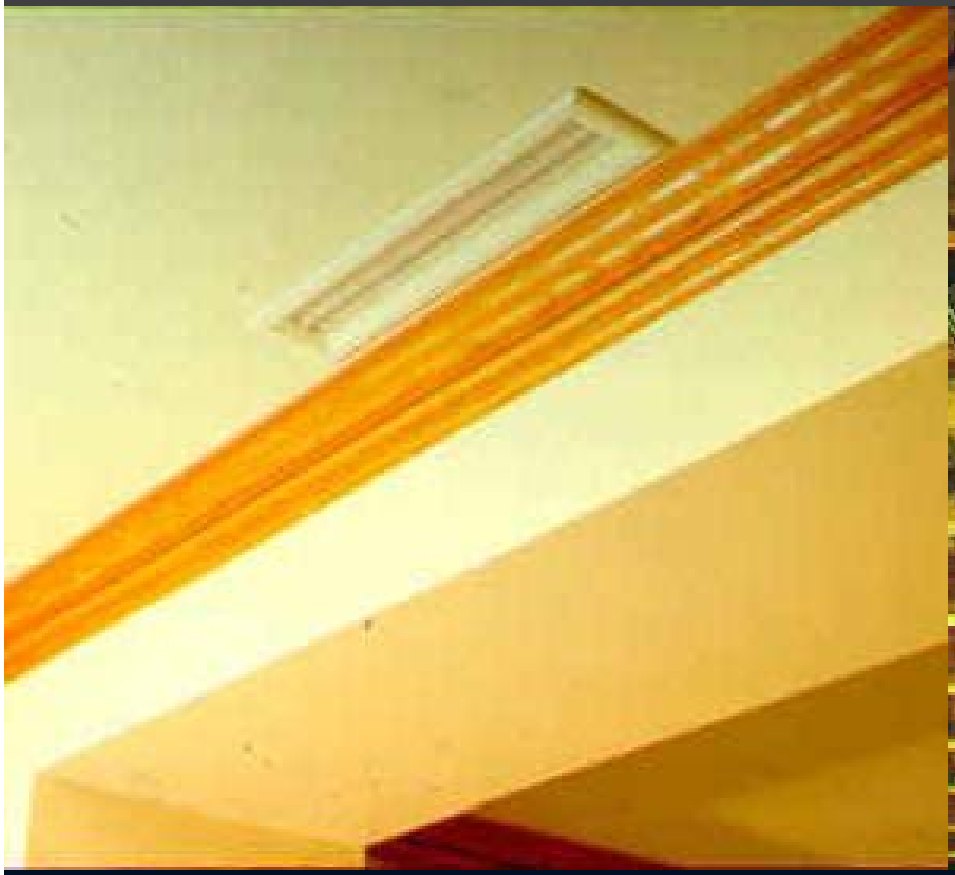
So, Registers

Now that we can somewhat reasonably get air to the room, what is the role of the register or diffuser?

Objectives

1. Develop a register location strategy that places registers in the ceiling or high on the wall.
2. This strategy must work as well for heating as for cooling.
3. For shorter duct runs, the strategy should locate registers in from the perimeter of the house.

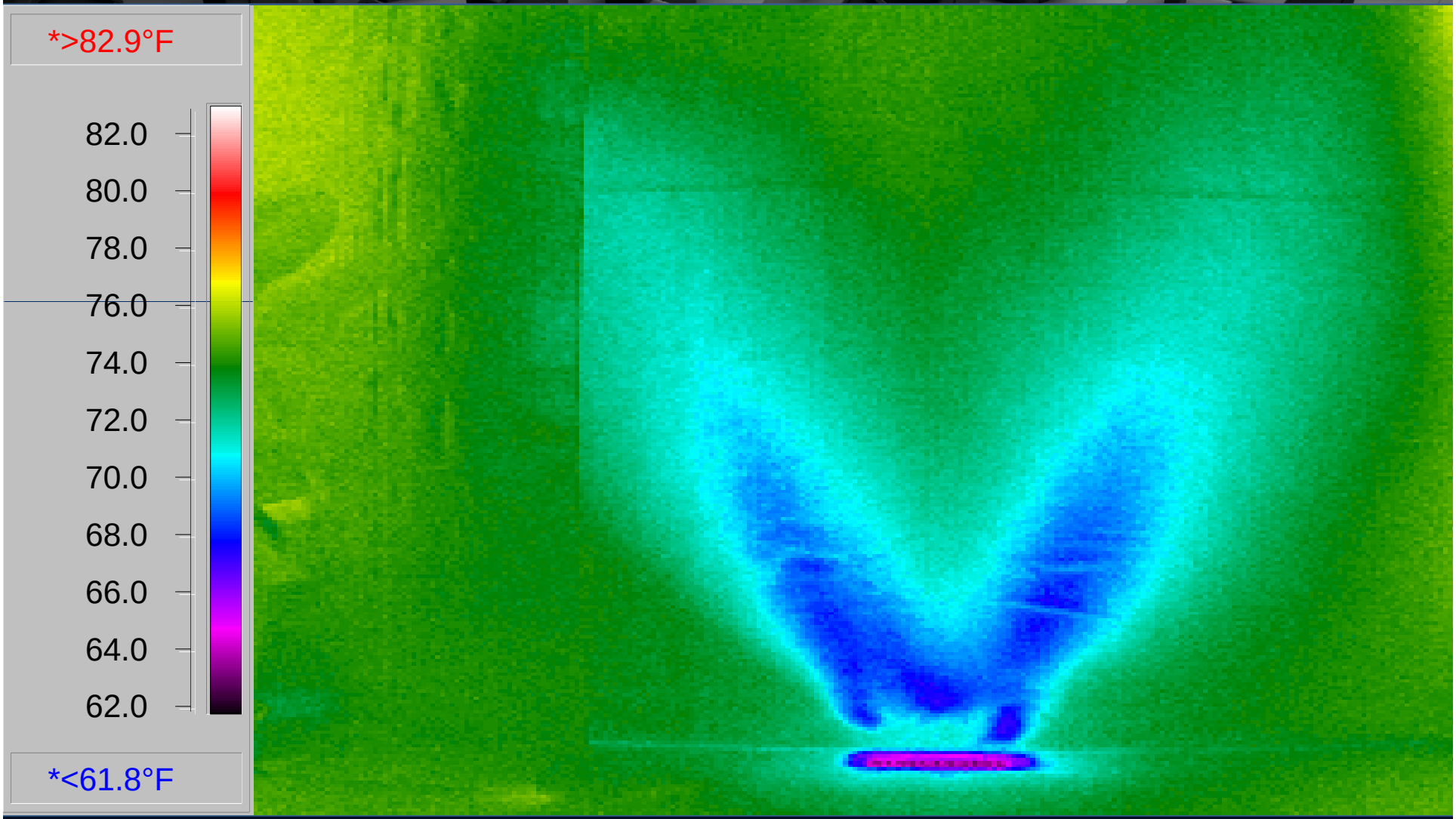
Commercial Diffuser



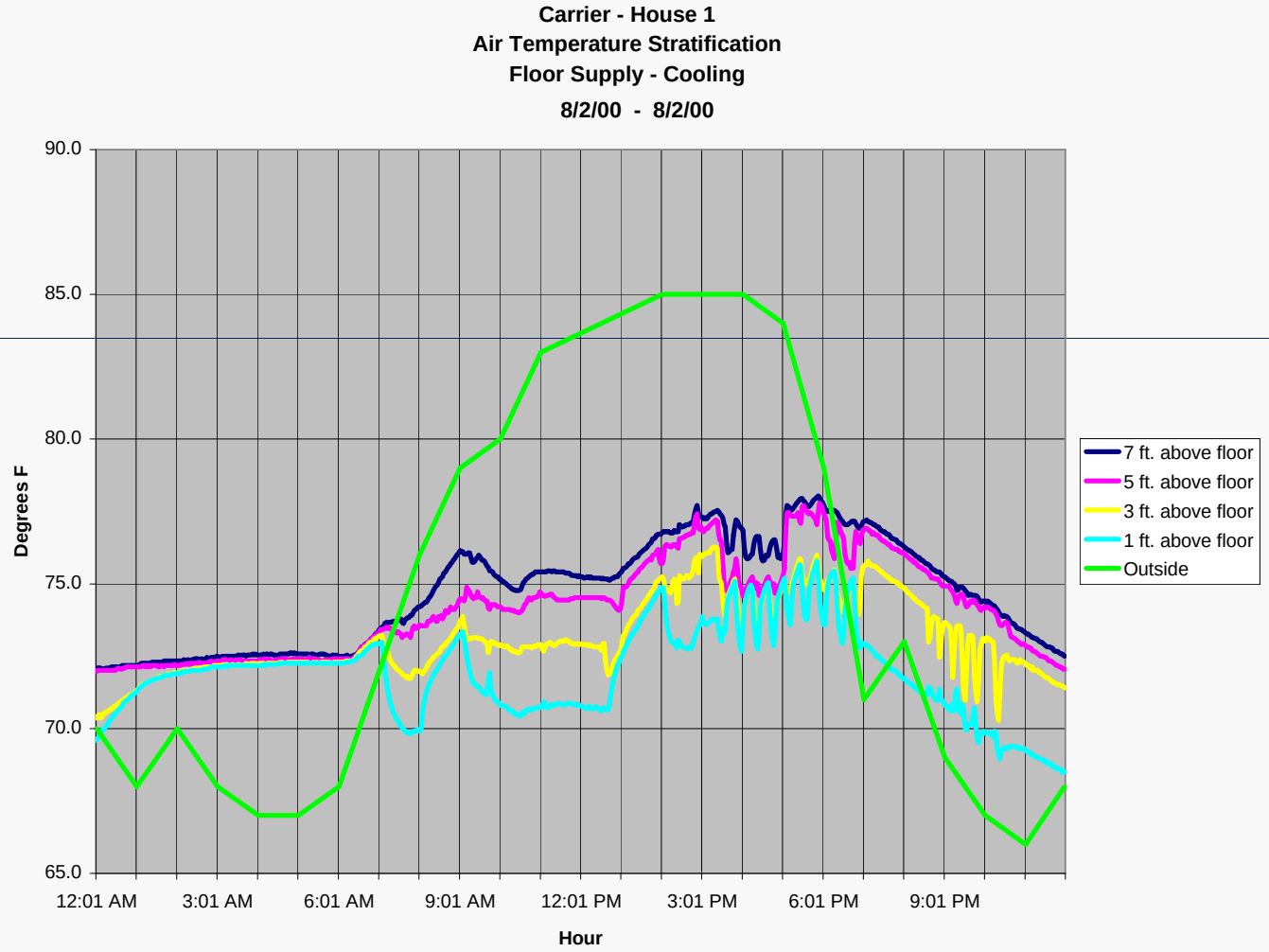
IBACOS / NREL Test Program 1997

Carrier Test Houses

Carrier Test Houses



Carrier Test Houses



Current Test Program

Test Room

- Heat / cool / ventilation
- Supply: from floor / wall / ceiling
- Return: wall- near / far, high / low, door undercut
- Surface temperature measurement

Low Velocity Mixing Study

Evaluation of design requirements for mixing of room air using low velocity, low delta T ceiling jets

Figure 1. Trends in Space Conditioning Loads in Building America Houses

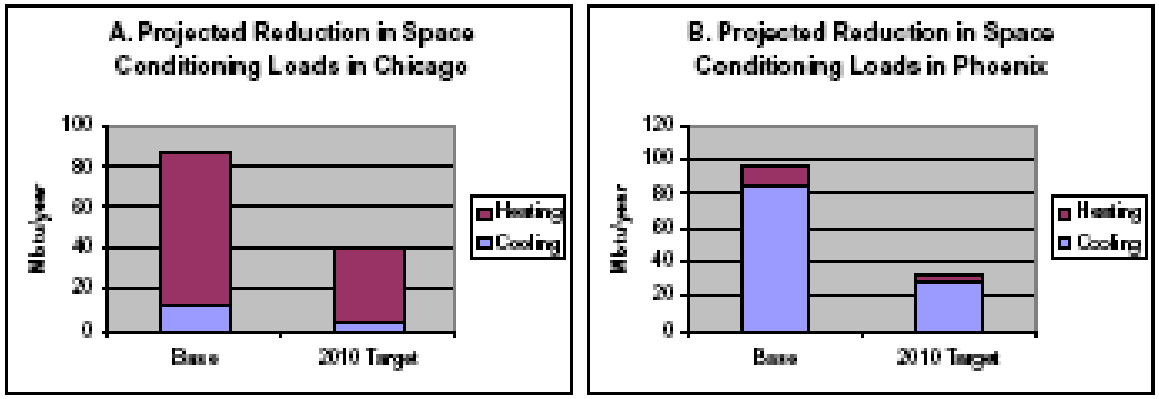
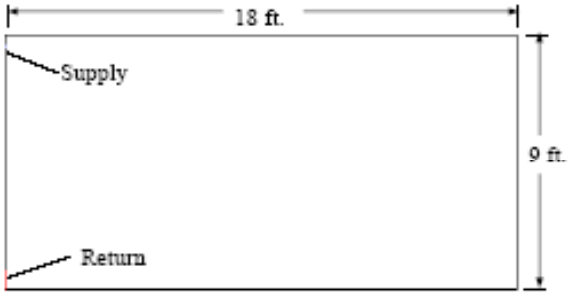


Figure 2. Room Dimensions Used in Study

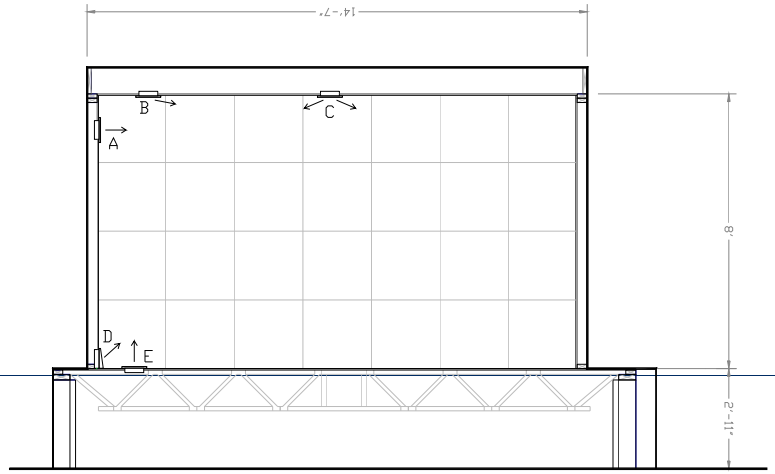


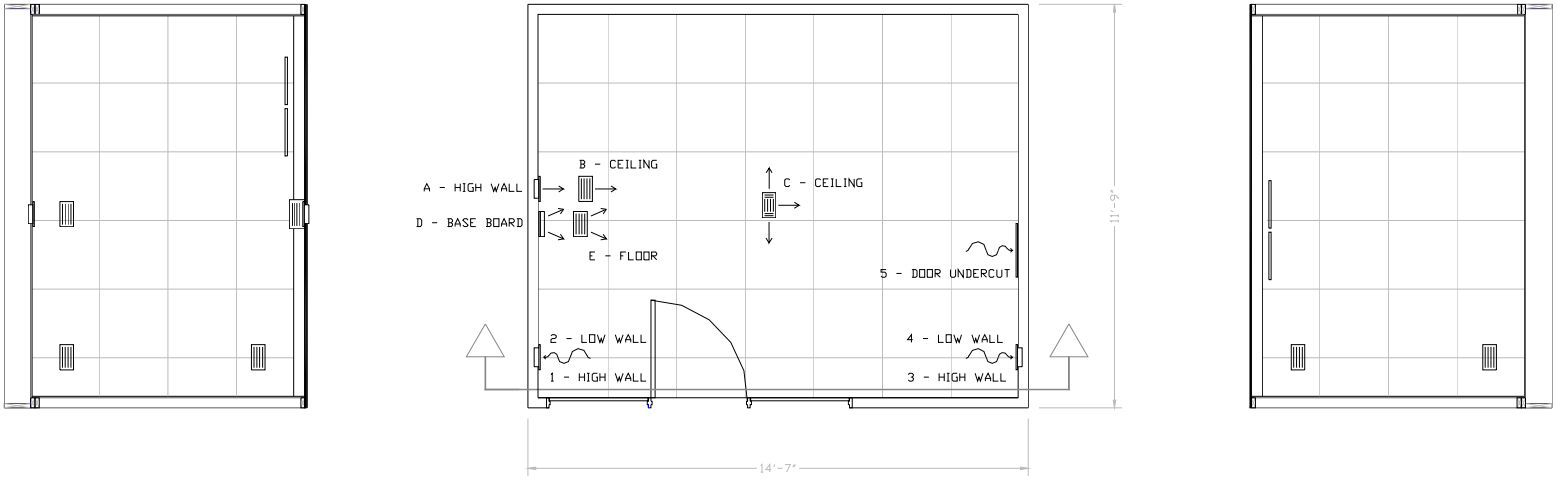
Ren Anderson
Keith Gawlik
National Renewable Energy Laboratory
Progress Report
March 23, 2005

Register Performance Test Program

Selecting Ducts and Registers for Comfort

Register Performance Test Program





Current Test Program

- Floor Diffuser
- Baseboard Diffuser
- Ceiling Diffuser
- High Wall Diffuser
- Commercial Diffuser

Test Program

We studied several different registers in several locations to develop an understanding of the characteristics involved.

- Floor- Hart & Cooley 421 4x10, 100 cfm = 7.5’ throw
- Base- Hart & Cooley 406 18”, 100 cfm = 24’ throw
- High Wall- J/J 90H, 8x4, 100 cfm = 19’ throw (0°)
- Ceiling- J/J 90H, 8x4, 100 cfm = 12’ throw (45°)
- Commercial- Tuttle & Bailey Agatair, 6EH 10-18”, 100 cfm = 24-36’ throw

Isothermal Test

Floor Register,
100 CFM
High Return

(Basic performance, as rated by manufacturer)

Isothermal Test

Floor Register,
100 CFM
High Return

(Basic performance, as rated by manufacturer)

Cooling Test

Floor Register,
100 CFM

High Return

Cooling Test

Floor Register,
100 CFM

High Return

Cooling Test

Ceiling Register,
100 CFM

High Return

Cooling Test

High Wall Register, 100 CFM

High Return

Heating Test

Ceiling Register,
125 CFM

High Return

Heating Test

Commercial Ceiling Register, 80 CFM

Low Return

Heating Test

Commercial Ceiling Register, 100 CFM

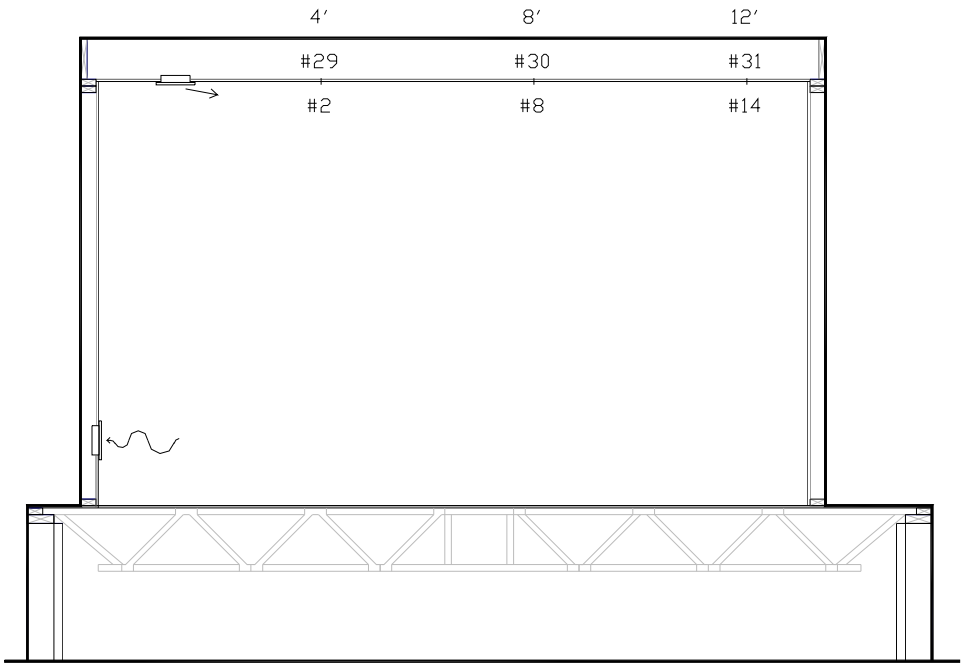
Low Return

Ceiling Chilling Test

Time	Supply Air Temp	@ 4' distance		@ 8' distance		@ 12' distance	
		inside	outside	inside	outside	inside	outside
		#2	#29	#8	#30	#14	#31
2:00 pm	54°F	Start of cooling test…					
2:30 pm	56°F	63°F	64°F	65°F	66°F	66°F	67°F
3:00 pm	56°F	64°F	65°F	66°F	67°F	67°F	68°F

Outdoor Ambient Temp = 73 F

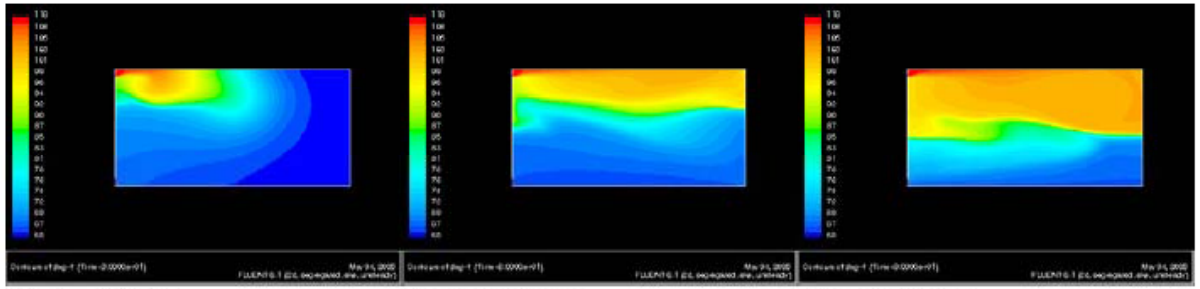
R-19 batt insulation over all test points



110 F Supply Air Temperature

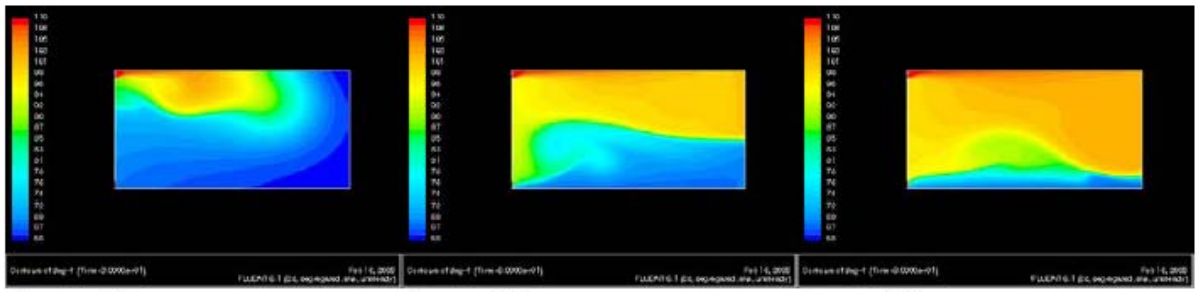
Supply Air Velocity

394 f/m



time = 30 sec | time = 60 sec | time = 90 sec

591 f/m



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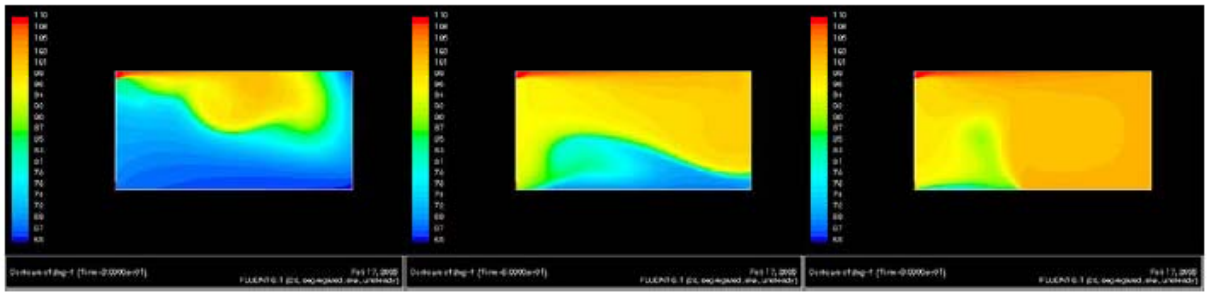
787 f/m



