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REPORT

GTI PROJECT NUMBER: 20144/20543

Energy efficient Community Development in California: Chula Vista Research Project

Report Issued:

June 2009

Prepared For:

Tom George, NETL Project Manager
National Energy Technology Laboratory (NETL)
Prime Contract No. DE-FC26-04NT42106 with NETL

Gas Technology Institute
1700 S. Mount Prospect Rd.
Des Plaines, Illinois 60018
www.gastechnology.org

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Executive Summary

In 2007, the U.S. Department of Energy joined the California Energy Commission in funding a project to begin to examine the technical, economic and institutional (policy and regulatory) aspects of energy-efficient community development. That research project was known as the Chula Vista Research Project for the host California community that co-sponsored the initiative.

The researches proved that the strategic integration of the selected and economically viable buildings energy efficiency (EE) measures, photovoltaics (PV), distributed generation (DG), and district cooling can produce significant reductions in aggregate energy consumption, peak demand and emissions, compared to the developer/builder's proposed baseline approach. However, the central power plant emission reductions achieved through use of the EE-DG option would increase local air emissions. The electric and natural gas utility infrastructure impacts associated with the use of the EE and EE-PV options were deemed relatively insignificant while use of the EE-DG option would result in a significant reduction of necessary electric distribution facilities to serve a large-scale development project.

The results of the Chula Vista project are detailed in three separate documents;

- "Energy-Efficient Community Development in California; Chula Vista Research Project" report contains a detailed description of the research effort and findings. This includes the methodologies, and tools used and the analysis of the efficiency, economic and emissions impacts of alternative energy technology and community design options for two development sites. Research topics covered included:
    - Energy supply, demand, and control technologies and related strategies for structures;
    - Application of locally available renewable energy resources including solar thermal and PV technology and on-site power generation with heat recovery;
    - Integration of local energy resources into district energy systems and existing energy utility networks;
    - Alternative land-use design and development options and their impact on energy efficiency and urban runoff, emissions and the heat island effect;
    - Alternative transportation and mobility options and their impact on local emissions.

- "Creating Energy-Efficient Communities in California: A Reference Guide to Barriers, Solutions and Resources" report provides the results of an effort to identify the most innovative existing and emerging public policy, incentive and market mechanisms that encourage investment in advanced energy technologies and enabling community design options in the State of California and the nation. The report evaluates each of these mechanisms in light of the preceding research and concludes with a set of recommended mechanisms designed for consideration by relevant California State agencies, development and finance industry associations, and municipal governments.

- "Creating Energy-Efficient Communities in California: A Technical Reference Guide to Building and Site Design" report contains a set of selected commercially viable energy technology and community design options for high-efficiency, low-impact community development in California. It includes a summary of the research findings referenced above and recommendations for energy technology applications and energy-efficient development strategies for residential, commercial and institutional structures and supporting municipal infrastructure for planned communities. The document also identifies design options, technology applications and development strategies that are applicable to urban infill projects.

Glossary

Btu	British Thermal Unit
BPB	Builder's Proposed Baseline
CCHP	Combined Cooling Heat and Power technology
CEC	California Energy Commission
CO2	Carbon Dioxide
CVRP	Chula Vista Research Project
DG	Distributed Generation technologies
DR	Demand Response
EE	Energy Efficiency Measure
EE-PV	Energy-Efficiency and Photovoltaic technology option
EE-DG	Energy-Efficiency and Distributed Generation technology option
GHG	Greenhouse Gas emissions
GTI	Gas Technology Institute
HVAC	Heating, Ventilation and Air Conditioning equipment
IC	Internal Combustion Engine
kWh	Kilowatt hours
LEED	Leadership in Energy and Environmental Design
NOx	Nitrogen Oxides
RE	Renewable Energy
ROI	Return-On-Investment
SDG&E	San Diego Gas and Electric
SDSU	San Diego State University
SOx	Sulfur Oxide
SPV	Solar Photovoltaic
STH	Solar Thermal
T-24	California's Title-24 building energy efficiency standard, 2005
TDV	Time Dependent Valuation
TDVI	Time Dependent Valuation Inclusive
TES	Thermal Energy Storage
UHI	Urban Heat Island effect
USDOE	US Department of Energy
USEPA	US Environmental Protection Agency
VMT	Vehicle Miles Traveled