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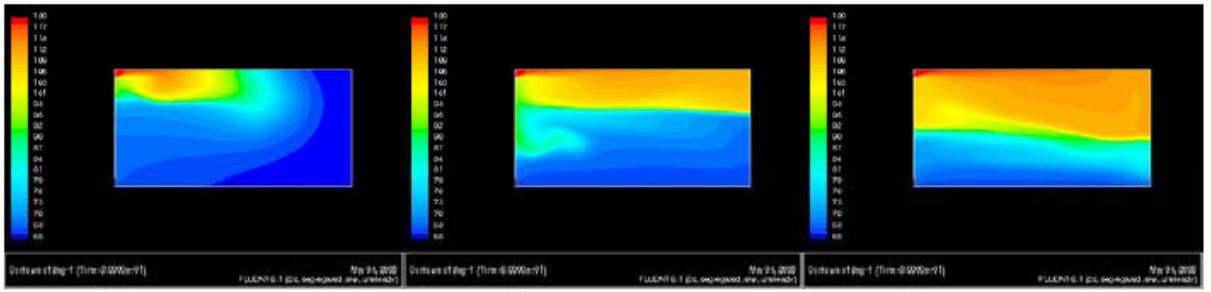
130 F Supply Air Temperature

Supply Air Velocity

394 f/m



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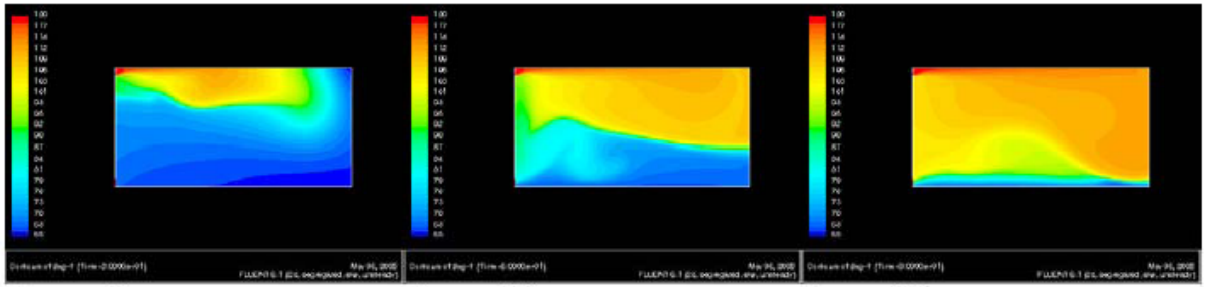
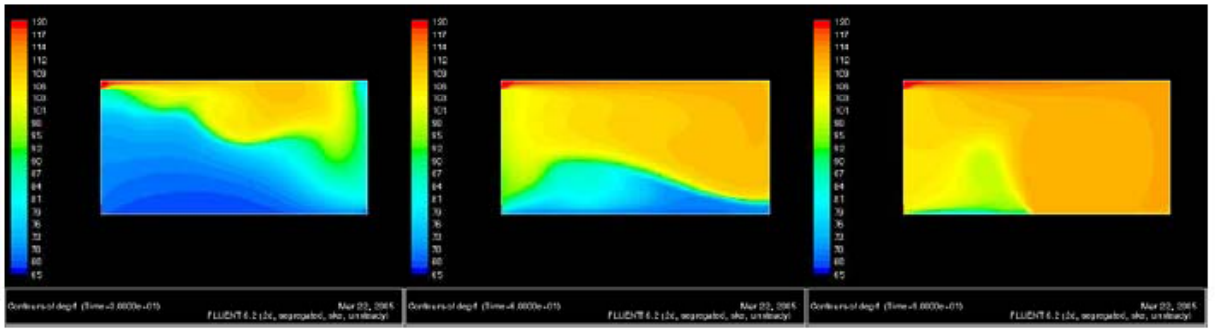
591 f/m



time = 30 sec | time = 60 sec | time = 90 sec

787 f/m



time = 30 sec | time = 60 sec | time = 90 sec

140 F Supply Air Temperature

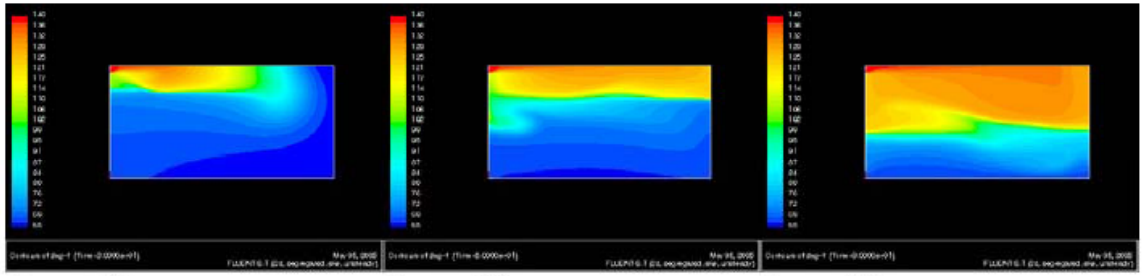
Supply Air Velocity

394 f/m

394 f/m

Radiation Enabled Wall
heat loss allowed

787 f/m



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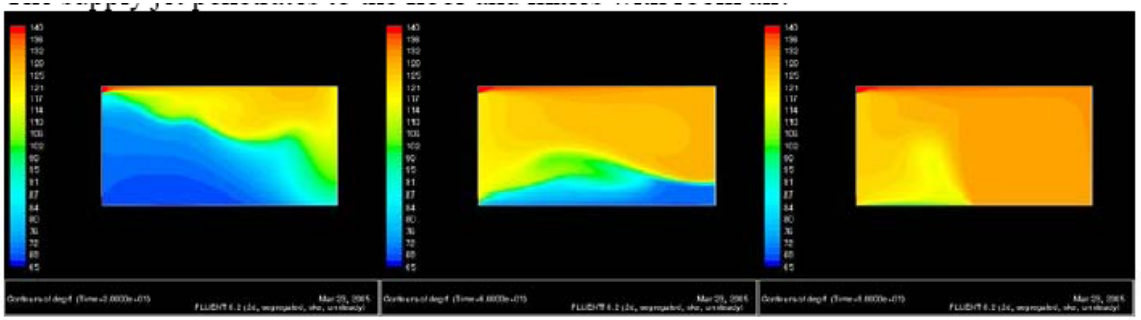


time = 30 sec time = 60 sec time = 90 sec

Design Implications: Supply

65	dT	T-sec
110	45	90
120	55	74
130	65	62
140	75	54

Figure 3. Summary of Observations from 2-D Study

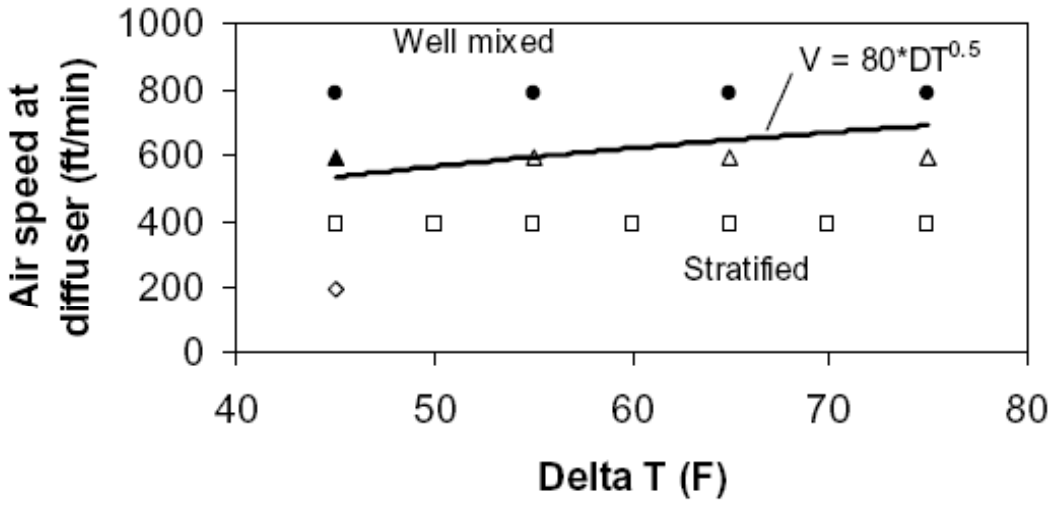


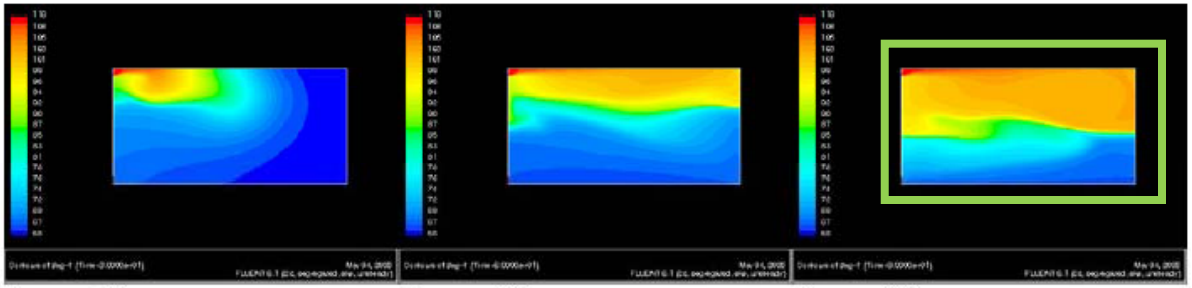
Table 1. Initial Register Specifications (100F Supply @ 470 fpm)

cfm	Area (in2)	Size	Peak Heating Energy Demand (BTU/hr)
50	15	2"x8"	1512
100	31	2"x15	3024
150	46	3"x15"	4536
200	61	2-2"x15"	6048

394 f/m Supply Velocity

Supply Air Velocity

110 F



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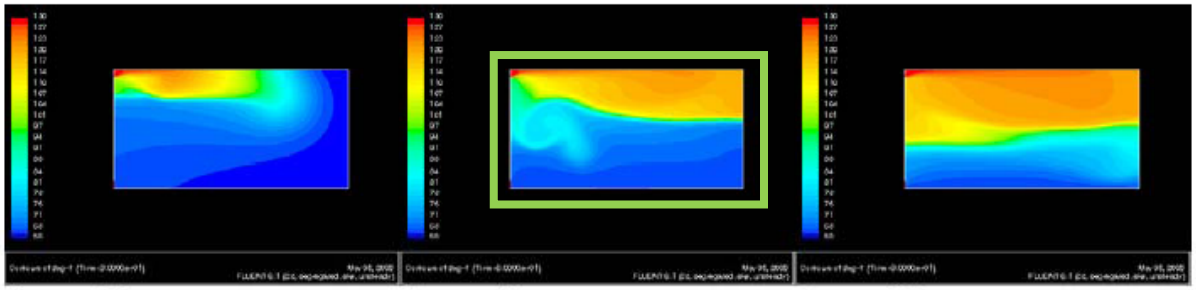
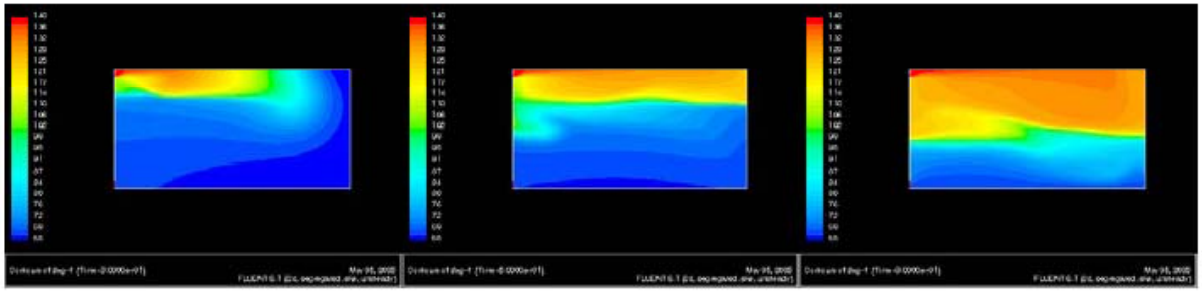
130 F



time = 30 sec time = 60 sec time = 90 sec

140 F

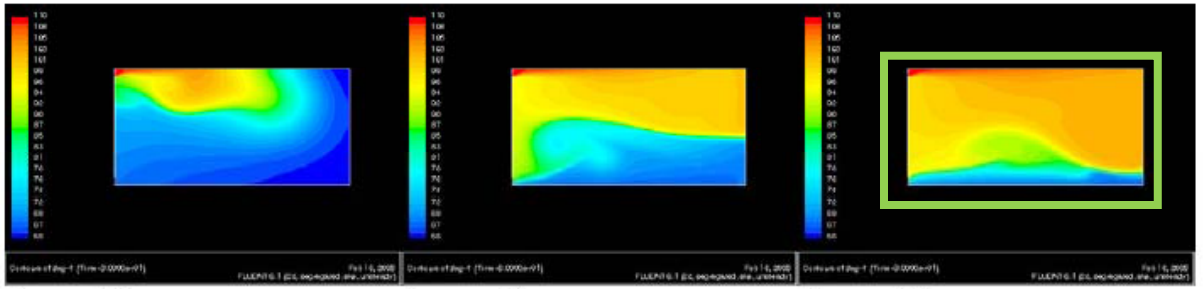


time = 30 sec time = 60 sec time = 90 sec

591 f/m Supply Velocity

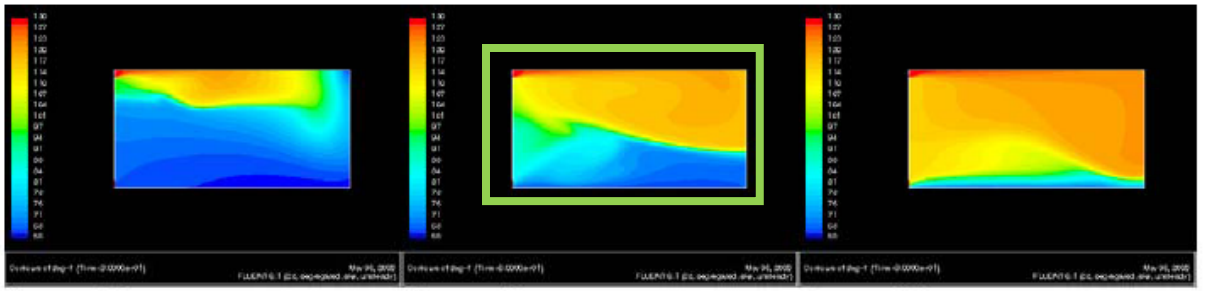
Supply Air Velocity

110 F



time = 30 sec | time = 60 sec | time = 90 sec

130 F



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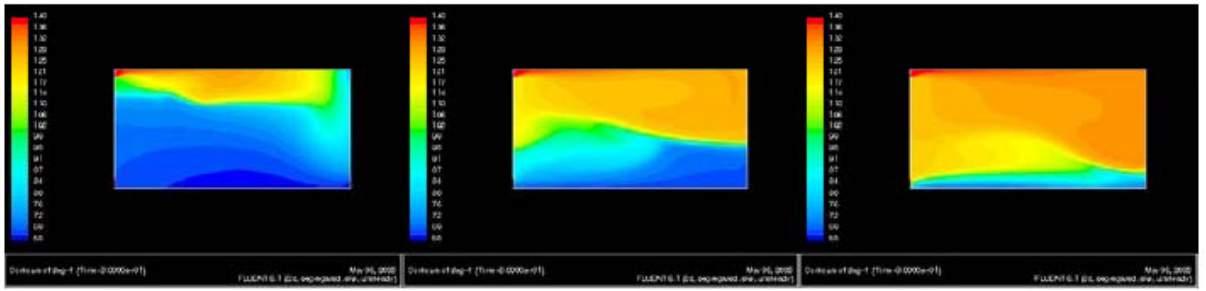
140 F

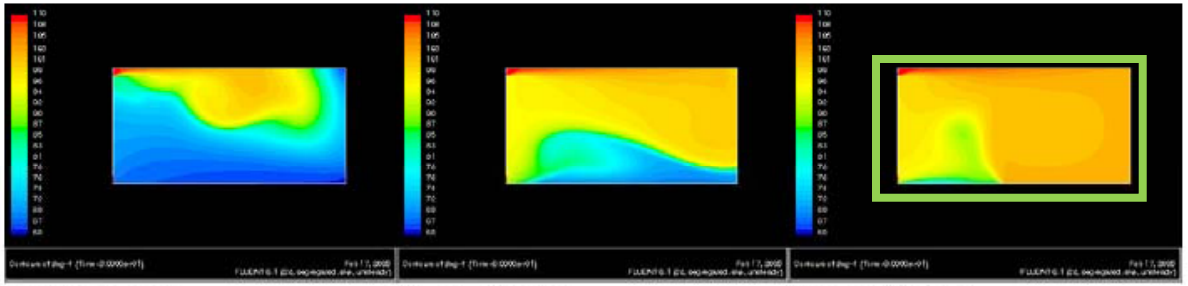


time = 30 sec | time = 60 sec | time = 90 sec

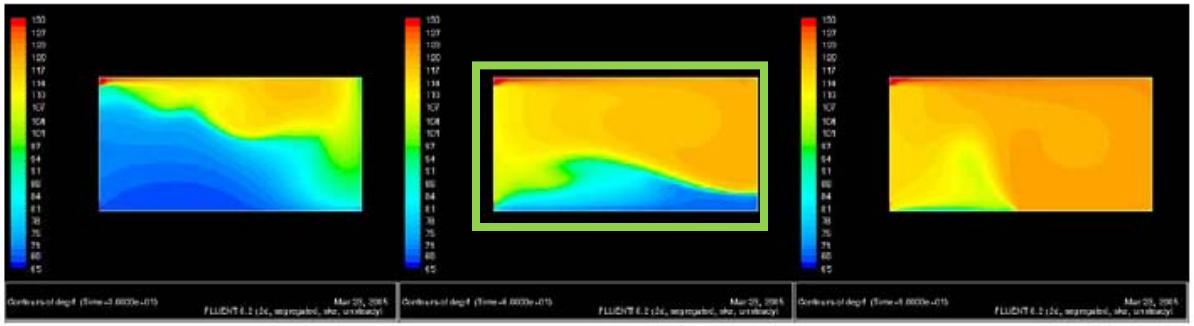
787 f/m Supply Velocity

Supply Air Velocity

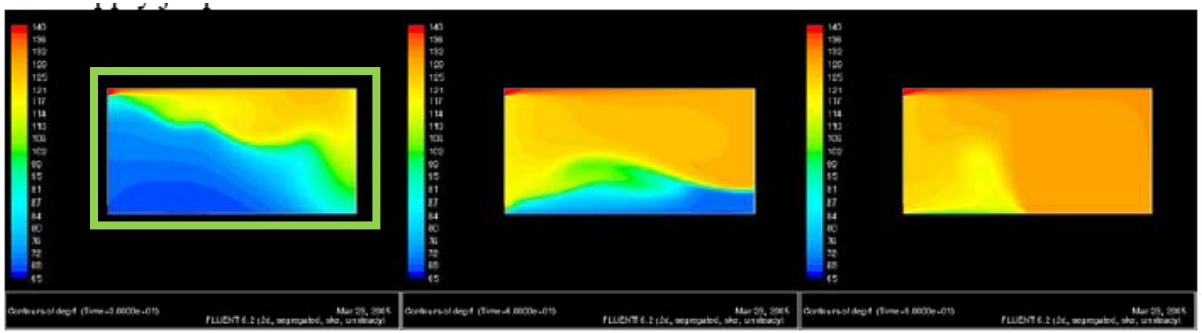
110 F



130 F



140 F



Simple Truths

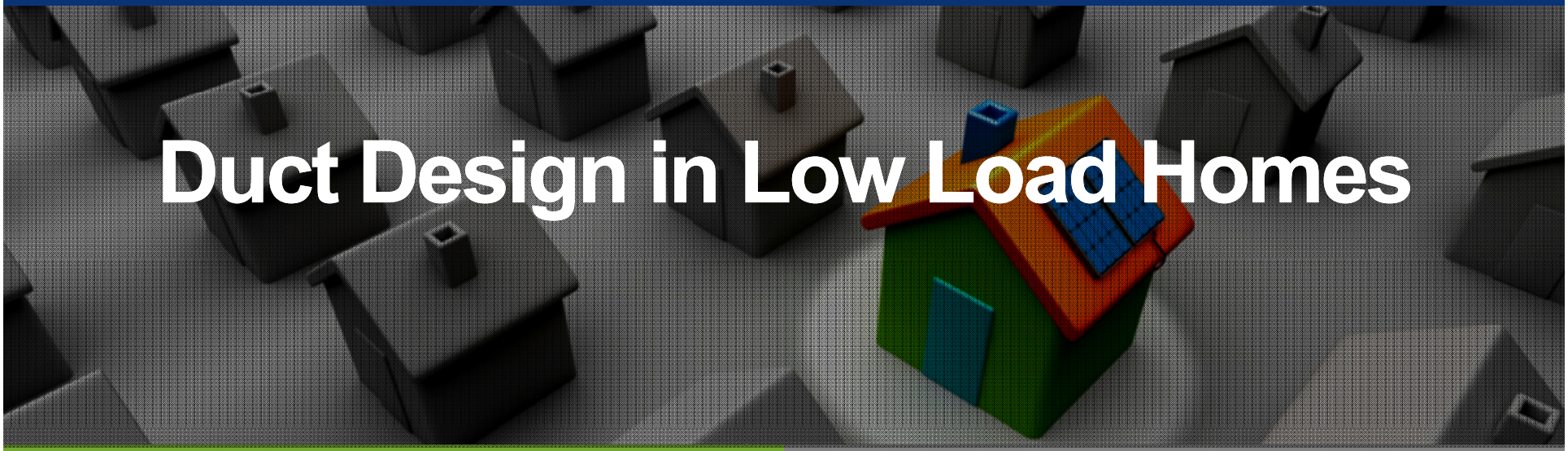
- Higher delta T will meet a given load faster than lower DT
- High performance homes have rooms with lower loads
- Lower loads and higher DT supplies allow significantly reduced mixing time
- All this assumes “perfect mixing” and equivalent delivery efficacy

Conclusions

1. Buoyancy matters
2. Floor / baseboard at outside wall can give a pool of cold air around the register
3. High wall / ceiling registers that throw across the ceiling can provide good performance. This area currently under study - the problems are heating performance and surface chill condensation
4. Floor supply at rear of room works for neither heating nor cooling
5. Returns are appropriate on an inside wall

Conclusions (Continued)

6. Low returns are best with high supply for heating or cooling.
7. Low return works as well as a transfer grille.
8. Surface chilling studies have just started. There should be satisfactory design solutions.
9. For good register performance design air flow needs to be near the upper acceptable face velocities.
10. To complete a high performance HCVI system requires the careful design of the supply air plume and the register.



Duct Design in Low Load Homes

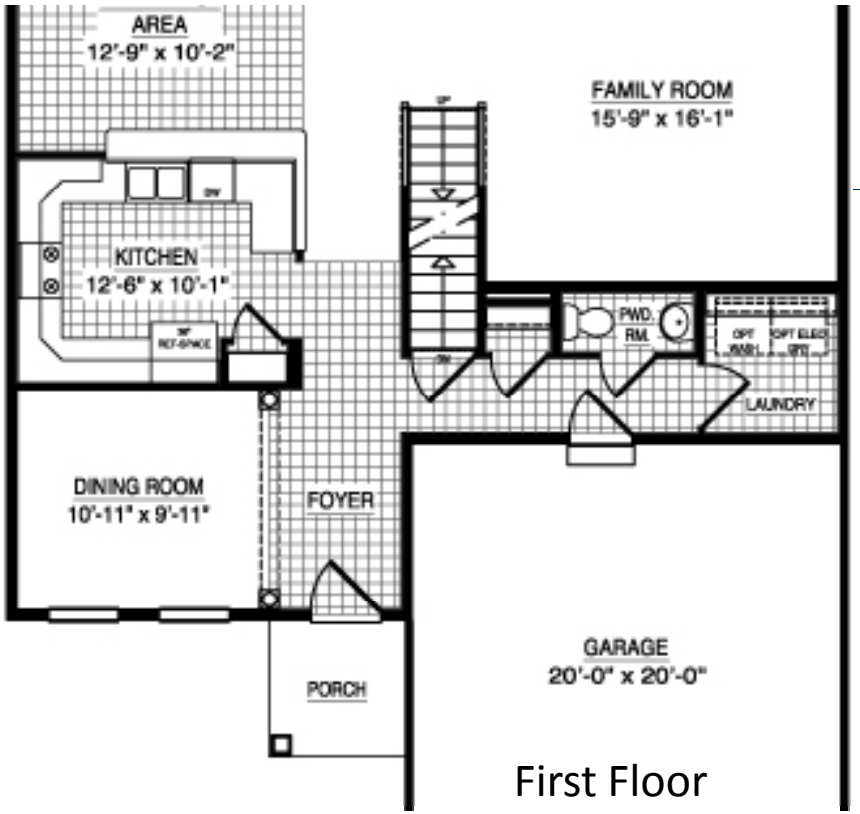
Brad Oberg
IBACOS
July 2010

Peak Heating and Cooling Loads Comparison IECC vs. 50%

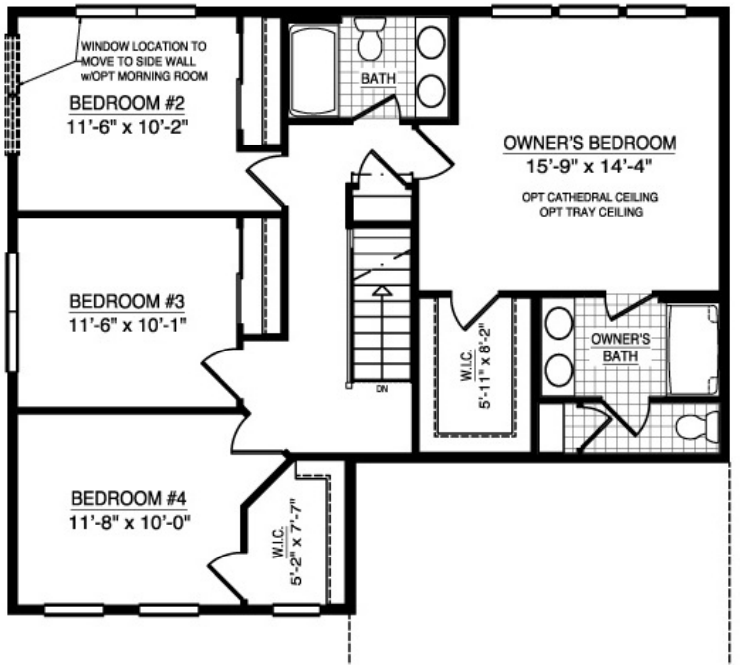
	Peak Heating IECC (Btuh)	Peak Cooling IECC (Btuh)		Peak Heating 50% (Btuh)	Peak Cooling 50% (Btuh)
Phoenix	**22176**	**28899**		**13099**	**17755**
Atlanta*	**45469**	**24448**		**18458**	**13082**
Orlando	**23184**	**20890**		**12965**	**11739**
Pittsburgh*	**35379**	**16072**		**26901**	**14184**

* includes ~1000 sf conditioned, unfinished basement

Airflow Comparison



First Floor

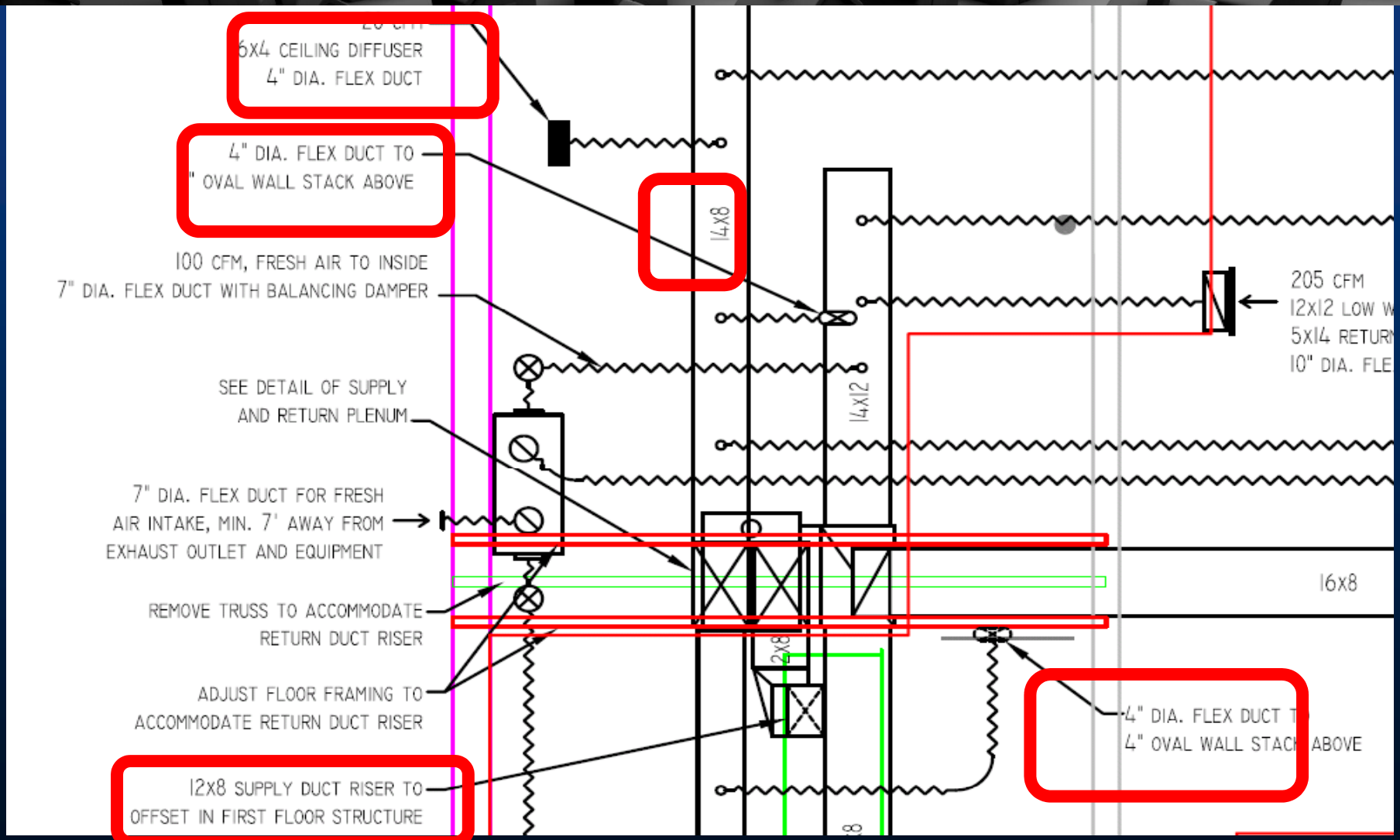


Second Floor

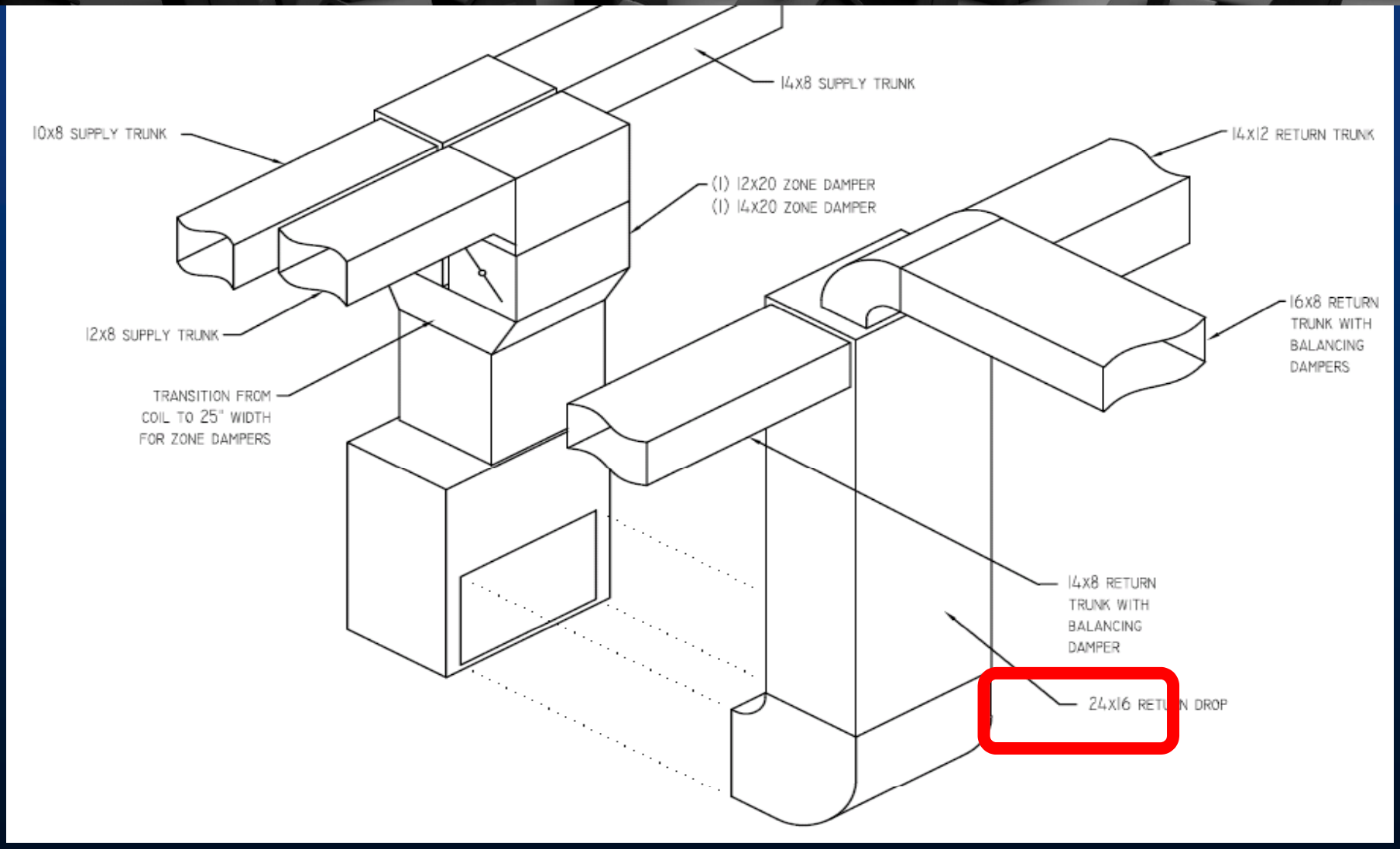
Peak Heating Flow ~ 2x summer flow on one floor and vice versa on other floor

			Phoenix			Atlanta	
ROOM NAME	Area (ft²)		Htg AVF (cfm)	Clg AVF (cfm)		Htg AVF (cfm)	Clg AVF (cfm)
Basement						35	33
Breakfast	142		81	49		140	38
Kitchen	139		28	9		8	5
Dining	132		74	53		30	40
Family	421		138	82		57	55
Laundry	46		28	12		13	6
Powder	21		0	0		0	0
Foyer	155		82	70		63	43
First Floor Zone			**431**	**275**		**346**	**220**
Bedroom2	160		43	59		34	43
Bedroom3	152		31	123		23	111
Bedroom4	185		59	92		47	72
Bath2	50		10	8		7	5
MasterBedroom	255		60	79		46	58
MasterBath	85		20	17		15	10
MasterWic	56		9	8		6	5
Hall	114		9	9		5	7
Second Floor Zone			**241**	**395**		**183**	**311**
Total House CFM			**672**	**670**		**529**	**531**

Low Load Duct Layout
(4,000+ SF house, ~2 ton load ~1,000cfm)



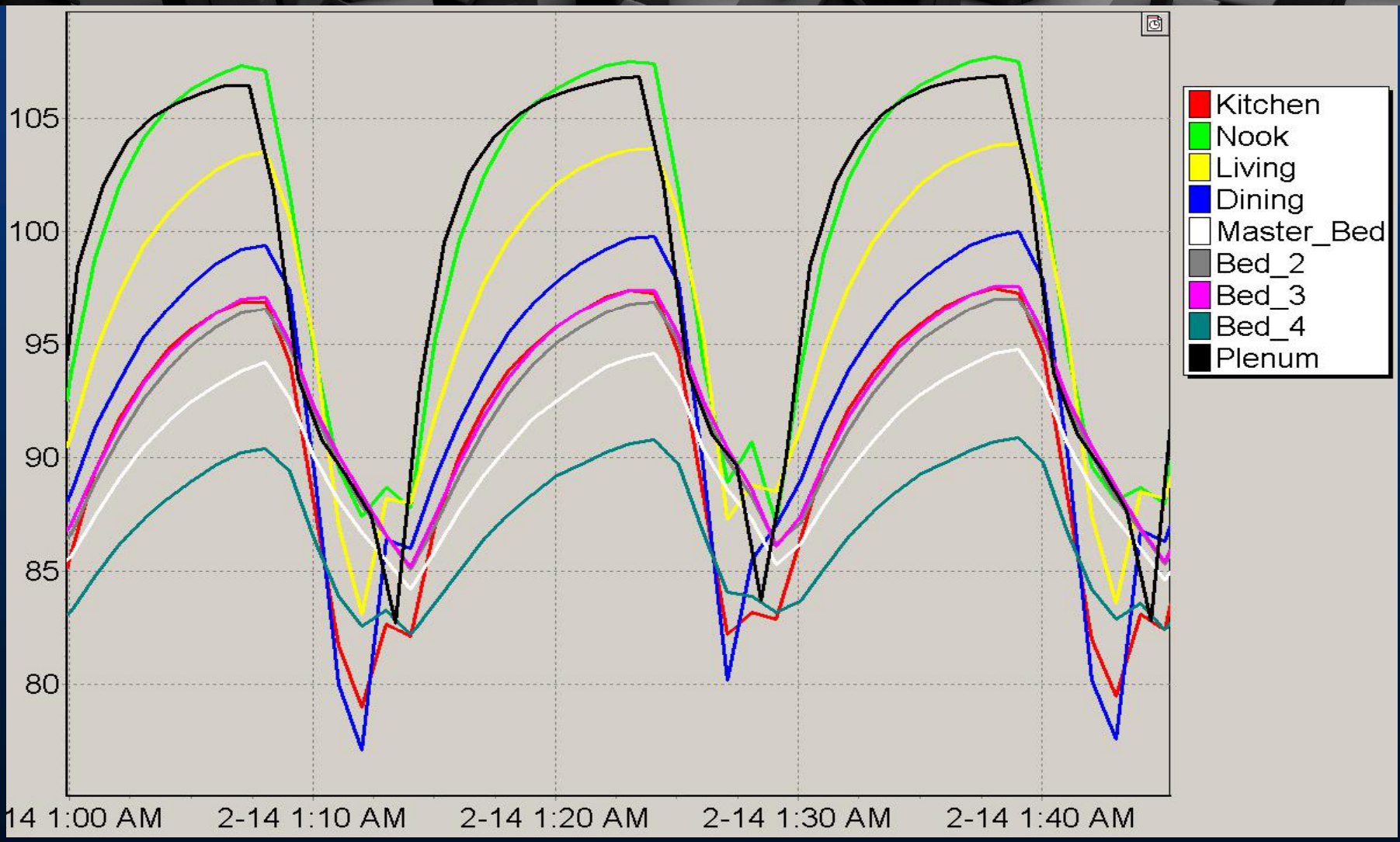
Low Load Duct Layout
(4000+ SF house, ~2 ton load ~1,000cfm)



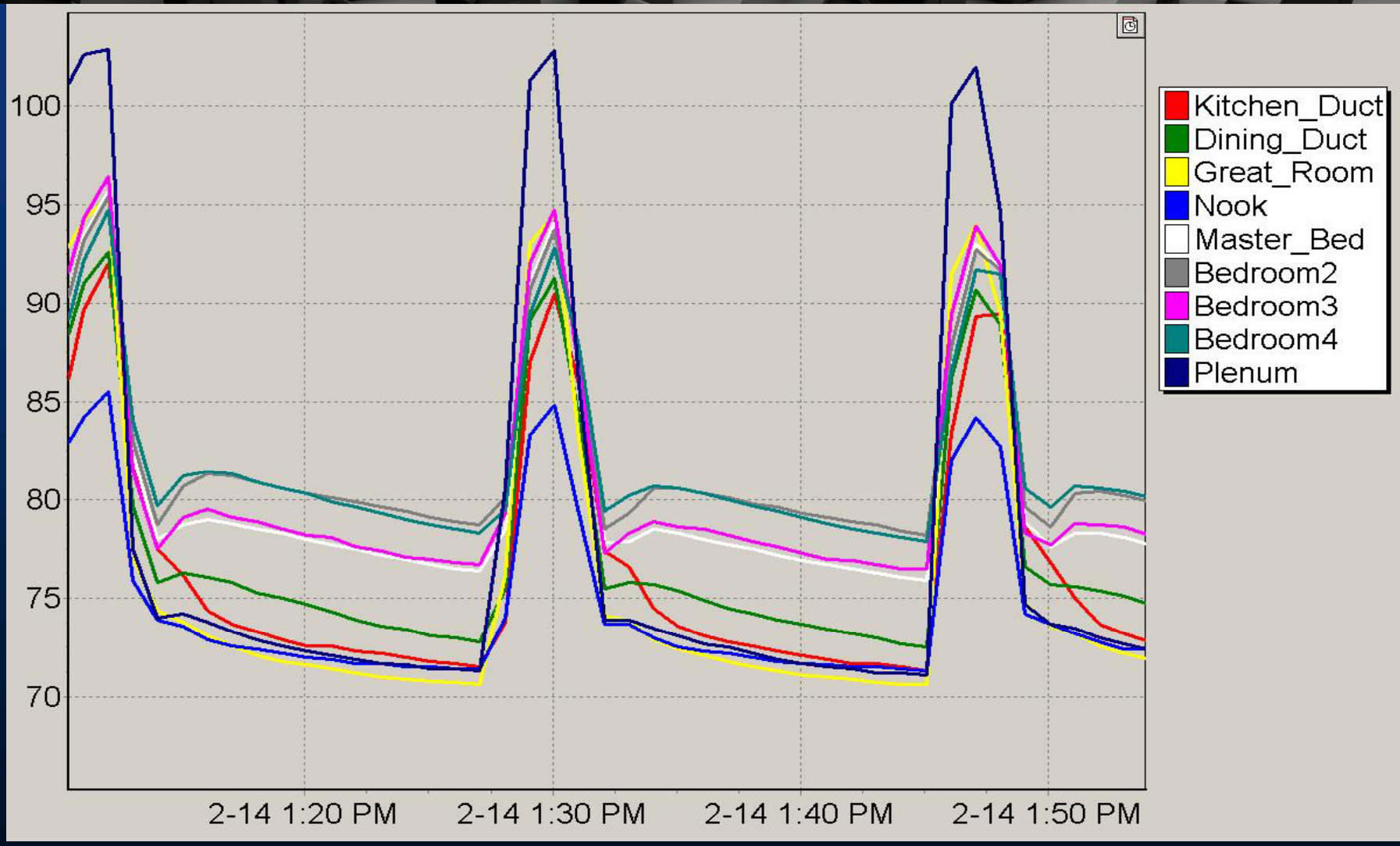
High Mass vs. Low Mass Ducts

- Side-by-side houses, one with low mass central system, other with traditional sheet metal perimeter system

Terminal Air Temperatures: High Mass Duct System



Terminal Air Temperatures: Low Mass Duct System



Low Mass Implications

- Low mass systems (flex duct and duct board) may be a key strategy in lower load houses in the 30%-50% savings level
  - But the opportunity to install poorly is increased (pinched ducts, not stretched for smooth flow, etc.)

Low Load Home Implications

- Same size house, still need to get air to each room, but quantities are greatly reduced and vary from room-to-room and season-to-season by as much as 50%
- Zoning airflows show high variation season-to-season: Peak heating flow ~ 2x summer flow on one floor and vice versa on other floor
- Adequate flow over coil without freeze up at low speed (where unit operates most of the time)

Low Load Home Implications

- With lower loads and flows, wider temperature swings from room-to-room can be expected with more customer complaints
  - Longest vs. shortest run
  - Thermostat location near shortest run
  - Impact of duct system material
- Fan continuous operation is an energy intensive way to try and even out temperature imbalances

Low Load Home Implications

- Higher airflow with smaller capacity? (800–1000 cfm / ton)
  - Risk of “cold blow” if industry does not take register placement seriously; what about retrofit where register location is fixed?
  - Not gaining any synergy on reduced duct size, runs, etc.
- Distributed fan coils: Heated/chilled water or refrigerant?
  - Easily zoned, small units with minimal duct design (if any?)
- Distributed individual systems?
  - 5,000–9,000 Btuh mini-splits, but aesthetics and room-to-room mixing are issues
- Integration of ventilation
  - Unclear where ASHRAE 62.2 is going to end up

Low Load Design Barriers

- Design methodology does not address dominance of internal loads or windows
  - Opaque walls and infiltration are less dominant
- Multi-point data is needed to drive comfort systems
  - Treatment of cooling load excursions
- Developing strategies to deal with load diversity is important
  - Overlaying an auxiliary zone

Low Load Design Barriers

- Humidity control and ventilation is still an inelegant issue
  - Ventilation must be code mandated
- Multi-capacity/speed systems are needed to meet base and peak loads
- Duct system mass is significant
- Temperature loss/gain for ducts in semi-conditioned space is now significant

Low Load Implementation Barriers

- Duct design (and installation) for low flows is outside the current industry capabilities
- Low mass systems (flex duct and duct board) are prone to poor installations (pinched ducts, not stretched for smooth flow, etc.)
- Smaller duct pieces are not standard stock items
- Higher performance registers are not standard stock items and therefore more expensive
- Commissioning has not been a “residential” thing but now must become a standard practice

Questions?