Background

Within the next 25 years, the United States will design, construct, and remodel more than half of all structures in this country. This equates to 213 billion square feet of built space, half of it in new homes, which have yet to be designed and constructed. This presents an unprecedented opportunity to design and build our homes, offices, public facilities and whole communities to a new level of energy and resource efficiency. Although technologies exist that can improve the energy efficiency of individual buildings and processes, little research has been conducted on how to optimize the efficiency of these technologies in relation to one another or in the aggregate, to achieve community-scale energy efficiency. Further, little or no research has sought to determine how to maximize the performance of energy efficiency, demand response, renewable energy, and distributed energy technologies and strategies through energy-efficient community planning, design and development.

City Integration – Chula Vista research project objective was to design and develop a comprehensive model for efficient energy networks for two new communities being planned in the City of Chula Vista, California. The two new communities will be located on 1,500 acres of land within a larger 6,000 acre parcel known as the Otay Ranch, which will eventually house 70,000 residents. The new communities are to be built on the larger parcel and will accommodate 27,389 residents in 10,306 dwelling units. The City anticipated that this research project will directly influence the energy infrastructure, development patterns and the building design adopted for these communities and that they will be applied to all future development in Chula Vista. The primary intent of the project was to develop transferable resources that California communities can use to exceed the State's energy goals and standards. These resources produced through technical and economic research were designed to achieve the following objectives:

- Generate energy technology and enabling community design options that can optimize energy efficiency, reduce peak energy demand and improve grid utilization,
- Utilize sensitivity analysis to estimate the energy and economic efficiency of alternative energy technologies that can be used by CEC to determine future research priorities,
- Estimate the impact of the optimal mix of energy efficiency, renewable energy, combined-heat-and-power and demand response technologies on greenhouse gas emissions,
- Develop technology integration and implementation strategies that will contribute toward meeting the State's Renewable Portfolio Standard requirements and exceed Title-24'05 building energy efficiency standards by the maximum amount acceptable to the market,
- Explore financial and business models and associated public policies and incentives that will lead to accelerated deployment of energy efficiency, renewable energy, and distributed resources throughout California.

Approach and Deliverables

The City Integration – Chula Vista research project is relatively unique in its focus on community-scale energy efficiency and in its involvement of public and private development professionals in the formulation of energy technology and community design options that are acceptable in today's marketplace. This is a particularly important aspect of the research for the private development community that must meet the Title-24'05 building energy efficiency standards and maintain reasonable profit margins on products that remain attractive to consumers. Collaboration between municipal planning and development officials and private developers, builders and real estate brokers will ensure that these options are economically feasible and have potential for market penetration.

The new communities that will serve as models for this research are located on the Otay Ranch parcel in the City of Chula Vista, California. Although the communities will be built on greenfield sites, most of the analyzed alternatives will apply to urban brownfield, greyfield and infill development sites elsewhere in the City and the State.

The methodology employed in the study entailed detailed computer modeling and an examination of the energy consumption, costs and environmental impacts of both a conventional approach and a set of alternative approaches to the design of the buildings for the site. Specifically, the study modeled building envelope energy loses and internal energy loads for occupants and all fixtures, appliances and equipment, including space conditioning and ventilation systems.

The conventional approach, referred to in this report as the "Builder Proposed Baseline", was defined as one in which the construction materials, lighting and operating equipment for each building structure are designed to meet the California Title-24, 2005 energy efficiency standard or to exceed it if specified as such in the builder's provided structure-specific building plans.