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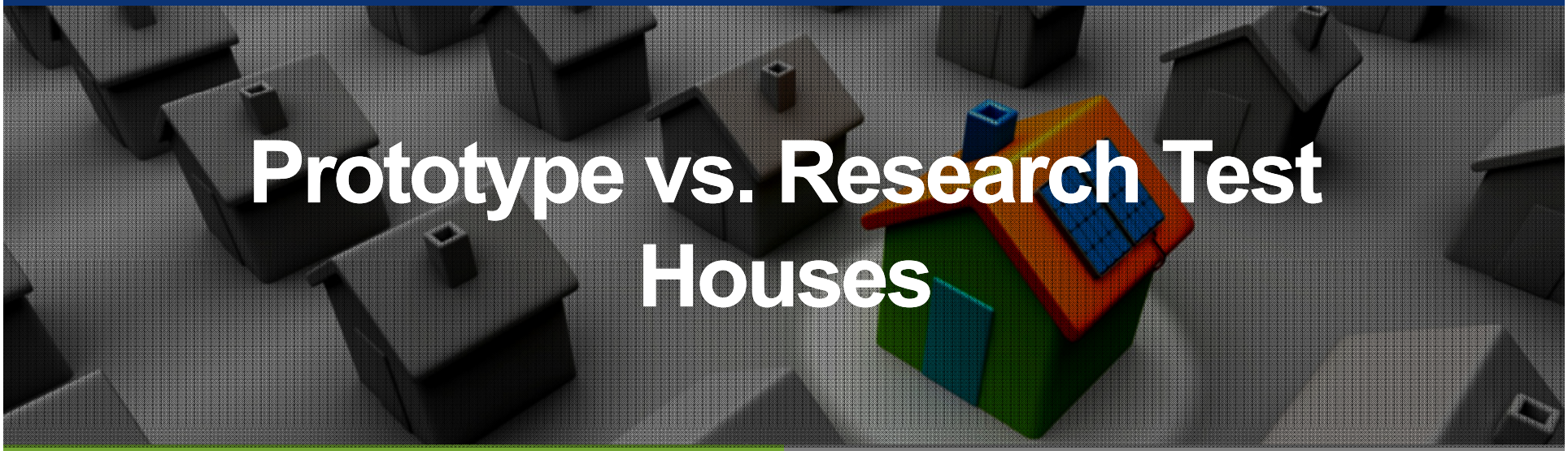


Prototype vs. Research Test Houses

Brad Oberg
IBACOS
July 2010

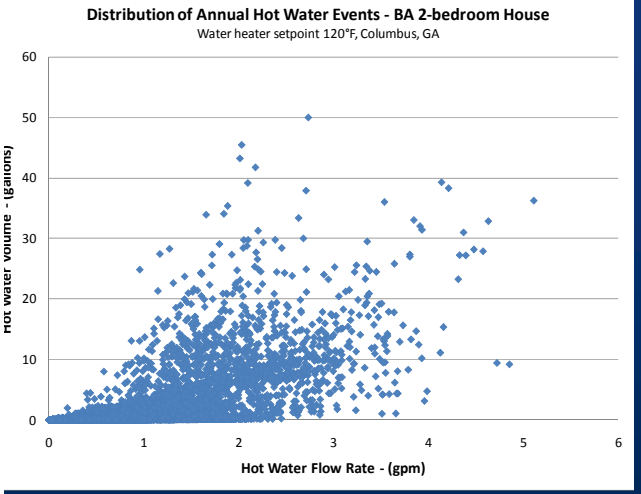
Prototype & Research Test Houses

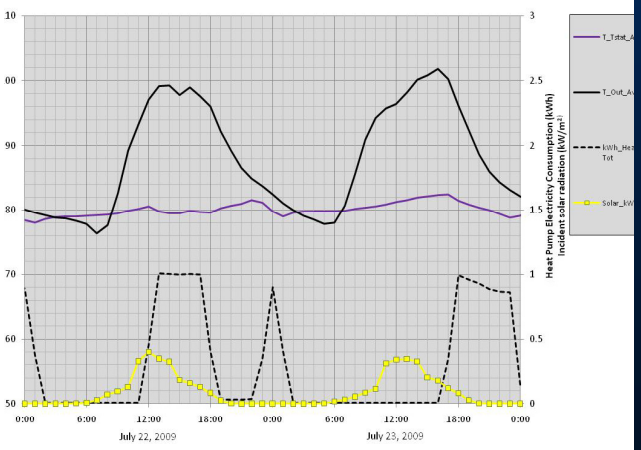
- Prototype test houses achieve 50% energy efficiency savings (40% in the past) in new home production environment using existing technologies
- Research test houses, a.k.a. lab house or test house, feature experimental systems and strategies
- Measure performance of experimental approaches

Prototype Test Houses

- Monitoring strategies
- Combination of known systems to validate strategies can be implemented and can work properly together
- Systems monitored to validate performance with occupants in place

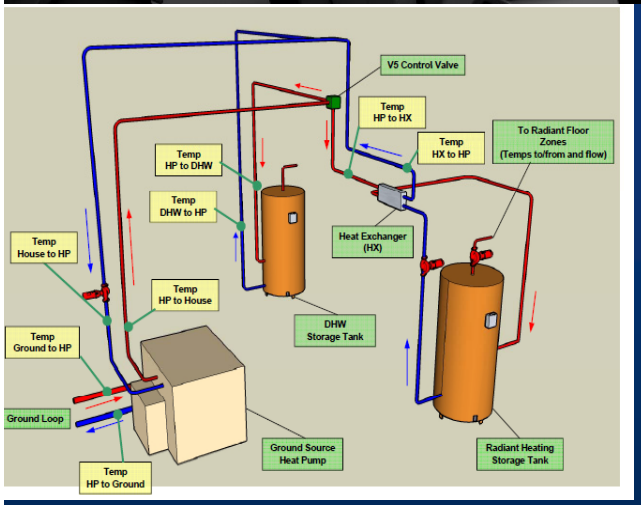
Occupants & Prototype Test Houses





- Real houses with real people can really effect monitoring results
- Sometimes the monitoring reveals as much about occupant behavior as system behavior
- Often the performance limits of the strategy are witnessed

Occupants & Prototype Test Houses



- Challenges can happen
  - Ground source heat pump constantly failing in one house
  - Occupant running house primarily in resistance heat instead of using the heat pump as primary heat

Research Test Houses Different

- Novel approaches
  - Non-occupant controlled
  - Allowed to operate to “breaking point” to test system limits and potential failure modes without putting builder or occupants at risk
  - Experimental systems and strategies based on sound building science or past experimental results but with a risk of failure

Research Test Houses Different

- Specific experimental operations
  - Run system to point of failure
  - Explore new building science theories
  - Understand prototype systems better
- Provides a research outlet for manufacturers

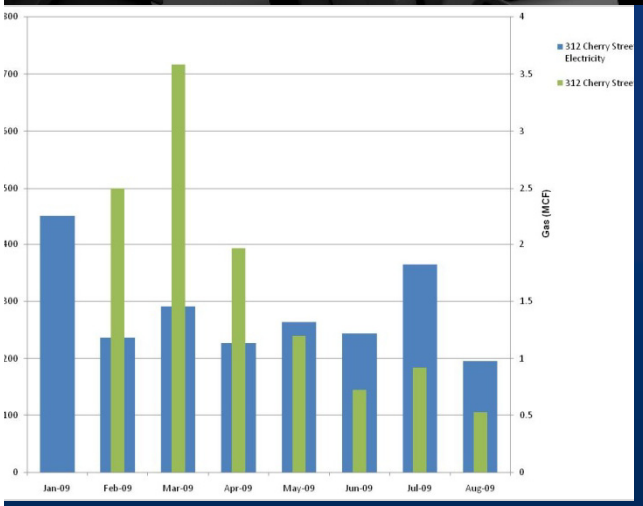
Costs and Prototype Test Houses

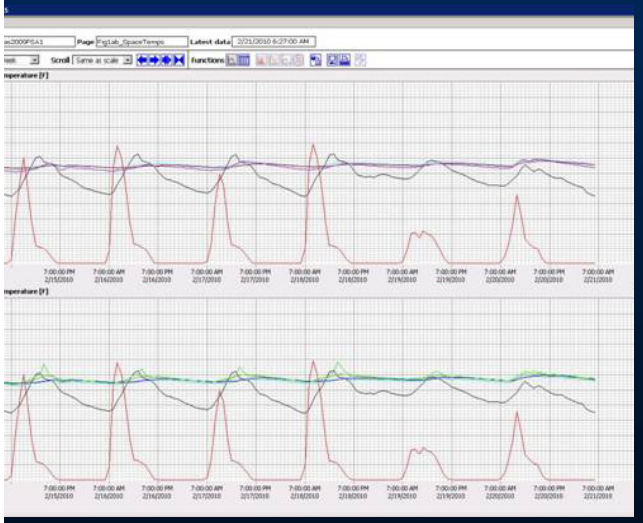
- Builder makes an investment up front in staff time
- Little actual hard cost, mostly builder soft cost
- Risk that homeowner may not agree to allow monitoring

Costs and Research Test Houses

- Greater commitment
- House must be held unoccupied for 2-3 years
- Pittsburgh Lab Home monthly carrying cost is $2,735
  - Includes mortgage, property insurance, real estate taxes, HOA fee, utilities (allowance)

Monitoring Objectives for Prototype Houses



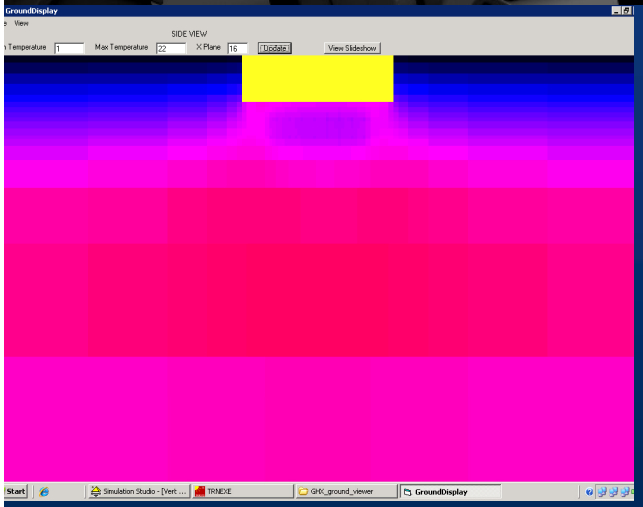


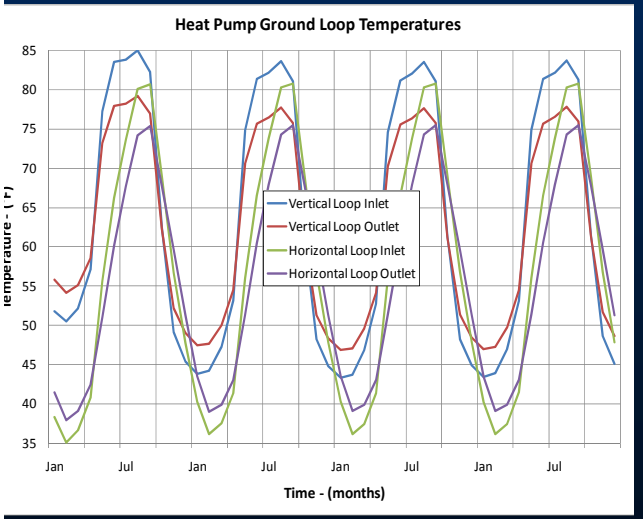
- Monitoring
- Validate expected performance of systems with low risk of failure
  - Whole house energy use
  - Specific end use category
  - Specific system

Monitoring Objectives for Research Houses

- Detailed measurements
- Determined performance with high risk of failure
- Can help validate modeling assumptions
- Collect data to develop more accurate models, analytical tools, predictive tools (i.e. load calculations)

TESS Modeling Enhancements



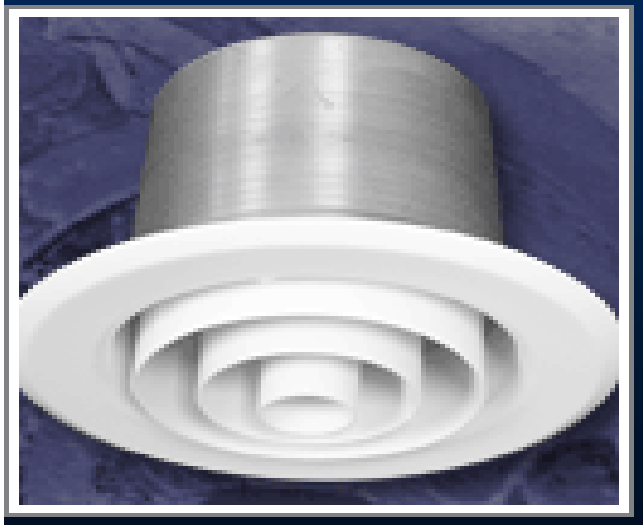


- Enhancements for TRNSYS that facilitated detailed modeling of novel systems/approaches
- Basement sub-slab horizontal ground heat exchanger application used with ground source heat pump component
- Can help validate modeling assumptions

Lab Home: Thermal Enclosure Experiments

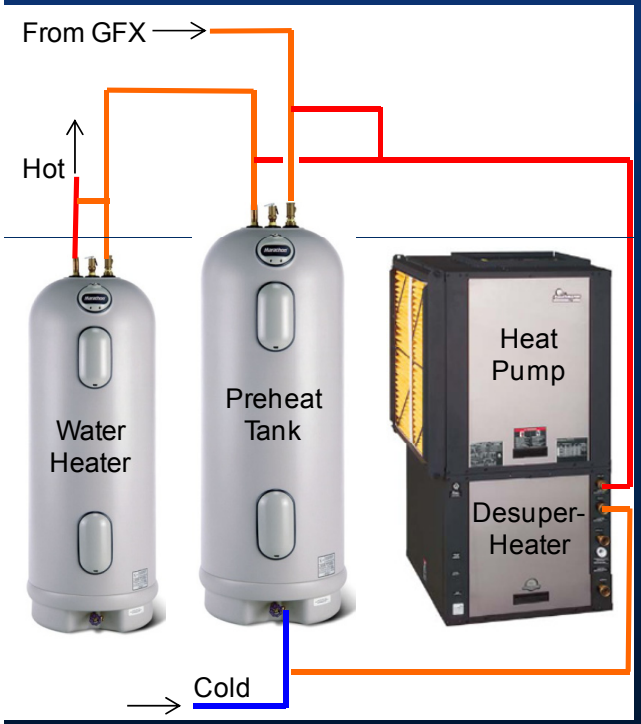
- Concrete slab and walls
- Framed walls
- Windows and doors
- Determine if temperature and humidity conditions could cause occupant discomfort and potential durability concerns
- Validate modeling results for comfort, energy use, thermal bridging, and moisture conditions

Lab Home: Space Conditioning Experiments



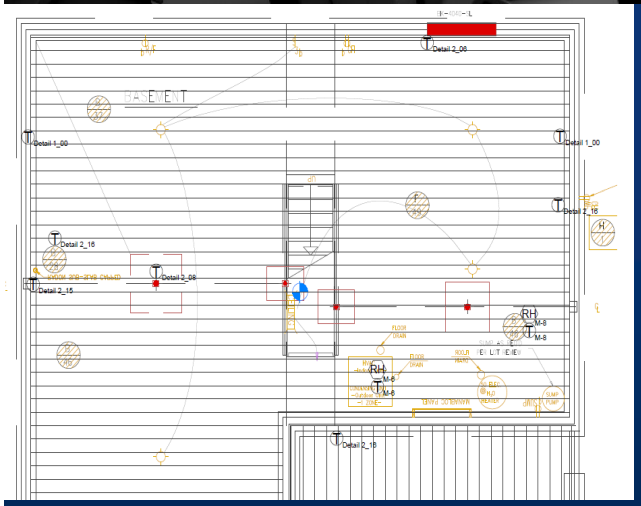
- One zone vs. two zones
- Multiple outlets vs. single outlet
- ERV with dedicated PVC distribution system
- 3” circular diffusers for good throw characteristics at low volumes
  - 90° diffuser boot could be better
- Low-mass distribution system and insulated flex duct for improved system efficacy
- Distribution designed for low-stage operation

Lab Home: Domestic Hot Water Experiments



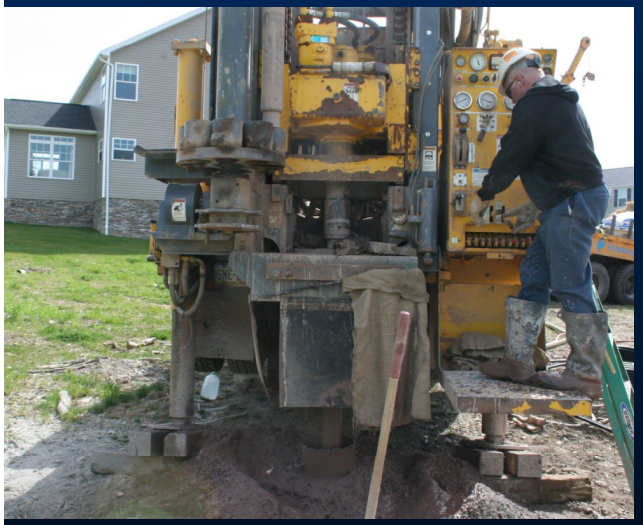
- GSHP with desuperheater
- One tank vs. two tanks
- Three usage schedules
- Single tank
  - 200 L vs. 400 L
  - Dip tube: full length or half length
  - Bottom element: min. set point or off
- Two tanks
  - 400 L preheat and 200 L WH optimal
  - Savings ≈ 50% (2150 kWh/yr)

Lab Home: Internal Gains



- Simulated occupancy, controlled
- Consider thermal mass and moisture capacitance
- NREL experience

Lab Home: GSHP Horizontal Sub-Slab HX vs. Vertical Wells



- Horizontal
  - Significant cost savings (≈ $3200 or 60%) compared to two 150-ft. wells
  - Slight reduction in performance
  - Thermocouples and soil moisture monitored for simulation model calibration
- Vertical
  - Baseline for comparison
  - Backup in case of unforeseen failure of horizontal HX
  - Grouting process not a slam dunk

Lab Home Research: Summary

- Determine if thermal enclosure systems perform as expected, per the modeling, and result in a comfortable, energy efficient, and durable environment
- Assess the performance of a horizontal sub-slab ground loop and compare with vertical well system to identify less expensive methods
- Determine the effectiveness of a standard space conditioning air distribution method and two alternative methods of providing comfort
- Characterize DHW performance for one-tank and two-tank configurations and compare to modeling

Opportunities in Existing Houses: 30% to 50% Load Reduction

- How do you deal with existing ducts, air flows, registers?
- Abandon forced-air system?
- Use ducts as chase for fan coil piping or small ventilation ducts to each room?
- High-efficiency furnaces and water heaters may free up chimney "chase" through house
- How do strategies change for various levels of load reduction?

Future Work to Close Gaps

- Answer lab home research questions and identify other gaps and barriers that resulted
- Develop an efficient “pre-designed” air distribution system for low-load houses
- Determine lab home research gaps in other climate zones and develop research plan
- Develop research plan to tackle gaps and barriers in existing housing

Engaging the HVAC Industry to Look Beyond "Traditional Box" Solution

Thinking Outside the Box (or "Lock" in this Case)

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Best Practices Research Alliance®

Building America Team Meeting

Questions?

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Quality Management for High Performance Homes: Research Update

Duncan Prahl, RA
Sr. Research Associate, IBACOS

July 2010

Where Are We Now?

- Technology research
  - 30% savings readily achievable, 40% becoming reality
  - 70% whole house savings on horizon

2005 - Ideal Homes builds first "Zero Energy Home" in the U.S. under $200,000

Where Are We Now?

- Operational Excellence & Quality Management is known but not widely utilized
  - Increase productivity: More with same or less
  - Standardize systems and processes
  - Continual improvement
  - Cultural and corporate alignment
  - e.g. Even flow, cycle time, customer satisfaction, return on assets, first time quality, trade relations…

Changes Ahead

- Code push for 30% and 50% savings in 2012 and 2015
- ARRA: 90% Energy Code compliance if accepting funding
- Builders Challenge Quality Criteria
- Energy Star Homes 2011: Checklists, checklists, checklists
- But….

General Assumption is that Builder Needs "Adult Daycare"

Execution is Critical

- Increased energy efficiency requires greater attention to detail in design and execution
  - Water management, HVAC design, thermal enclosure, comfort, IAQ

Code

30% - Builders Challenge, ES 2011

50% +

Merging of Energy Efficiency and Quality Management

Part of the solution is…

Technology Systems

The other part of the solution is…

Business Management Systems

Combine these and you have…

Integrated Solutions

Sustained Implementation of EE Homes

Two Quality Strategies

ENERGY STAR Qualified Homes
National Builder Option Package

The requirements for the ENERGY STAR Builder Option Package (BOP) are specified in the table below.
To qualify as ENERGY STAR using this BOP, a home must meet the requirements specified, be verified and field-tested in accordance with the HERS Standards by a RESNET-accredited Provider, and meet all applicable codes.

	Hot Climates [1] (2004 IRC Climate Zones 1,2,3)	Mixed and Cold Climates [1] (2004 IRC Climate Zones 4,5,6,7,8)
Cooling Equipment (Where Provided)	Right-Sized [2]: • ENERGY STAR qualified A/C *(14.5 SEER / 12 EER)*; OR • ENERGY STAR qualified heat pump [3] *(14.5 SEER / 12 EER / 8.2 HSPF)*	Right-Sized [2]: • 13 SEER A/C; OR • ENERGY STAR qualified heat pump [3] *(14.5 SEER / 12 EER / 8.5 HSPF)*
Heating Equipment	• 80 AFUE gas furnace; OR • ENERGY STAR qualified heat pump [2,3] *(14.5 SEER / 12 EER / 8.2 HSPF)*; OR • 80 AFUE boiler; OR • 80 AFUE oil furnace	• ENERGY STAR qualified gas furnace *(90 AFUE)*; OR • ENERGY STAR qualified heat pump [2,3] *(See Note 3 for specifications)*; OR • ENERGY STAR qualified boiler *(85 AFUE)*; OR • ENERGY STAR qualified oil furnace
Thermostat [3]	ENERGY STAR qu	
Ductwork	Leakag R-6 min. i	
Envelope	• Infiltration [6,7] (ACH50): 7 in (• Insulation levels that meet or • Completed Thermal Bypass	
Windows	ENERGY STAR qualified win	
Water Heater [13,14]	Gas (EF): 4 Electric (EF): 4 Oil or G	
Lighting and Appliances [16,17]	Five or more E ceiling fans equipped w	

Note: Due to the unique nature of some state codes and/or climate
California, Hawaii, and the Pacific Northwest to continue to define p
requirements of the national program or the regionally-developed p

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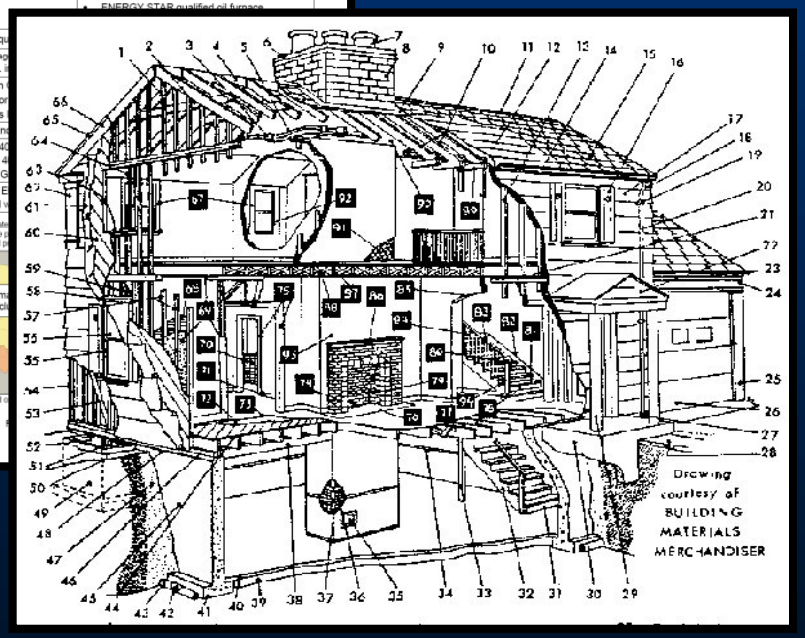
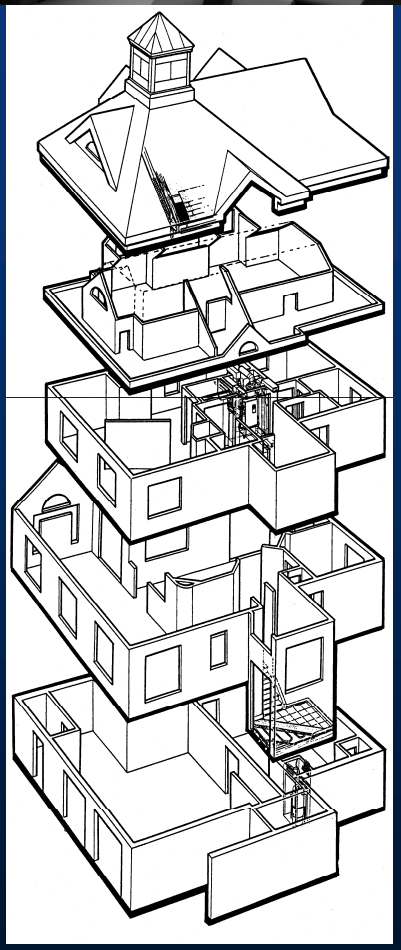
Map is for illustrative purposes only and is based o





"Spec and Purchase"

"Systems Approach"

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Building America Team Meeting

Building Company Organization

Planning & Development

Product Design & Purchasing

Marketing & Sales

Home Construction

Customer Care

Systems Approach:
Integration for High Performance & Quality Management

Spec and Purchase

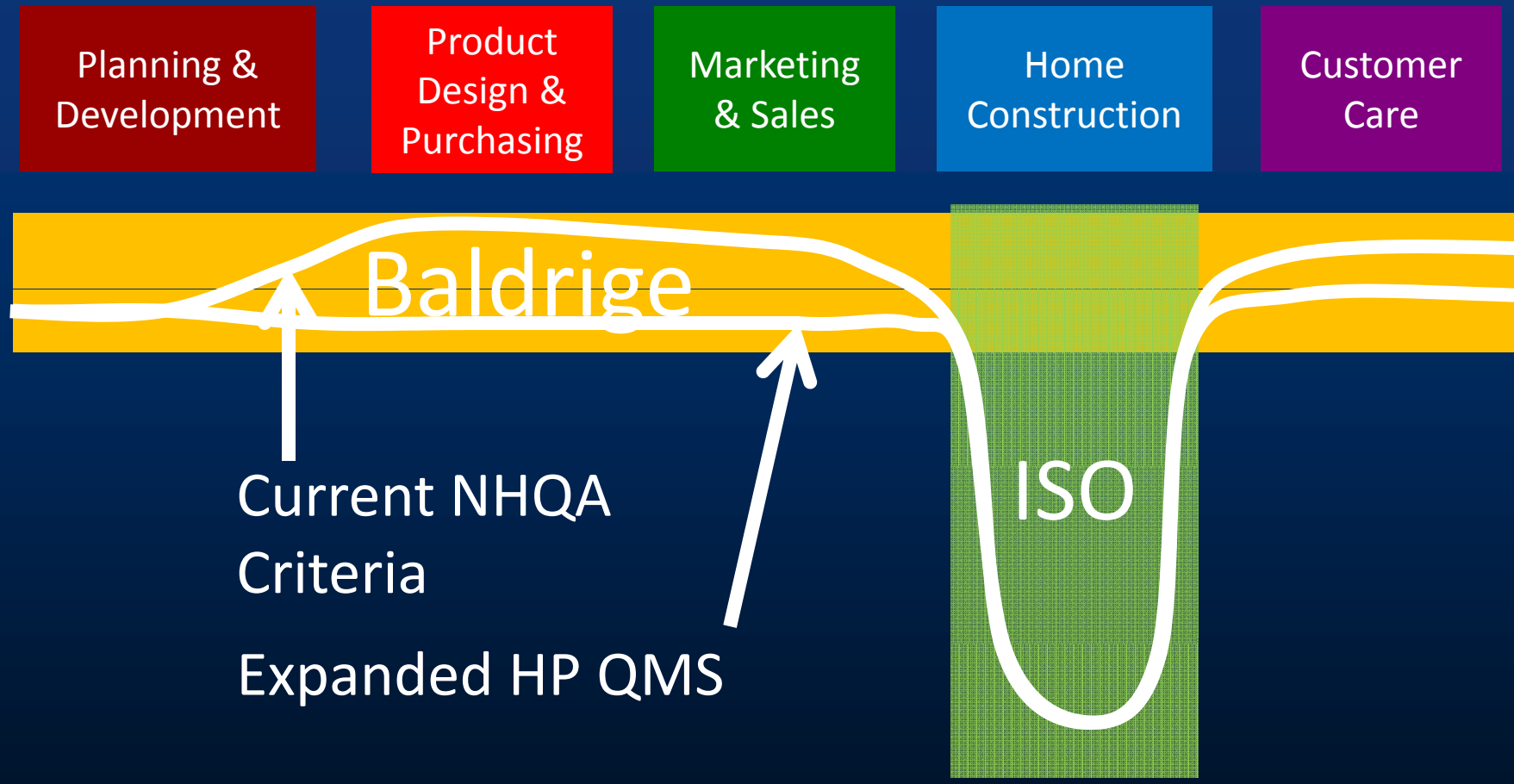
Barriers to High Performing Homes that Quality Management Can Help Overcome

- Don’t know where to start
- Inability to change organizational culture
- Improper planning
- Lack of continuous training
- Incompatible organizational infrastructure
- Isolated/Silo departments
- Building one prototype only and not taking it to scale

Research Questions

- What are some “systems approach” models of Quality Management?
- How does a builder get from where it is to one of those models?
- What do builders need to accelerate the change?
- What does it take to make the change ($$$, effort, manpower)?
- What are the financial and business benefits, and how are those measured?

Quality Models: ISO vs. Baldrige Criteria



2010 Research Activities

1. Expert Meeting: “Quality Management Tools & Integration” October 26, Pittsburgh, PA
2. Characterization of best-in-class practices from NAHBRC Quality Certified Builders, NHQ award applicants and winners, and others
3. Lead development of standardized business metrics
4. Coordinate collection of BMS data from existing BA Teams, Builders Challenge builders, or BA research builders
5. Lead development of model characteristics for companies with a systems approach
6. Develop strategies for adoption of systems approach QMS – Pathways to Quality

2. Characterizing Quality Management Best Practices for High Performing Homes

- Looked at builders associated with NHQA, EVHA, Builders Challenge, ENERGY STAR, Professional Builder Magazine Builders of the Year, Hanley Wood Best Builder
- Management systems help structure, define, and coordinate standards and processes , especially in design, construction, and with trade partners
- Drive the efficiency and effectiveness of design and construction
- Easier to implement changes in product or processes

Study of Management System Impact on High Performance Home Builders

- Total population of 59 NHQA-winning builders
- Studied a sample of 21 (36%)
- Compared analysis of two builder groups
- 14 ENERGY STAR/Green Standard builders
- 7 non-ENERGY STAR/Non-green 'traditional' builders
- Builder performance evaluated using NHQA scoring results from in-depth expert desk and site visit reviews
- 19 of the builders in the study had won NHQA Gold, Silver, or Honorable Mention
  - Other two (one in each group) were considered future winners if they reapplied
- Mix of small, medium, and large builders

High Performance & Traditional Builders

- 14 currently ENERGY STAR/Green Standard builders
  - 9 certified to NAHBRC third-party audited QMS
  - 1 had a third-party trade monitoring system
  - 4 had no formal documented QMS
- 7 non-ENERGY STAR/Non-green 'traditional' builders
  - 3 were certified to NAHBRC third-party audited QMS
  - 1 had its corporate office certified to ISO9001 third-party audited
  - 2 had no formal documented QMS

Performance Impact

- Organizational size had no impact
- In both high performance (HP) and traditional groups, the lowest performing builders were those that did not have a certified QMS
- Those builders that had a third-party independently audited and certified QMS had the best performance

Those without QMS Certification

- The traditional uncertified builders were weakest in:
  - Construction quality
  - Trade relationships
  - Business results
- The HP uncertified builders were also weaker in those areas BUT had two additional low performing areas:
  - Performance management
  - Human resources

Low Performance Areas for HP Uncertified Builders

- The HP uncertified builders were specifically weakest in:
  - Performance management
    - How you develop, manage, measure, and improve your key processes
  - Human resources
    - How you support superior work performance
    - How you ensure organizational alignment
  - Construction quality
    - Education and reinforcement of quality standards
  - Trade relationships
    - Integration of trades in building a better company
  - Business results
    - Business operating results
    - Employee satisfaction and turnover rates
    - Supplier and trade satisfaction

Weaknesses can be Resolved thorough the Strengths of QMS

- This study shows that the use of a certified QMS will improve performance and make HP homebuilding easier, since the focus of a certified QMS is the following:
  - Process management
  - Work performance
  - Organizational alignment
  - Reinforcement of quality standards
  - Integration of trades
  - Measures and metrics

Key Attributes of HP Builders

- Cultural and corporate alignment
- Clear intent for quality and performance
- Increased collaboration across internal and external teams
- Better communication practices and systems
- Disciplined approach to quality control
- Measurement and verification of performance
- Continuous feedback and improvement
- Whole house integrated design and specification

4. Business Metrics

- Gathered information from past Quality Builder Council
- Under evaluation and refinement
- Review will be part Expert Meeting

5. Develop a Model of a Systems Approach Operational Platform

- Integrated Quality Management System based on an integration of the principles of:
  - DOE's Builder Challenge QEHS Criteria Guide Version 1.3
  - NAHB Research Center's NHQ Quality Management System Requirements for Builders
  - ISO9001, 14001
  - OHSAS18001
  - Malcolm Baldrige National Quality Award (MBNQA) Criteria for Performance Excellence
  - National Housing Quality Award
  - Six Sigma and other quality tools and approaches

Systems Approach QMS Model

- Includes Land Development and Design
- Specifically addresses and requires an Environmental Management System focusing on all aspects of producing high performing homes
- Incorporates Builder Challenge Quality Criteria
- Drives whole house design by requiring Design to create an integrated design approach involving all internal departments and trades
- Eliminates silo approach
- Includes building performance attributes as part of performance metrics to be measured and tracked

Proposed Structure of Systems Approach Model QMS

- 1.0 General
- 2.0 QMS System Management
- 3.0 Land Development
- 4.0 Sales
- 5.0 Design
- 6.0 Estimating
- 7.0 Purchasing
- 8.0 Construction
- 9.0 Customer Relations & Warranty
- 10.0 Additional Functional Areas

Section 8.0 Construction Operations

- 8.1 Construction operations policies and procedures
- 8.2 Construction operations inspections
- 8.3 Construction operations continual improvement
  - Other operational areas (Land Development, Sales, Design, Estimating, Purchasing, Customer Care) have same subcategories

8.1 Construction Operations Policies & Procedures

- Scope of construction operations
- Process flow
- Codes, standards, & regulations
- Manufacturers installation instructions
- Trade partner contracts / Scopes of work
- Scheduling
- Selection & approval of trade partners
- Control of plans & specs

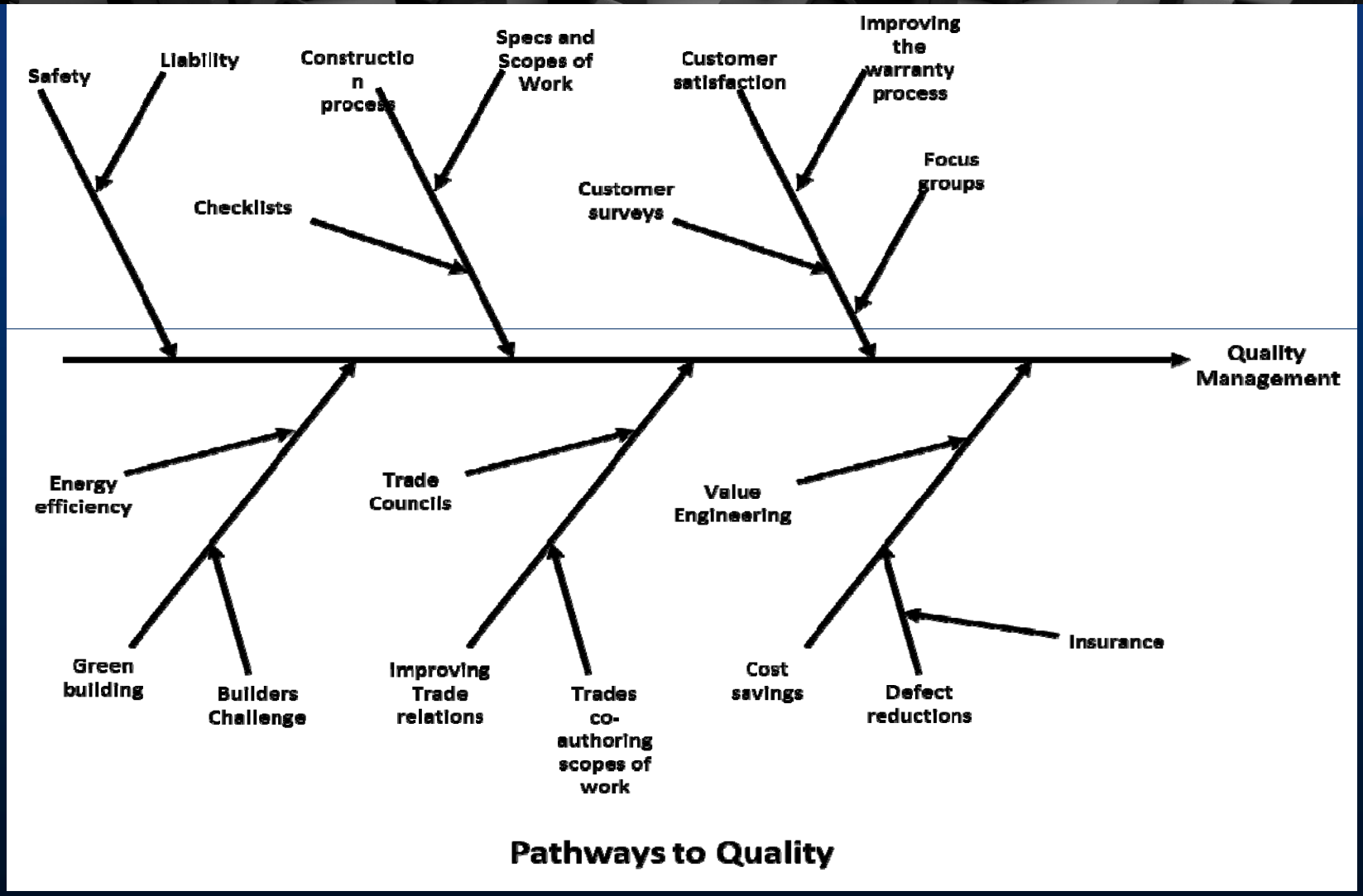
8.2 Construction Operations Inspections

- General
- Job ready procedure
- In process inspections
- Final inspection
- Inspection & review of records

8.3 Construction Operations Continual Improvement

- Corrective & preventive
- Construction training
- Trade contractor QMS support

6 . Pathways to Quality



Pathways to Quality

Expert Meeting: October 26, 2010

- Plan submitted
- Initiations out
- Meeting topics
  - Draft QMS
  - Business metrics
  - Transformation pathways
  - Identify barriers and gaps

Questions?

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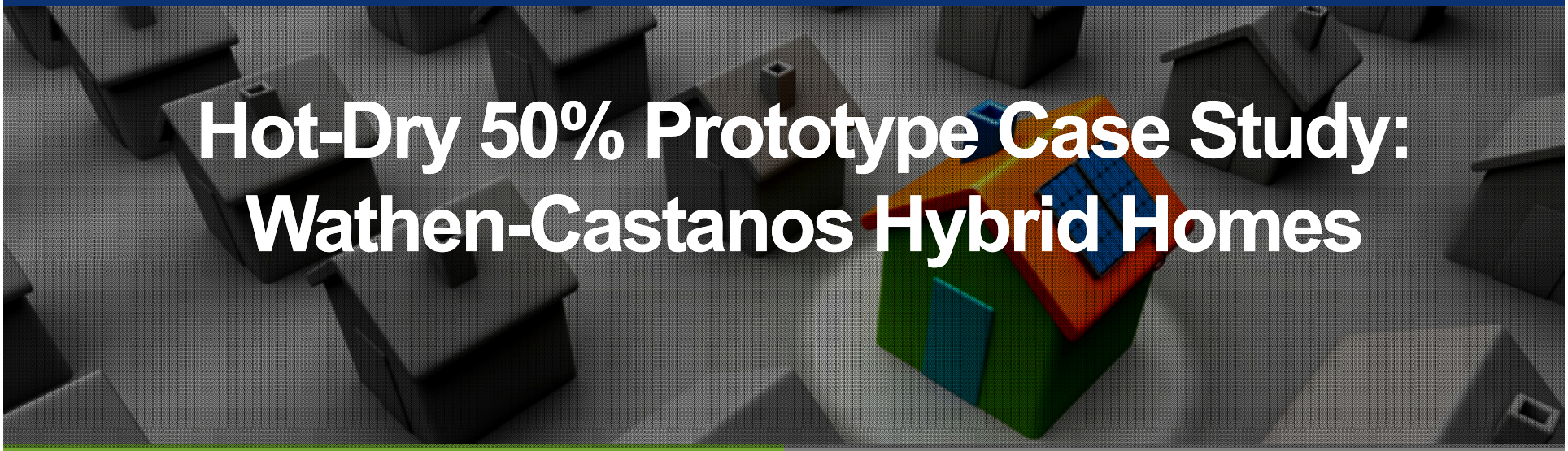


Hot-Dry 50% Prototype Case Study: Wathen-Castanos Hybrid Homes

Duncan Prahl, RA

Sr. Research Associate, IBACOS

July 2010

Wathen-Castanos Hybrid Homes, Inc.

- Company profile:
  - ~180 homes per year in Clovis/Fresno, CA
  - First-time, move-up and empty-nester buyers
  - House sizes from 1,100 to 2,700 square feet
  - Started high performance homes in 2006
  - Current standard practice ~48% WRT BA Benchmark
  - 36 employees currently

Initial Evaluation: Mapping and Gap Analysis

- In 2 days, mapped operational activities in 5 areas:
  - Planning and Development, Product Design and Purchasing, Home Sales and Marketing, Construction, and Customer Care
  - Identified key strengths and gaps as a builder of high performance homes
  - Strong corporate culture, trade relationships, brand awareness, and reputation
  - Integrated Design Process
- Identified 6 Work Improvement Groups (WIGs)

Work Improvement Groups (WIGs)

- Company had to invent a new operational model
  - Reduced staff by 2/3 from 2007-2009
- Developed cross-functional teams to address highest value gaps
- Training provided to company and trades on Building Science, Quality Management, and Quality Tools
  - DMAIC (Define, Measure, Analyze, Improve, Control) process for WIGs
- Applied for National Housing Quality Award in 2010; received site visit by judging panel

Initial Evaluation: Technical

- Results from IBACOS' Quality Assessment:
  - Two days of site evaluations
  - Overall score 3.2 (scale of 0 to 4)
    - "Low Risk" Category

Initial Evaluation: Technical

Observed best practices:

- Excellent HVAC duct installation
- High efficiency equipment
- 92 AFUE furnace
- 14 SEER air conditioner
- Zoned distribution
- Rinnai tankless, gas-fired water heaters

Initial Evaluation: Technical

Observed best practices:

- Grade I fiberglass batt installations
- R-13 cavity + R-4 continuous exterior insulating sheathing
- Good air sealing of the enclosure

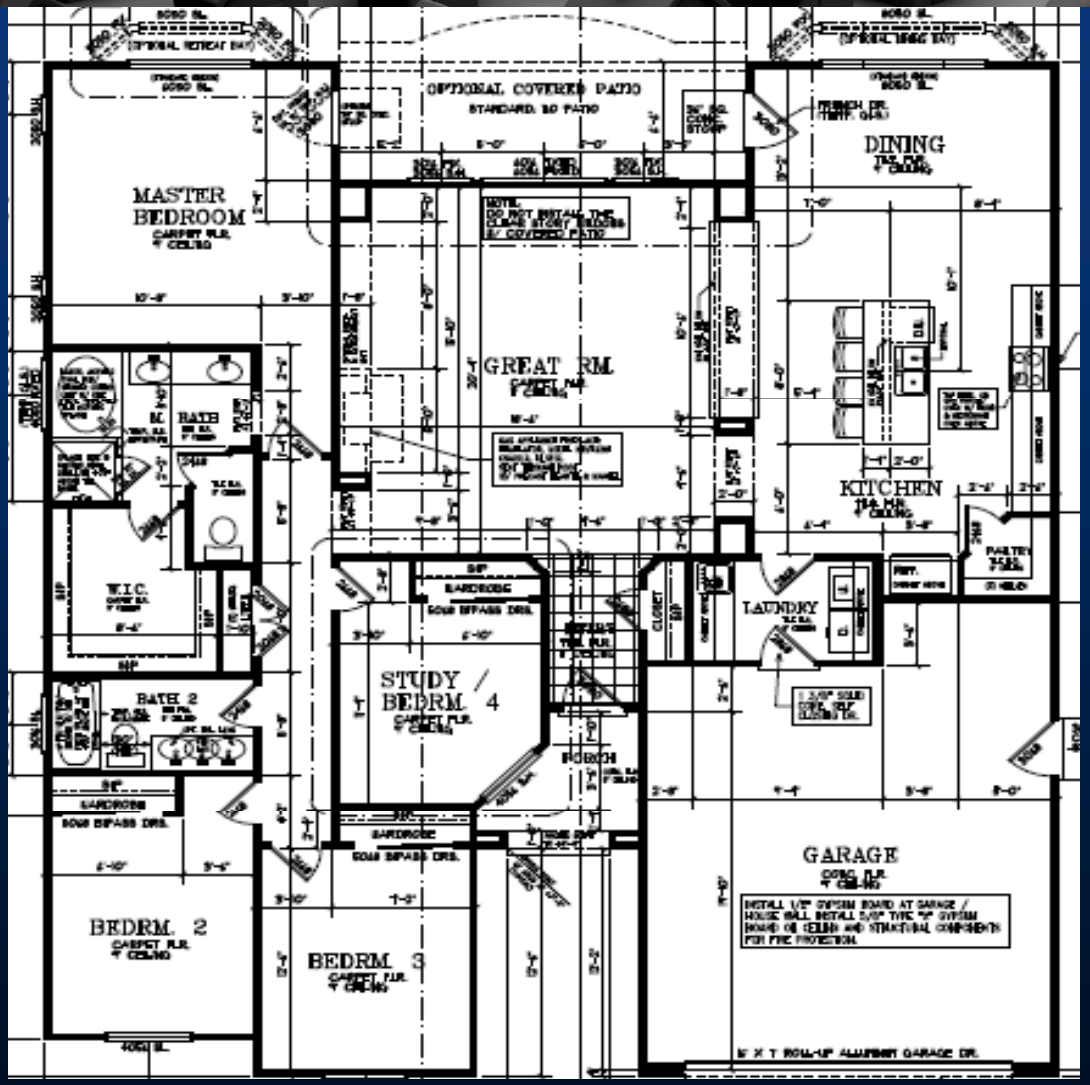
Initial Evaluation: Technical

- Energy performance of existing practices (Jan. 2010):
  - 48% above Building America Benchmark
  - Participating in Builder's Challenge, California Build It Green, & ENERGY STAR
  - 30% beyond 2008 CA Title
  - Average duct leakage < 5%
  - Average building tightness < 3.5 ACH50
  - Taking advantage of every tax incentive and energy rebate available to offset all energy upgrades
  - Homes marketed competitively at $/sq. ft. for region

Prototype: Design Strategies

- Wathen-Castanos Hybrid Homes, Inc. wanted to roll out a fresh product offering for a community development, “Loma Vista”
- Plan #200 is a 2,000 square foot, 3-bedroom ranch style home
  - IBACOS encouraged the builder to consider moving the HVAC system and ducts to inside conditioned space
  - Cost to do a conditioned attic proved too high for the builder’s price point
  - Very concerned about marketability of 8’ ceilings in areas of the house

Plan 200



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Building America Team Meeting