The alternative energy efficiency approaches evaluated were;

- "EE Package" design approach incorporating advanced energy efficiency measures including alternative grades of wall and roof insulation, windows, doors, lighting, HVAC equipment including thermal storage, appliances, and implementation of solar thermal technology,
- "EE Package with PV" design approach supplements EE Package with the solar PV-based power generation and,
- "EE Package with DG" design approach which supplements EE Package with the fossil fuel (natural gas) microturbine or IC-engine-based power generation with heat recovery in CHP configuration.

The research project was designed to produce three deliverables that will: advance technical understanding of energy-efficient community development in California; recommend public policy, incentive and market mechanisms to support this form of development; and generate a resource to guide public and private developers in the development of more sustainable communities. The three deliverables include:

1. Project Report (see **Appendix A** to this report "Energy-Efficient Community Development in California; Chula Vista Research Project")

   The report contains a detailed description of the research effort and findings. This includes the methodologies, and tools used and the analysis of the efficiency, economic and emissions impacts of alternative energy technology and community design options for the Site-A and Site-B development sites. Research topics covered include:

- Energy supply, demand, and control technologies and related strategies for structures;
- Application of locally available renewable energy resources including solar thermal and PV technology and on-site power generation with heat recovery;
- Integration of district energy/cooling system and existing energy utility networks;
- Alternative land-use design and development options and their impact on energy efficiency and urban runoff, emissions and the heat island effect;
- Alternative transportation and mobility options and their impact on local emissions.

2. Report on Public Policy, Incentive & Market Mechanisms (see **Appendix B** to this report "Creating Energy-Efficient Communities in California: A Reference Guide to Barriers, Solutions and Resources"

   The report provides the results of an effort to identify the most innovative existing and emerging public policy, incentive and market mechanisms that encourage investment in advanced energy technologies and enabling community design options in the State of California and the nation. The report evaluates each of these mechanisms in light of the preceding research and conclude with a set of recommended mechanisms designed for consideration by relevant California State agencies, development and finance industry associations, and municipal governments.

3. Reference Guide for Development Professionals (see **Appendix C** to this report "Creating Energy-Efficient Communities in California: A Technical Reference Guide to Building and Site Design"

   The document contains a set of selected commercially viable energy technology and community design options for high-efficiency, low-impact community development in California. It includes a summary of the research findings referenced above and recommendations for energy technology applications and energy-efficient development strategies for residential, commercial and institutional structures and supporting municipal infrastructure for planned communities. The document also identifies design options, technology applications and development strategies that are applicable to urban infill projects.

Overview of Research Results

The strategic integration of EE, EE-PV and EE-DG building energy technologies and district cooling produced significant reductions in aggregate energy consumption, peak demand and emissions, compared to the developer/builder's proposed baseline approach. However, the central power plant emission reductions that could be achieved through use of the EE-DG option would increase local emissions. The electric and natural gas utility infrastructure impacts associated with the use of the EE and EE-PV options were deemed relatively insignificant while use of the EE-DG option would result in a significant reduction of necessary electric distribution facilities to serve a large-scale development project.

The details of the EE, EE-PV and EE-DG building energy technologies impacts on the two evaluated Chula Vista development sites are provided below. In addition, where appropriate, direct quotations from the Summary section of Appendix A are reprinted for reader convenience to highlight major findings of the Chula Vista research project. References to the Appendix A sections relevant of the overview of research results summarized in this cover report are provided as well.

Building Technology Research Results - Commercial, Mixed-Use, Residential Site-A

(See Chapter 3.1.1 to 3.1.1.5 of the Appendix A)

The Site-A study examined a new community planned for development in the City of Chula Vista, CA. This new community will consist of 180 buildings with total of 6,600,719 square foot of floor space representing various configurations of 6 basic space-use types; restaurant, retail, hotel, office, library, and residential. Residential floor areas will represent approximately 41% of the total or 2,711,980 square foot.