Prototype: Specification Package

Component	2010 Base Package	Prototype
Concrete Slab	Uninsulated	Uninsulated
Exterior Walls	2x4 16" o.c. R-13 + R-4 cont. sheathing (R19 knee walls)	2x4 16" o.c. **R-15**+ R-4 cont. sheathing (R19 knee walls)
Roof	Attic floor - R-38 + Radiant Barrier	Attic floor - R-49 + Radiant Barrier
Exterior Doors	R-4	R-4
Windows	U-.34, SHGC-.25	U-.32, SHGC-.25
Building Air Tightness	3.5 ACH50	2.7 ACH50
Mechanical Ventilation	Exhaust with pressure relief	Exhaust with pressure relief
Heating	92 AFUE	94.7 AFUE
Cooling	16 SEER	18 SEER
Ductwork	R-8 in unconditioned	R-8 in unconditioned
Water Heater	Tankless, gas .82 EF	Tankless, gas .98 EF
Appliances	All Energy Star	All Energy Star
Fluorescent Lighting	100%	100%
Photovoltaic System	variable	3.7 kW
% Better than Building America Benchmark	**48.4%**	**52.6% & 70% w/PV**

- The point deficiency to get from 48% to 50% beyond Benchmark would have to be made up in system efficiency and an enhanced building enclosure
- Net positive cash flow to the consumer of ~$935/year
- Rating for this design package:
  - –RESNET HERS Index - 53
  - –CA HERS I – 46
  - –CA HERS II – 68

Prototype: Design Strategies

- Wathen-Castanos Hybrid Homes has been adamant that the resulting prototype product would still fit into a price point that would be competitive in its market
- Demonstrates the builder's commitment to taking this specification package to community-scale production

Prototype: Design Strategies

- Strategies to achieve a tighter building envelope (to get from 3.5 to below 3.0):
  - Addition of seal sill that layers up under stucco weep screed
  - Glued drywall to top and bottom plates and around openings

Prototype: Design Strategies

- Builder was already:
  - Sealing all penetrations through plates and enclosure
  - Sealing all window and doors between R.O.s and frames
  - Sealing all penetrations through the drywall
- Actual blower door test results indicate a total leakage rate of 2.7 ACH50; not amazing (but not bad for California) open frame construction

Prototype: Design Strategies

- Additional wall R-value was achieved by using Johns Manville Spider® blown-in fiberglass

Prototype: Design Strategies

- Though attic insulation was increased to R-49, (from R-38) raised heel trusses were priced but not included
- Some designs require raised heels for aesthetics

Design Challenges & Barriers

System sizing:

- Initial modeling indicated that a 2 ton AC was sufficient
  - Total cooling load was 20,888 Btuh
- Builder wanted to use the Bryant Evolution System
- Two ton AC was discontinued and a 2 ½ ton wasn't available
  - Therefore, a 3 ton system was installed
- Again, the industry is faced with manufacturing split AC systems that are high efficiency and small enough for low load, high performance homes

Challenges & Barriers

- Bringing ducts inside conditioned space
  - Aesthetic concerns
  - Footprint of the HVAC unit
  - Noise concerns
- How much is enough?
  - 50% package is possible, but incremental step above 48% builder standard practice is marginal
  - Even if we “threw everything at it,” we’d only be achieving mid-50% savings
- CA HERS I, II & RESNET Ratings
  - T-24 vs. 2006 IECC reference homes
  - States rights vs. national uniformity

Buyer Response

- 3.7 kW photovoltaic system cost $13,940 with a rebate of $7,709 for a final cost to the builder of $6,231 to the builder
- Since the opening of this home, WCHH has offered a PV package as an included upgrade. Buyers can opt for any other options instead. The majority are taking the other options.
- “The home is efficient enough, I’ll take the granite countertops” is the common response to this offering

Next Steps

- Implement a model Quality Management System within the organization
  - Way to document and standardize procedures for high performance homebuilding
  - Identify operational best practices for translation to other building companies
  - Track operational metrics to demonstrate benefits of making high performance a basic operational strategy
- Evaluate Prototype
  - Are incremental strategies enough to maintain market leadership?
  - Re-evaluate systems strategies

Questions?

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American Council for an Energy-Efficient Economy

Thermal Enclosure Design Challenges for a Cold Climate Net Zero Energy House

John Broniek
Senior Building Performance Specialist
IBACOS
August 18, 2010

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Building America
U.S. Department of Energy

Cold Climate Net Zero Energy House by Pittsburgh Production Builder

- Production situation
- 70% whole house energy savings per Building America Benchmark Definition
- Two floors, 2,160 ft^2 of floor area, three bedrooms, fully conditioned, partially finished basement
- Paper summarizes design challenges and solutions encountered in four thermal enclosure areas

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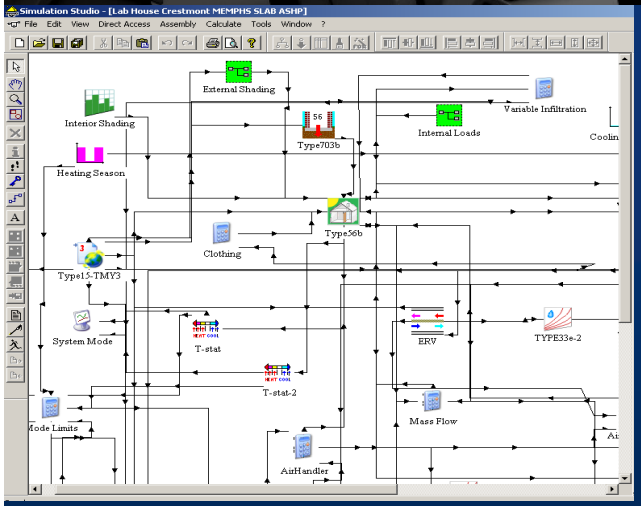
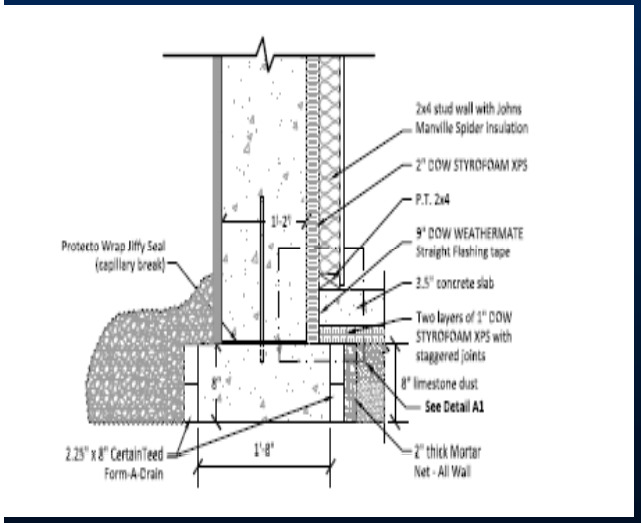
Common System Challenges

Systems: Basement Slab, Foundation Walls, Above-Grade Walls, Windows and Doors

- Deciding the optimum amount of insulation to meet energy use savings targets
- Deciding which specific insulation and system components to employ
- Water management, durability, and installation details require attention and development in all systems
- Constructability implications must be resolved to the satisfaction of the builder and subtrades
- Cost implications for production builder very important
- Design considerations for integrating different systems

Basement Slab Challenges: Modeling and Constructability



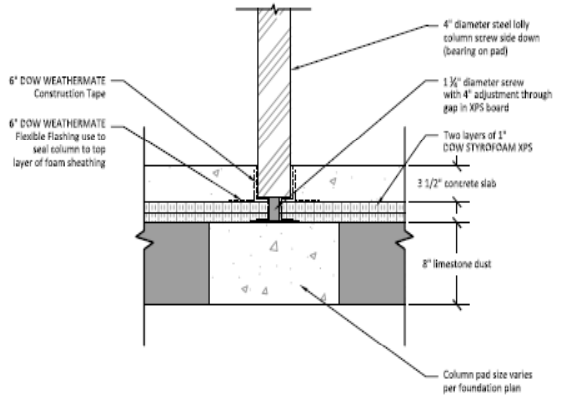


- TRNSYS detailed modeling indicated R-10 (2” of XPS) sub-slab insulation offers 212 kWh/yr heating and cooling energy savings (-9.6%) vs. uninsulated slab
- R-20 offered only 25 kWh/yr more heating and cooling energy savings
- R-10 easier to install than R-20 since thinner and saves $972 in material cost
- R-10 application scored well in constructability while offering substantial energy savings

Basement Slab Challenges: Installation Considerations

- Wall-to-floor continuous insulation; XPS provides vapor retarder eliminating need for sub-slab poly
- Flashing installed at the slab perimeter to form a termite break
- Design called for two 1” sheets of XPS to be installed with the joints staggered, leaves no gaps
- During construction a layer of 2” XPS with joints taped used (tape provided); easier to cut penetrations through one board

Basement Slab Challenges: Detailed Drawings and Practices



- Minimize the gap in thermal performance at penetrations
- Make penetrations airtight by placing flexible flashing around the steel column with another piece of flashing attached to it and the XPS layer, sealing the gap where the column meets the XPS

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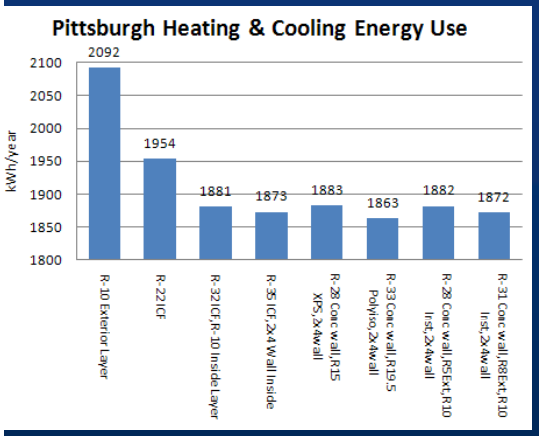
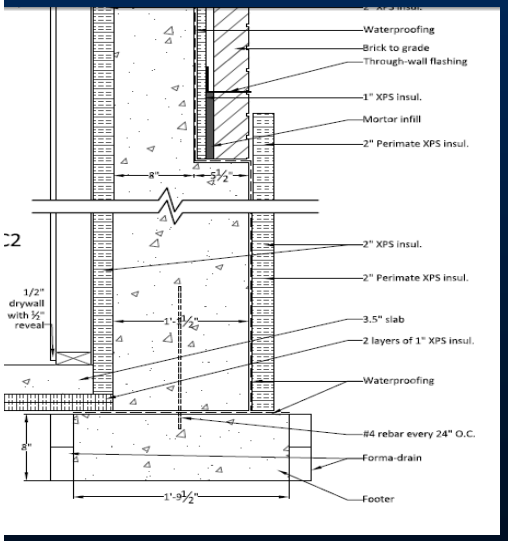
Basement Foundation Walls Challenges: Modeling and Constructability





- TRNSYS showed that energy performance increases as insulation is added, leveling off at a nominal R-28
- Builder preferred a poured concrete system:
  - It was more familiar
  - It was available at a low construction cost from its trade partner
  - It worked well for a site with varying grade levels
  - It could be stepped and sized to our exact dimensions making easier integration with brick and vinyl siding exterior finishes

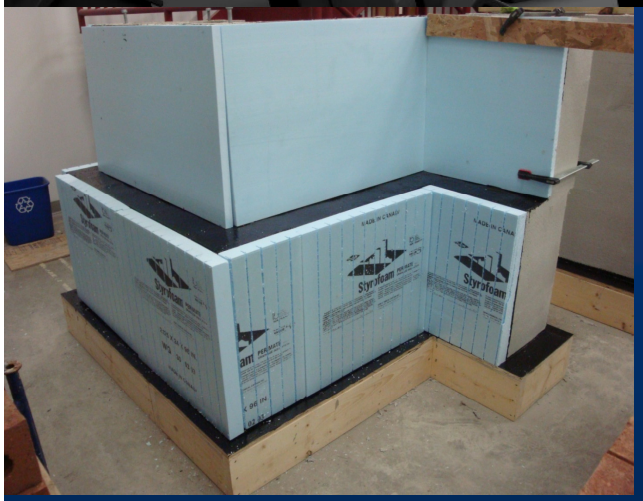
Basement Foundation Walls Challenges: Modeling and Constructability

- Was exterior insulation necessary? TRNSYS indicated 33 kWh energy savings
- External below-grade foundation insulation can drain water away from foundation wall, increasing wall durability
- Drainage board with insulating properties would be best scenario
- Drainage board made of recycled waste products (minimal fire retardants) found (and assumed to be R-3)
- Above-grade exterior portions of the foundation wall have R-5 XPS insulation

Basement Foundation Walls Challenges: Constructability in Interior

- A layer of 2” XPS R-10 insulation board with no facing provides good thermal performance and prevents condensation at interior surface of wall
- Insulated wood-framed wall with a pressure-treated plate, R-13 insulation and painted drywall finish the basement walls and provide nominal R-26
- At unfinished portion 3” thick R-19.5 polyisocyanurate board insulation (special order thickness hard to obtain) insulates the interior and provides a code-approved (exposed) thermal barrier
  - Joints in board taped to prevent moisture accumulation at concrete foundation wall interior surface

Basement Foundation Walls Challenges: Constructability Mockup



- Above-grade wall system integration, respective positioning, and detailing at the brick portion of the foundation wall needed to be figured out
- A sill sealer product placed under the sill plate with the ability to flash above and below it at the exterior provides good airtightness and termite control
- A through-wall flashing material with a flexible membrane will facilitate drainage through the brick façade (at grade)
- Polypropylene net material product will facilitate drainage behind brick to weeps

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Above-Grade Walls Challenges: Modeling and Costing Results

- Wall systems with a nominal thermal performance of R-40 (plus or minus R-10) would help achieve 70% savings
- Dozens of wall systems narrowed down to favorites: staggered 2x8 stud system, 2x6 studs with multiple layers of XPS sheathing, double wall construction, and SIPS
- TRNSYS detailed modeling of wall structure determined lowest energy use: single stud 2x6 wall, R-23 blown-in fiberglass in wall cavities, R-20 un-faced XPS sheathing
  - #2: Single stud 2x6 wall with R-15 un-faced XPS sheathing
  - #3: Staggered stud 2x8 wall (using staggered 2x4s), framing at 24“ spacing, R-31 insulation in wall cavities, R-10 un-faced XPS sheathing
- Most cost-effective wall: Single stud 2x6 wall with R-5 insulating sheathing (according to costs from builder and subtrades)

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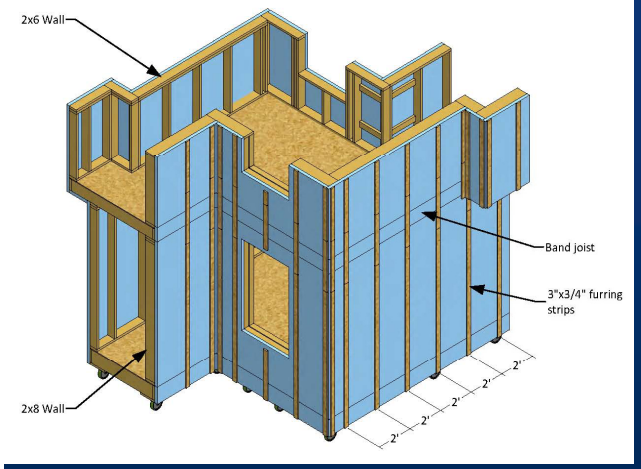
Above-Grade Walls Challenges: Mockup 2x8 and Thick 2x6 Wall Systems



- Evaluate constructability, durability, structural requirements, performance
- 2x8 staggered stud (at 24” o/c) construction takes longer, but doable
- Double top plates eliminate the need to precisely stack roof trusses and floor joists; 10 kWh/yr energy penalty
- Only outer layer of XPS (when using multiple layers) needs to satisfy manufacturer’s attachment requirements
- Greater sheathing thickness = greater drift from longer screws = harder to hit studs
- Furring strips needed for 2” thick or greater XPS sheathing; expensive screws for attachment to studs

Above-Grade Walls Challenges: Mockup 2x8 and 2x6 Walls

- Alternative 2” XPS sheathing product with recessed channels allowed for nailing (cheaper); uniform surface created for vinyl cladding
- Additional recessed channels for installing furring strips at corners, around window and door openings could be prepared easily using a hot knife cutter
- Cement fiber and vinyl siding attached to recessed furring strips
- 24” o.c. attachments are stable
- Blown in fiberglass in wall cavities favored since it blows in fairly dry

Above-Grade Walls Challenges: System Evaluation

- Best score: 2x6 wall system, R-5 insulating sheathing
- Second best score: 2x6 wall system with layer of closed cell spray polyurethane foam, R-5 insulating sheathing
- Third best score: Staggered stud 2x8 wall, R-10 insulating sheathing (then 2x6 walls with R-10 and R-15)
  - Out of top three, this wall offers greatest amount of heating and cooling energy savings for the whole house, saving an additional 317 kWh/yr (14%) in energy use than the first wall and 197 kWh/yr (9%) more than the second wall
  - An energy efficiency leader; constructability issues resolved during mockup research; it has merit as a wall system for a net zero energy house – lets try it!

Above-Grade Walls Challenges: Details of 2x8 Staggered Stud Wall

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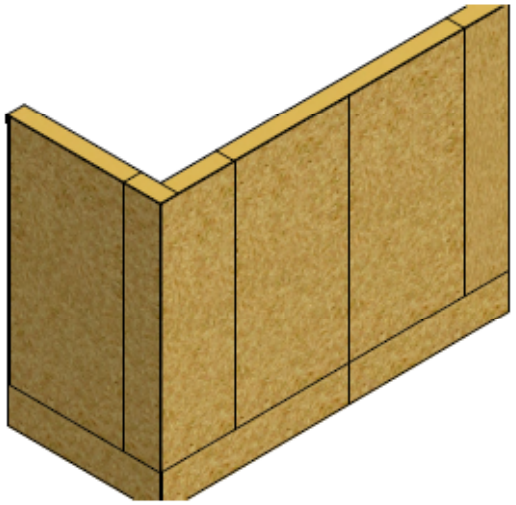
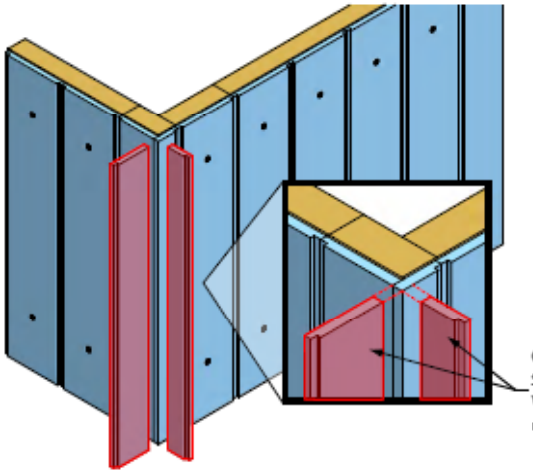
DOW STYROFOAM WALLMATE Installation on Pre-Fab Panels and Corners

3 - Above Grade Walls
Step-by-step

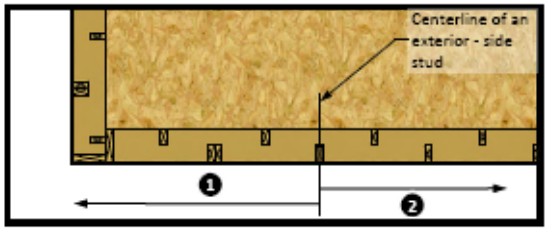


Step 1 - Install Pre-fab wall panels.

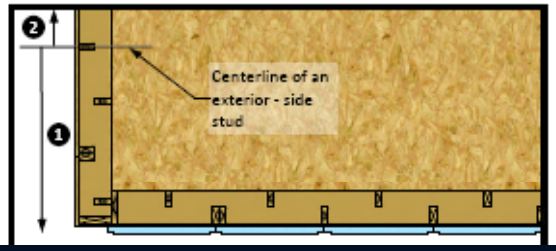


Step 3 - When approaching a corner trim DOW STYROFOAM WALLMATE as necessary for installation at corner, ensuring the foam overlaps at the corner.

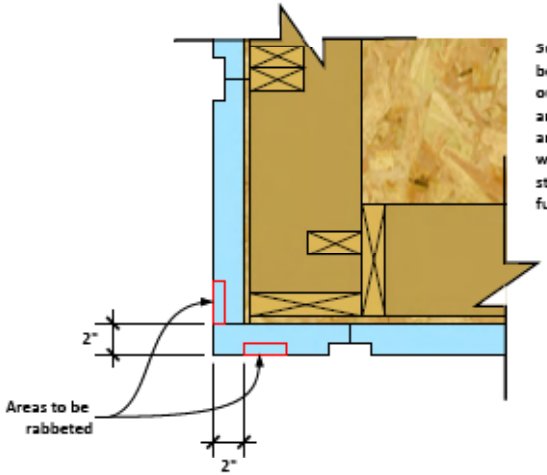
Cut excess off DOW STYROFOAM WALLMATE panels to make the corner.



Step 2 - Install DOW STYROFOAM WALLMATE panels. Start with a WALLMATE panel edge lined up with the center of an exterior-side stud. Fasten with two 8d 3" screws with 1 3/4" dia. Gridmate washers. Continue installing panels moving towards a corner (1). Then continue installing panels away from the starting corner (2).



When installing WALLMATE on an outside corner follow steps 3-6. If installing WALLMATE on an inside corner skip to steps 7-9.



Step 4 - Once the corner pieces have been trimmed to the right size, mark out the areas to be rabbetted. These areas should be 2" from the corner and 2 5/8" wide and 3/4" deep. This will allow for proper attachment to studs as well as use the same size furring strips.

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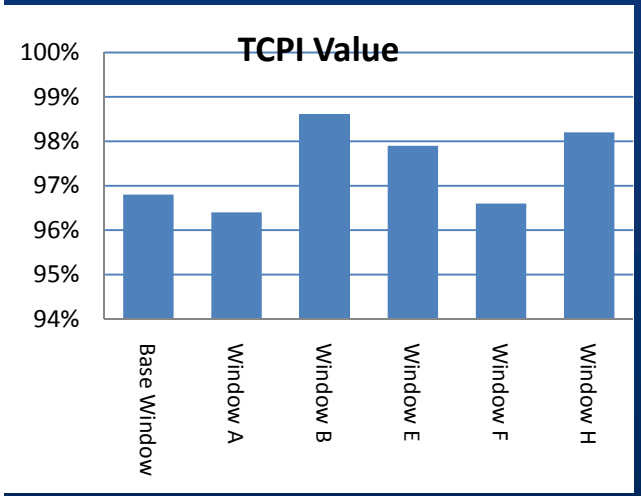
Windows Challenges: TRNSYS Energy Use and Comfort Results

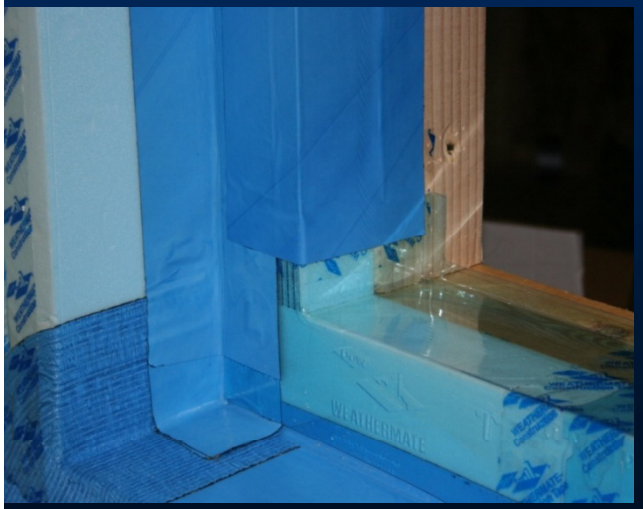


- Narrowed down available options to five high performance windows
- Modeling determined best windows for energy efficiency and comfort control:
  - Triple-glazed unit with suspended film, krypton and air gas fill, fiberglass frame, U=0.19, SHGC=0.22, VT=0.40
  - Closely followed by triple-glazed, krypton gas fill, two low emissivity coatings, fiberglass-reinforced vinyl frame, VT=0.36, but lower material cost
- Homeowner acceptance of low visual transmittance window is a visual concern in cold climate; should be close to 0.50

Windows Challenges: TRNSYS Energy Use and Comfort Results

- Window with low U-value, SHGC=0.47: TRNSYS showed that overheating/discomfort will result mainly during shoulder seasons; highest discomfort values of all windows
- Chose window with U=0.25, SHGC=0.27, VT=0.44; triple glazed with two low E coatings and argon fill, vinyl frame:
  - Scored highest for constructability with continuous nailing fin and integral J-channel, features important for production building not seen in other windows; 4th out 5th best energy savings; higher visual transmittance

Windows Challenges: Constructability

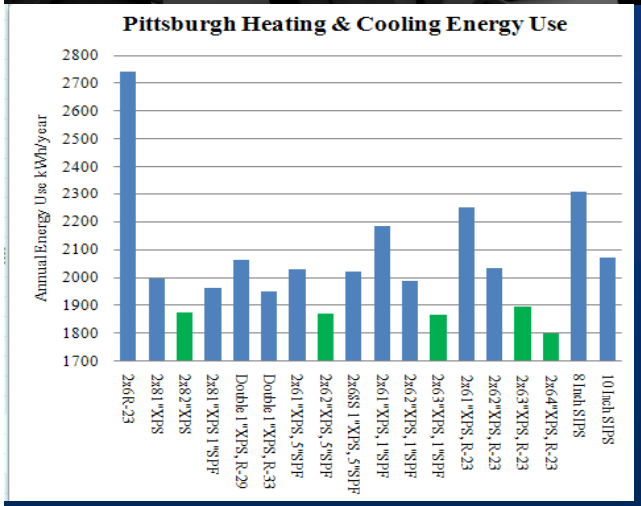


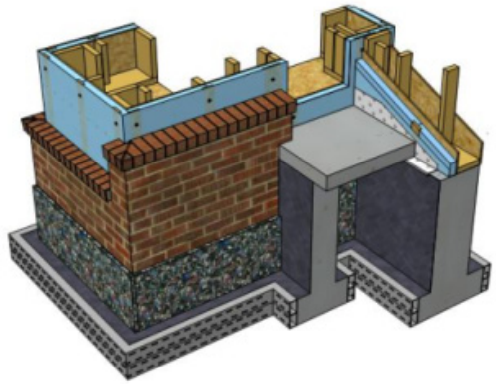
- Mockup used to gauge thick wall window/door placement strategies
- Flashing details for exterior mounted window similar to typical sheathing situation (eg OSB or thin XPS) were preferred; windows screwed to furring strips & framing beneath
- Recessing windows made flashing and insulation details onerous, especially since exterior jamb requires insulating sheathing too

Exterior Doors Challenges

- Polyurethane insulated fiberglass door balances high insulation and durability, while maintaining a traditional wood appearance
- Found that jamb and threshold extensions up to 9” available
- Best approach for installing the door was to position it toward the exterior and install a modified plastic flashing pan underneath the threshold to manage water penetration and drainage

Summary





- Thermal enclosure design challenges overcome by focusing evaluation on:
  - Determining a system's energy use and comfort implications through very accurate modeling
  - Thoroughly assessing CONSTRUCTABILITY and durability of systems with builder, stakeholders by using precise mock-ups and details
- Selected systems showed that net zero energy production houses can be built durably with existing products and new strategies
- Constructability characteristics of a system can rate as highly as its energy efficiency
- Net Zero Energy houses by production builder require highly constructible energy efficient systems

Thermal Enclosure Specification Summary

- R-10 sub-slab insulation provides energy efficiency and constructability benefits
- Poured concrete foundation wall was designed for high constructability while providing durability and energy efficiency
- Staggered stud 2x8 wall with R-10 insulating sheathing and blown-in fiberglass cavity wall insulation; it scored highly for energy efficiency, cost effectiveness, and constructability, although it did not score the highest in any of these criteria
- Selected window with a U-value of 0.25, SHGC of 0.27; most ready for production housing out of the high performance windows studied while still being acceptable to homeowners
- Polyurethane insulated fiberglass door balances high insulation and durability

Questions?

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Thank You

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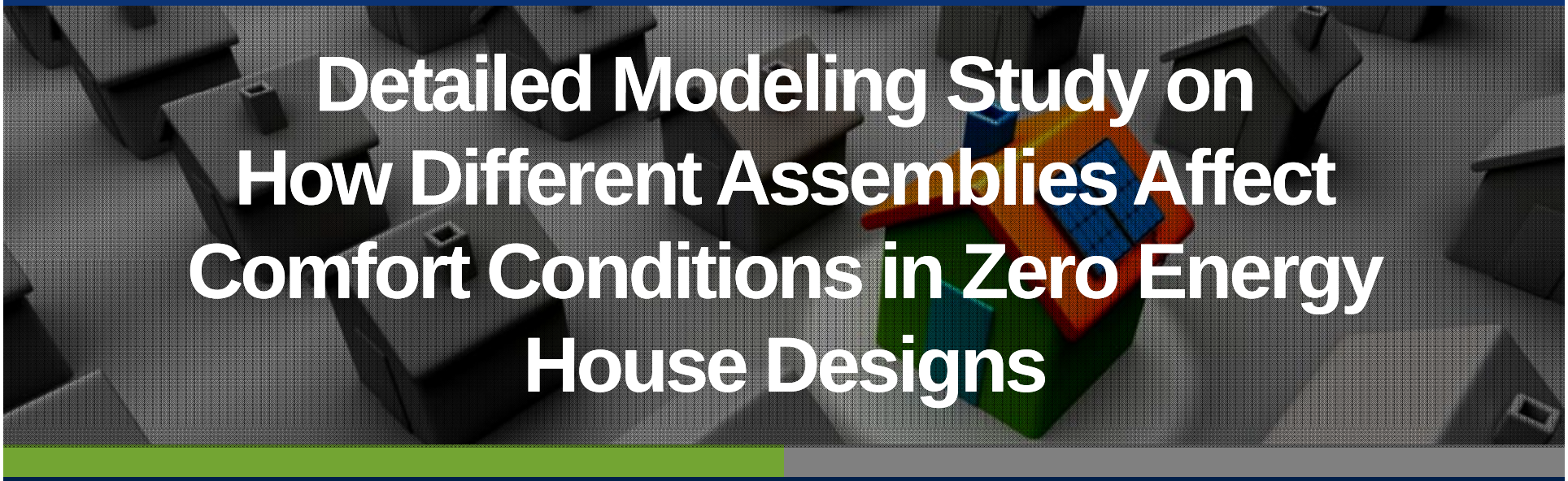

Detailed Modeling Study on How Different Assemblies Affect Comfort Conditions in Zero Energy House Designs

John Broniek
Senior Building Performance Specialist
IBACOS
December 7, 2010

Scope of Research

- Conduct very detailed modeling to determine the comfort implications of using different high performance exterior wall and window assemblies
- Use house designs at zero/net zero energy level of construction located in cold, mixed-humid, and hot-dry climate zones
- Detailed modeling provided information obtained on interior temperature and humidity conditions, which was used to produce comfort indices for each room and determine space conditioning energy usage

Cold Climate Super Energy Efficient Home Built by Production Builder

- Models based on house of 2,160 ft^2 floor area, 3 bedrooms, fully conditioned, partially finished basement
- Built to HERS Index of 26 or 81% whole house energy savings per Building America Benchmark Definition
- Expensive to upgrade to this level, so it better be comfortable!

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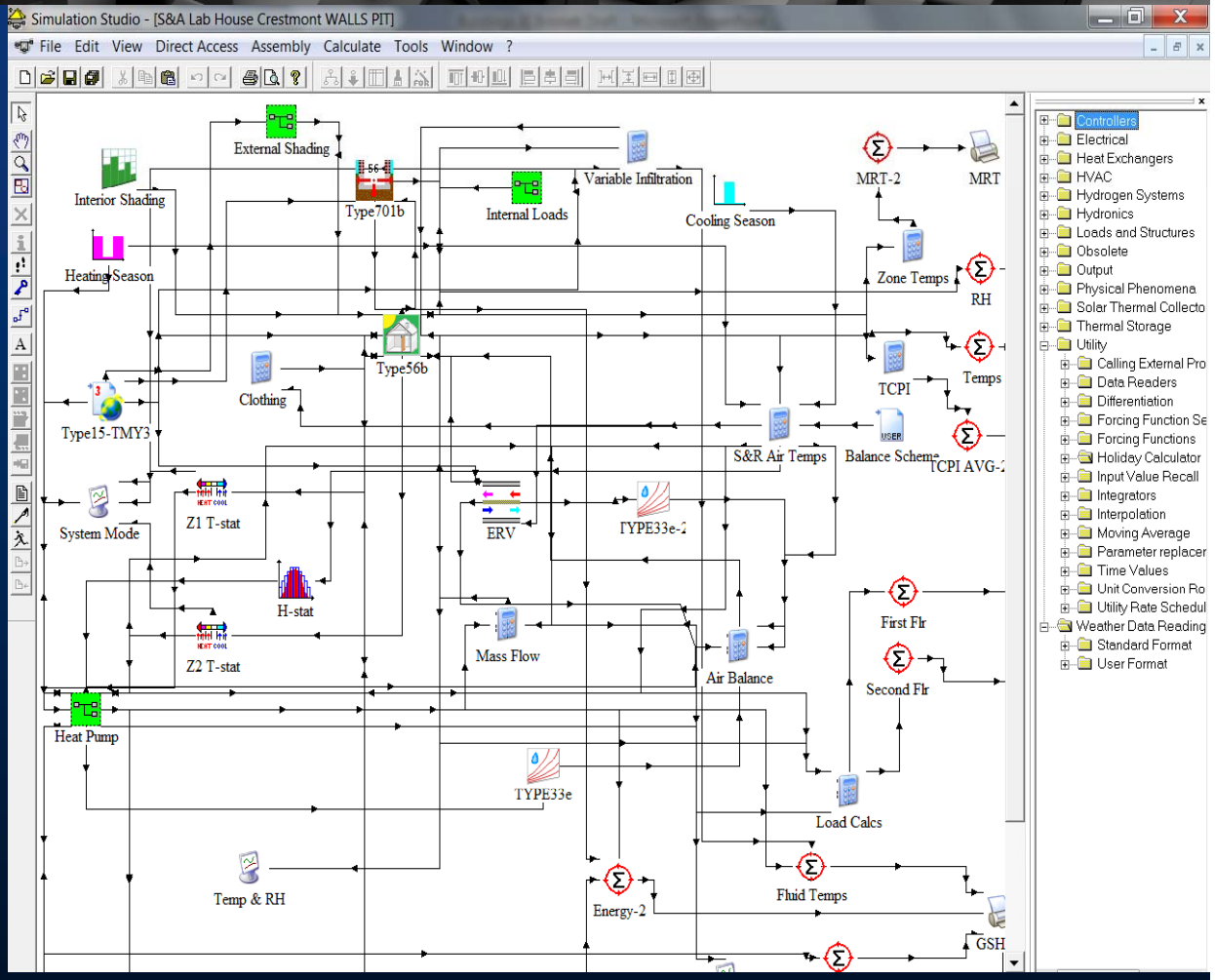
Specification Used in Modeling Follows House Built

- R-60 attic
- R-26 basement foundation
- R-10 under slab
- Air infiltration 0.00003 SLA (0.6 ACH50)
- High Efficiency GSHP with desuperheater for domestic hot water production
- Ductwork within conditioned space, 0% leakage to outdoors
- Energy recovery ventilation system
- 100% high efficacy lighting
- All ENERGY STAR® top tier appliances

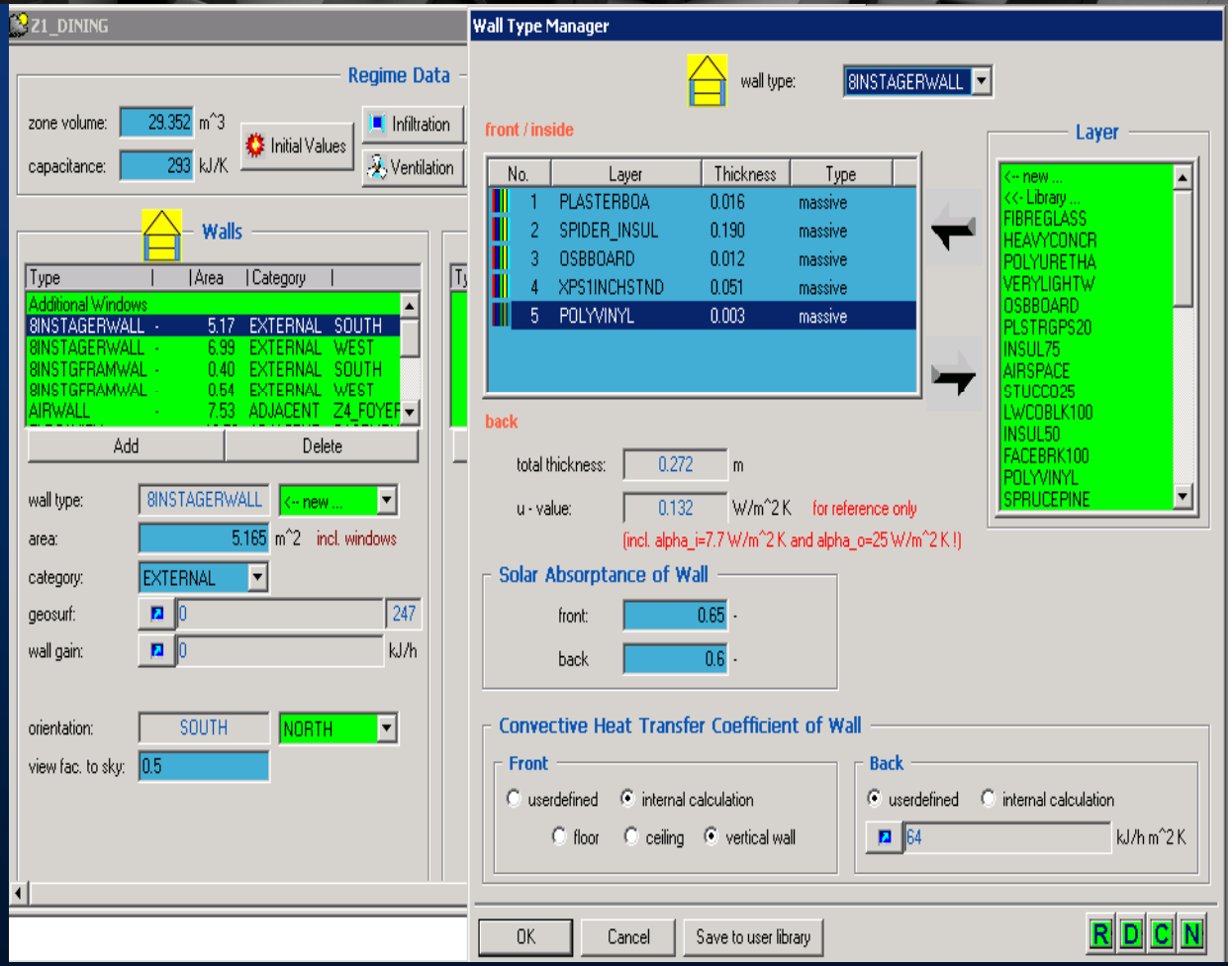
TRNSYS Transient Modeling Tool

- Model has 9 key living spaces, & garage, attic, basement zones
- Used six-minute time steps to best reflect operating conditions
- Schedules for occupancy & internal loads
- Obtained zonal temperature & humidity information



Several Layers of Data Contribute to How TRNSYS Handles Walls

- Each wall is divided into common material sections (framing and insulation)
- Thermal bridging well defined
- Each wall system section is made of layers of material components with info on their density, thermal capacitance, and conductivity



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Best Practices Research Alliance

Building America U.S. Department of Energy

Detailed Data File is Core of How TRNSYS Handles Windows

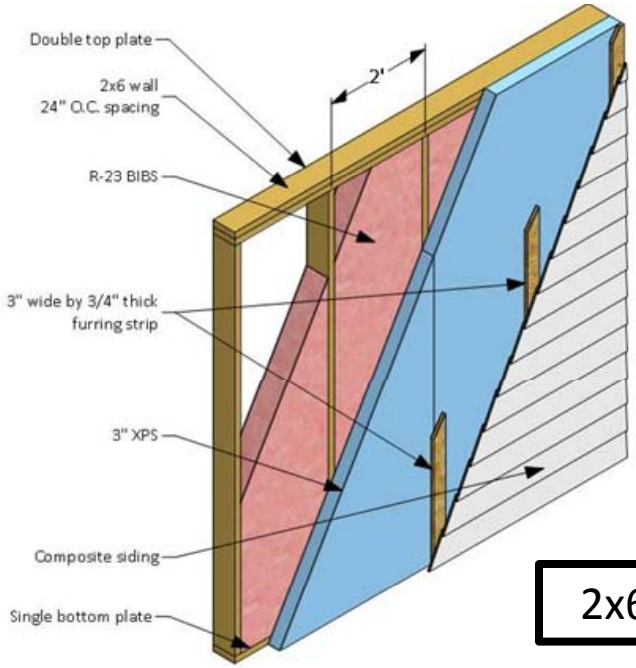
- Window manufacturers provided LBL WINDOW 5.2 data file that provides very detailed information on the glazing performance characteristics
- Add details on glazing spacer, framing material, percentage of framing determined for each window size

Gorell CW DOE-2 - Notepad

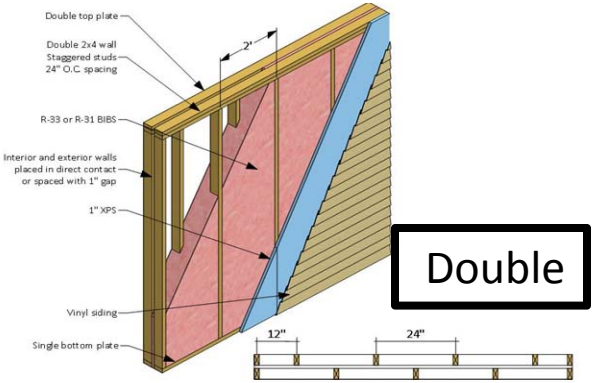
File Edit Format View Help

```
Window 5.2a  v5.2.17a  DOE-2 Data File : Multi Band Calculation

Unit System : SI
Name        : DOE-2 WINDOW LIB
Desc        : Gorell generic
Window ID   : 16
Tilt        : 90.0
Glazings    : 3
Frame       : 105 Gorell average gener  1.596
Spacer      :  0 Class1              -91229998193783603000.000 -91229998193783603000.000 -91229998193783603000.000
Total Height: 1500.0 mm
Total Width :  600.0 mm
Glass Height: 1319.0 mm
Glass Width :  419.0 mm
Mullion     : None
Gap         Thick    Cond  dCond    Vis   dVis   Dens   dDens      Pr     dPr
1 Argon (95   6.6 0.01670   5.270  2.083  6.381  1.757 -0.0062   0.673 -0.0001
2 Argon (95   6.6 0.01670   5.270  2.083  6.381  1.757 -0.0062   0.673 -0.0001
3               0       0       0      0      0      0       0       0       0
4               0       0       0      0      0      0       0       0       0
5               0       0       0      0      0      0       0       0       0
Angle     0    10    20    30    40    50    60    70    80    90 Hemis
Tsol  0.244 0.246 0.240 0.232 0.222 0.204 0.166 0.103 0.036 0.000 0.188
Abs1  0.283 0.285 0.292 0.296 0.297 0.299 0.309 0.313 0.253 0.001 0.294
Abs2  0.095 0.096 0.099 0.101 0.101 0.101 0.103 0.098 0.066 0.000 0.098
Abs3  0.009 0.010 0.009 0.009 0.010 0.009 0.009 0.006 0.004 0.000 0.009
Abs4      0     0     0     0     0     0     0     0     0     0     0
Abs5      0     0     0     0     0     0     0     0     0     0     0
Abs6      0     0     0     0     0     0     0     0     0     0     0
Rfsol 0.369 0.362 0.360 0.362 0.371 0.387 0.414 0.480 0.642 0.999 0.402
Rbsol 0.395 0.389 0.385 0.384 0.389 0.401 0.432 0.508 0.666 1.000 0.422
Tvis  0.581 0.588 0.572 0.554 0.530 0.487 0.395 0.243 0.084 0.000 0.450
Rfvis 0.133 0.121 0.116 0.119 0.134 0.161 0.206 0.304 0.526 0.999 0.186
Rbvis 0.153 0.143 0.140 0.146 0.164 0.199 0.269 0.417 0.674 1.000 0.236
SHGC  0.310 0.314 0.309 0.302 0.292 0.274 0.237 0.170 0.083 0.000 0.256
SC: 0.23



Layer ID#          5281     5281     5009        0        0        0
Tir               0.000    0.000    0.000        0        0        0
Emis F            0.840    0.840    0.840        0        0        0
Emis B            0.035    0.035    0.840        0        0        0
Thickness(mm)       3.3      3.3      3.3        0        0        0
Cond(W/m2-K     )305.3    305.3    305.2        0        0        0
Spectral File SB60 Clear-3 SB60 Clear-3  CLEAR_3.PPG          None          None          None

Overall and Center of Glass Ig U-values (W/m2-K)
Outdoor Temperature                -17.8 C      15.6 C      26.7 C      37.8 C
Solar      WdSpd  hcout hrout  hin
(W/m2)     (m/s)     (W/m2-K)
   0        0.00   4.00  3.27  6.73  0.96 0.96  1.01 1.01  1.04 1.04  1.07 1.07
```

Fifteen High Performance Wall Systems Studied (R-28 to R-43)



2x6



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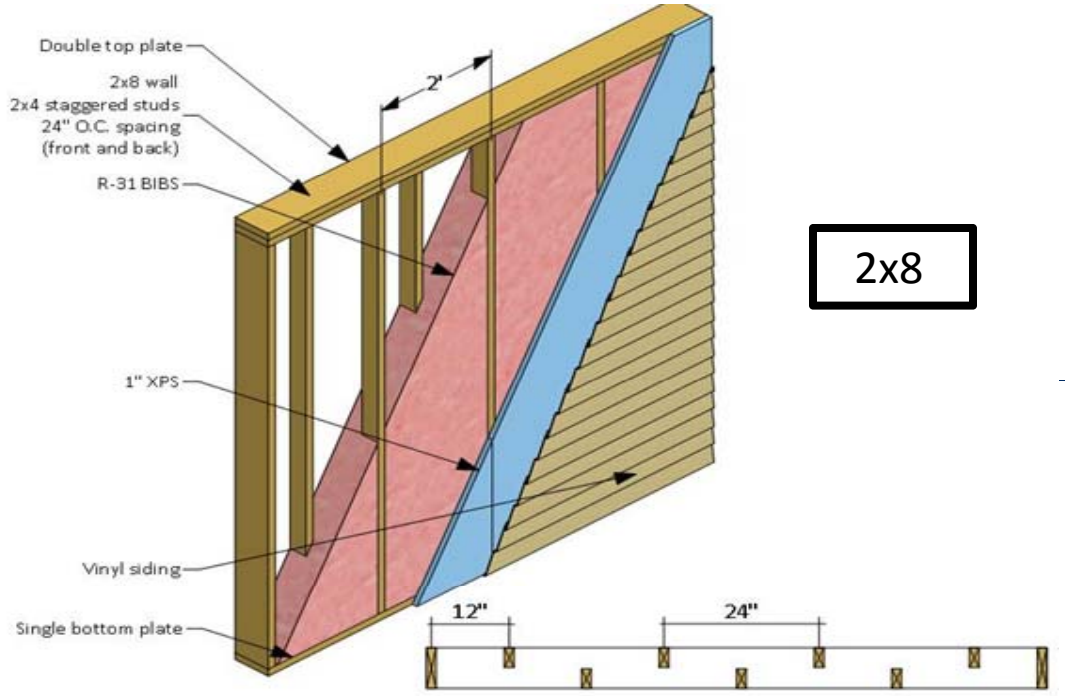

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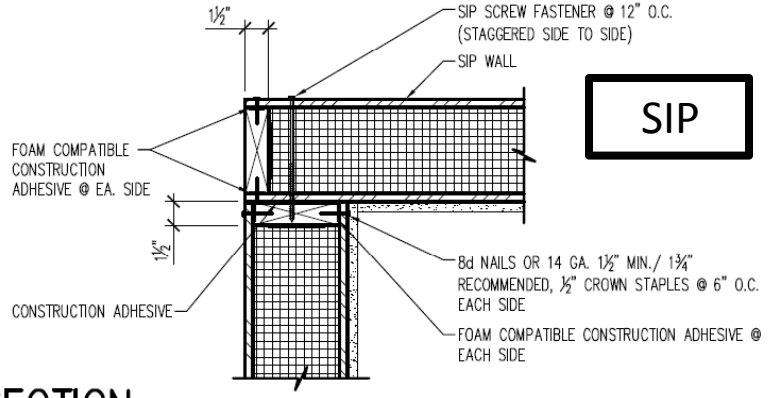


SIP

SECTION

Base Wall = R-20

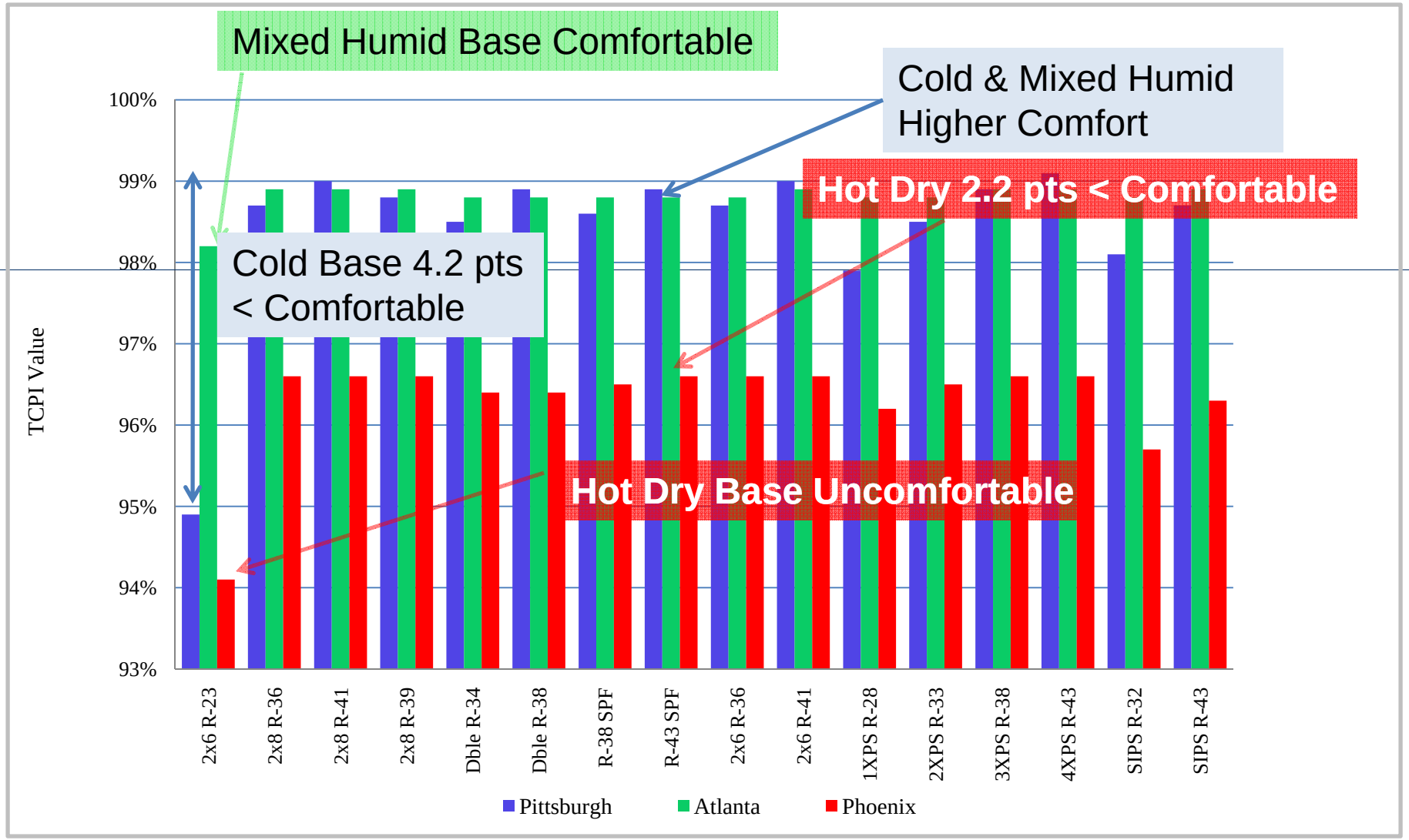
Five High Performance Window Systems Studied

	Total Unit U-Value	Total Unit SHGC
Base Window	0.30 BTU/hr·°F·ft2 (1.7 W/m²·K)	0.34
Window A	0.22 BTU/hr·°F·ft² (1.2 W/m²·K)	0.33
Window B	0.19 BTU/hr·°F·ft² (1.1 W/m²·K)	0.22
Window C	0.17 BTU/hr·°F·ft² (1.0 W/m²·K)	0.16
Window D	0.21 BTU/hr·°F·ft² (1.2 W/m²·K)	0.47
Window E	0.25 BTU/hr·°F·ft² (1.4 W/m²·K)	0.27

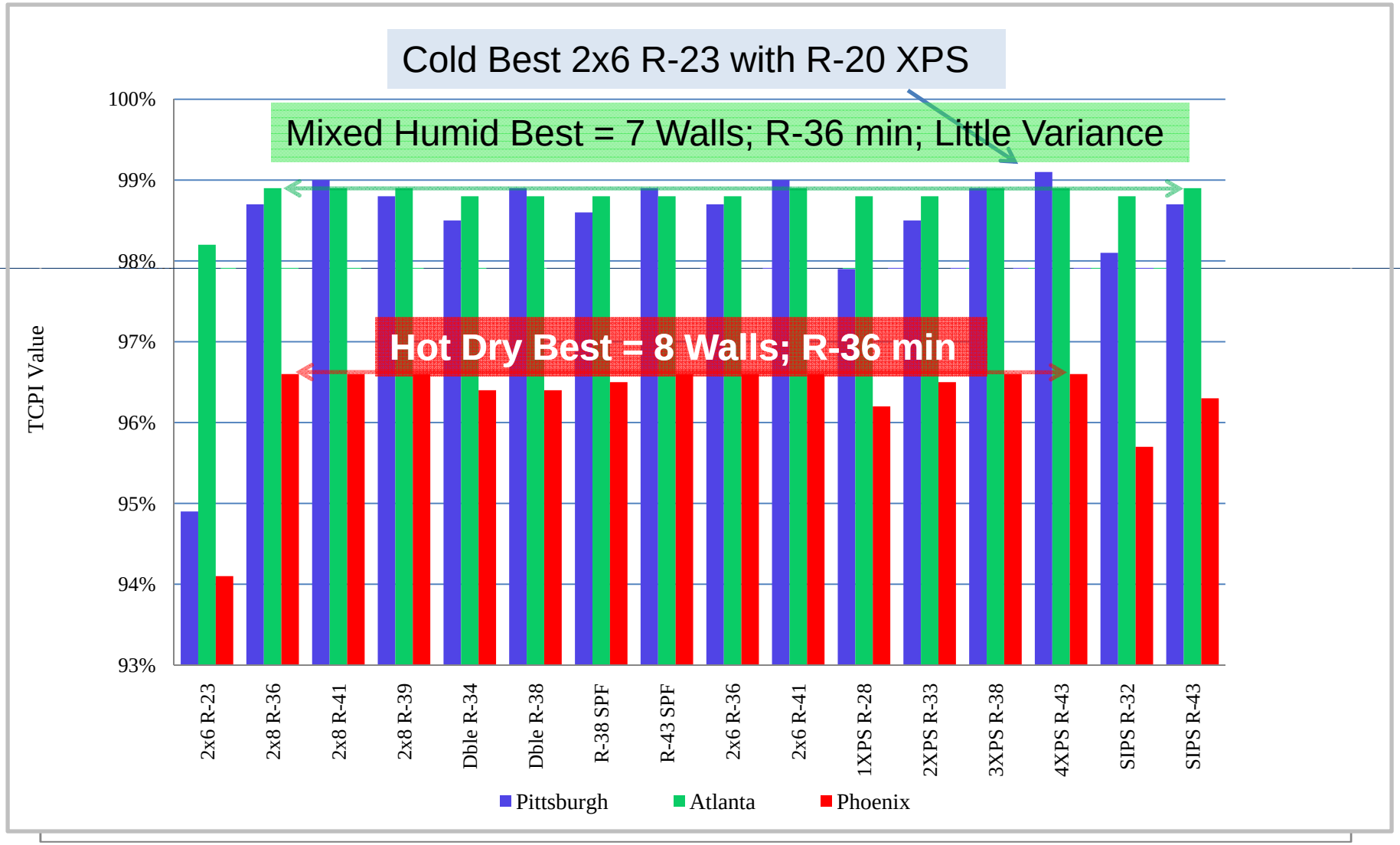
Quantifying Comfort in TRNSYS

- Thermal Comfort Performance Index (TCPI) parameter developed by IBACOS (Rittelmann 2008)
- TCPI compares the predicted mean vote (PMV) against predetermined neutral comfort criteria according to ASHRAE Standard 55 (ASHRAE 2004) at each simulation time step
- The TCPI value is calculated by dividing the number of values that meet the criteria by the total number of values calculated
- A value of 100% represents perfectly acceptable comfort
- Date specific comfort can be estimated

RESULTS - High Performance Wall
Annual TCPI Values for Each Location



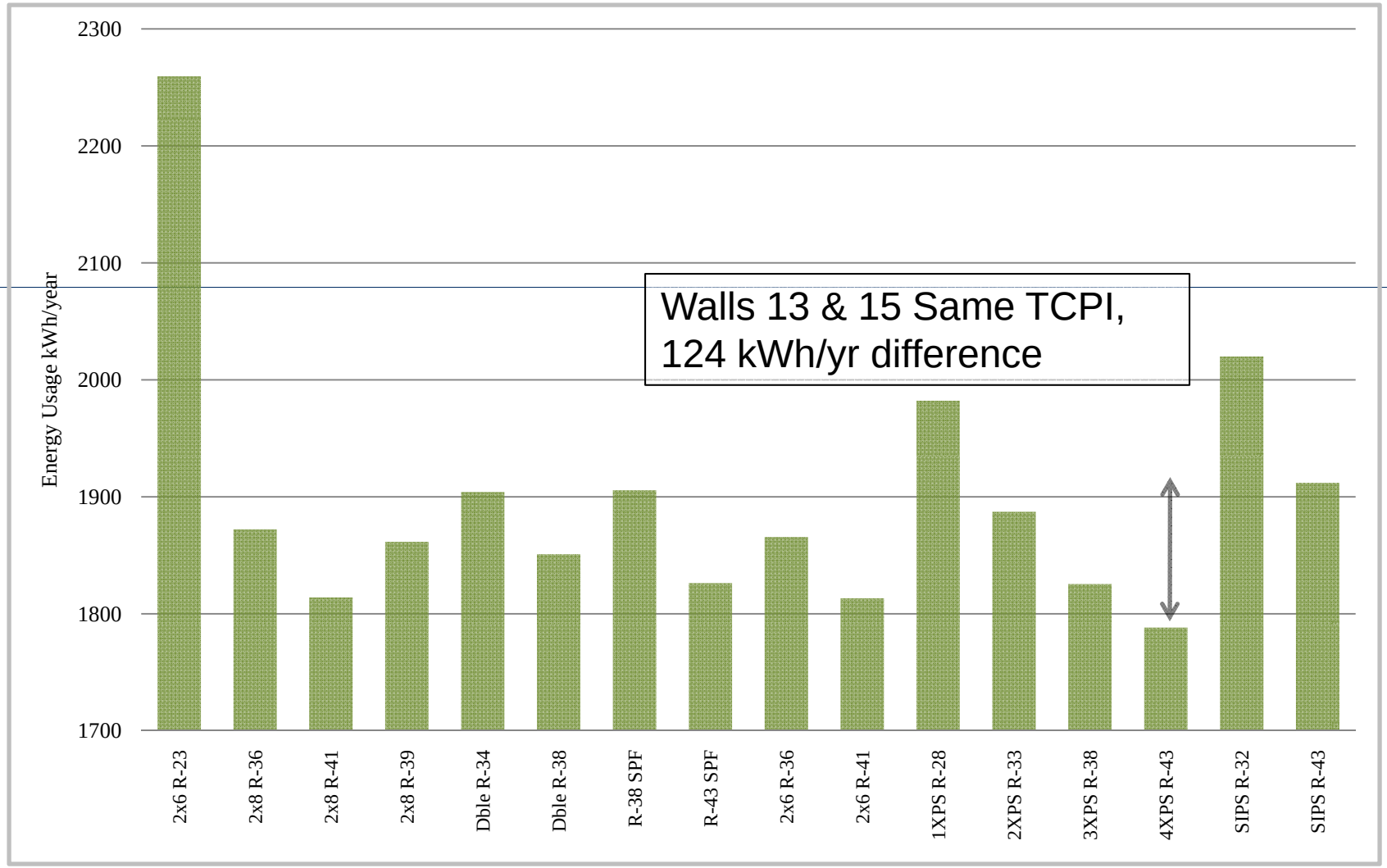
RESULTS - Wall Specific



Observations on High Performance Wall Modeling

- Across all of the climate zones, three wall types equally exhibited the best comfort conditions in their house designs. Each wall system had a minimum of 2” (51 mm) of exterior insulating sheathing, a minimum of 2x6 wood insulated framing, and a nominal thermal performance of at least R-41 (7.2 $m^2 \cdot K/W$)
- More comfort benefits come from upgrading to higher performance wall construction from standard construction (base wall) in a cold climate zone than in mixed-humid and hot-dry locations
- In the hot-dry location, TCPI values were lower largely due to low comfort index values occurring during November that resulted from elevated temperatures in south-facing second-floor rooms

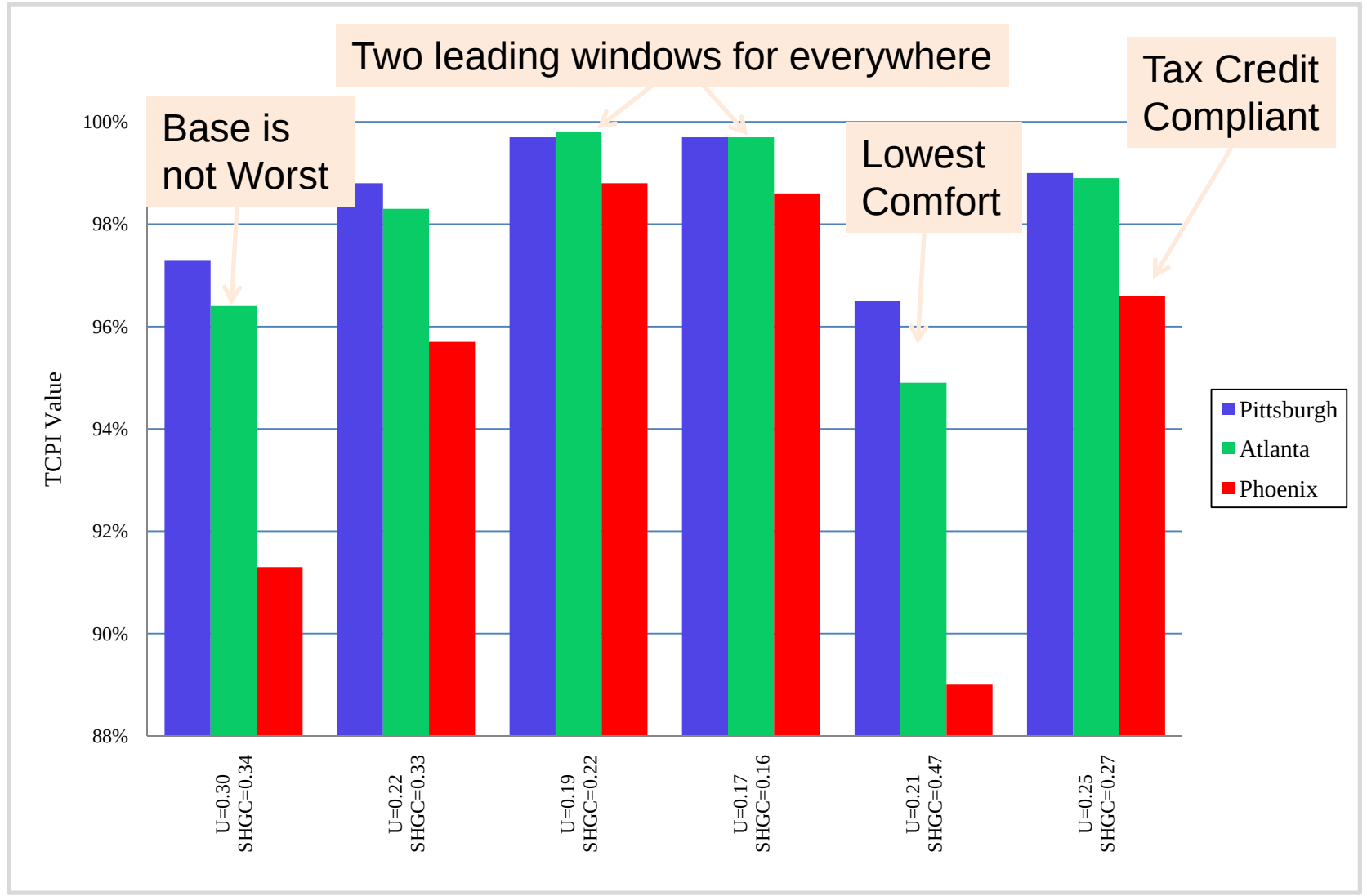
Mixed-Humid High Performance Wall Energy Usage



Observations on High Performance Wall Modeling

- In the mixed-humid location, the heating and cooling energy usage varied as much as 7% between wall systems with the same TCPI
- Walls with insulating sheathing resulted in less space conditioning energy usage
- In the cold and hot-dry locations the walls with the highest TCPI values also exhibited the least amount of heating and cooling energy usage

High Performance Windows TCPI Values for Each Location



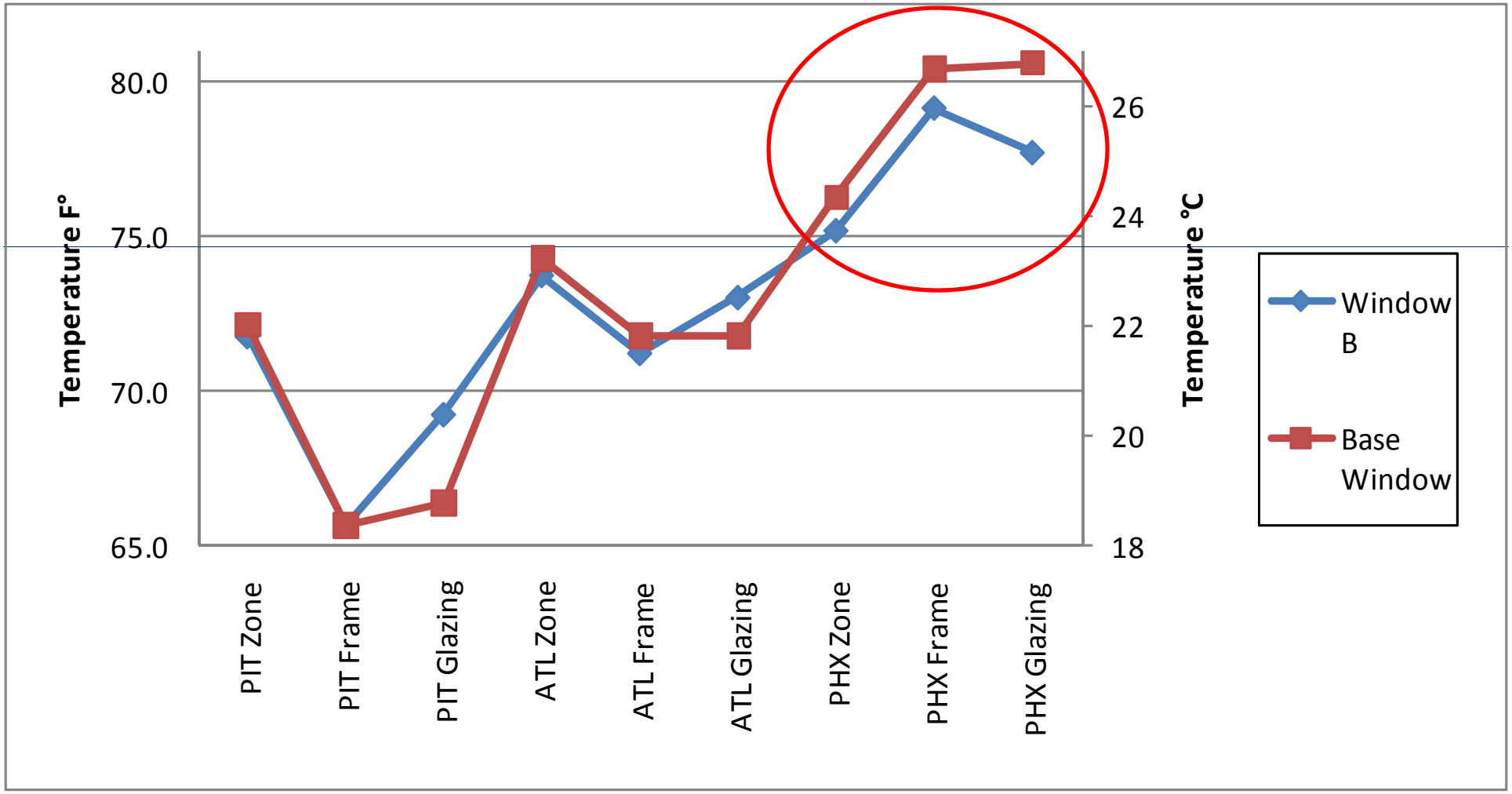
Observations on High Performance Window Modeling

- The window that provided the best comfort across all study locations was the unit with triple-glazing, krypton and air gas fill, a low conductivity fiberglass frame, a U-value of 0.19 BTU/hr·°F·ft^2 (3.5 kJ/hr·m^2·K) and SHGC of 0.22
- Close second best window has a U-value of 0.17 BTU/hr·°F·ft^2 (3.5 kJ/hr·m^2·K) and SHGC of 0.16
- All of the window house designs had lower comfort values in Phoenix. Even the window designs with excellent SHGC values were not able to prevent discomfort from occurring in south-facing bedrooms in Phoenix, suggesting the value of using shading devices, preferably exterior and permanent, to control solar heat gain.

Observations on High Performance Window Modeling

- A window with a low U-value is important in a cold climate, but if it has a high SHGC (such as 0.47), TRNSYS modeling shows that overheating and decreased comfort occurred during the shoulder seasons, thereby lowering overall comfort for the house design.
- Solar heat gain control in windows should not be disregarded in a cold climate location.

Key Seasonal Window Temperature Values Can Be Produced



Summary

- Detailed modeling estimates that walls with R-10 insulating sheathing and R-41 total nominal thermal performance will have best comfort & energy usage in all locations
- Detailed modeling estimates that low U-value (>0.19), low SHGC (>0.22) windows proved best in all locations for comfort & energy usage
- Date specific and localized (ie room) comfort conditions can be determined
- Detailed modeling can quantify comfort conditions, which can be used to sway design decisions particularly in low energy use houses

Questions?

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Thank You

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