For modeling purpose all Site-A buildings were represented by 15 distinct prototypical buildings. The prototypes geometry, floor plans as well as other building details were developed in collaboration and approved by the Site-A builder.

The results of the modeling study indicated that the use of the "EE Package" approach could reduce Site-A community annual TDVI based energy consumption (kBtu/sf-year) by 12.1% below what would be expected if the buildings were built per builder specifications. Supplementing "EE Package" with the solar PV-based on-site power generation systems could further reduce the site TDVI to 31.3% below the builder's baseline. Substituting solar PV power generation technology with the natural gas fired DG would result in 33.8% TDVI reduction.

Relative to natural gas, use of the "EE Package" approach would achieve a 16.6% reduction in annual consumption (MMBtu/year). Adding PV technology to EE packages for obvious reasons would not alter the site natural gas consumption. However, using DG technology instead of PV could result in a significant increase of the Site-A natural gas consumption by 106.5% as compared with the baseline.

With regard to electric energy consumption (kWh) and peak demand (kW), implementation of the "EE Package" approach could reduce site annual kWh by 11% and demand by 16.8% below the builder's baseline approach. Supplementing "EE Package" with the PV technology would result in a cumulative reduction of kWh by 34.3% and kW by 29.1%. Alternatively, using DG technology with the "EE Package" would reduce annual kWh by 31.2% which is close to the PV option impact. However, DG could be more effective in controlling electric peak demand and could reduce it by 45.2%.

Given the reduction in energy consumption resulting from the use of the energy-efficient "EE Package" approach, energy-related air emissions would be also significantly reduced. Specifically, Carbon Dioxide (CO2) emissions would be reduced by 11.4%, Sulfur Dioxide (SOx) emissions by 11%, and Nitrogen Oxide (NOx) emissions by 11.6% as compared to the emissions expected from the builder's baseline approach. Similar numbers for the "EE Package with PV" option show reduction of 33% (CO2), 34.3% (SOx), and 32.4% (NOx). The "EE Package with DG" option is not as effective in reducing emissions as the "EE Package with PV", however with the reductions of 21.2% (CO2), 30.9% (SOx), and 15.8% (NOx) it is still better than the "EE Package" alone.

Annual utility costs savings associated with the use of the energy-efficient "EE Package"approach are estimated at 11.3% when compared with the builder's baseline approach. Simple payback for the "EE Package" is estimated to be 5.9 years with ROI of 16.9%. The "EE Package with PV" option utility cost savings are 32.3% with simple payback of 12.4 years and ROI of 8.1%. Implementing "EE Package with DG" would result in annual utility cost savings of 16%, simple payback of 7 years, and ROI of 14.3%

Building Technology Research Results - Residential, Mixed-Use Site-B

(See Chapter 3.1.6 to 3.1.1.10 of the Appendix A)

The Site-B study examined a mixed-use residential/commercial project planned for development in the City of Chula Vista, CA. The project will consist of 4270 residential units with total of 6,776,027 square feet (sf) of living space and 357 retail store/commercial units representing total of 296,259 sf of commercial space. The total number of Site-B buildings structures will be 866.

The results of the modeling study indicated that the use of the "EE Package" approach could reduce Site-B annual TDVI based energy consumption (kBtu/sf-year) by 8.2% below what would be expected if the buildings were built per builder specifications. Supplementing "EE Package" with the solar PV-based on-site power generation could further reduce the site TDVI to 36.4% below the builder's baseline. Substituting PV power generation technology with the microturbine-based DG/CHP generation systems would result in 11.7% reduction which is smaller than the "EE Package with PV" option but still better than the "EE Package" option alone.

Relative to natural gas, use of the "EE Package" approach would achieve a 17.4% reduction in annual gas consumption (MMBtu/year). Adding PV technology to the "EE Package" for obvious reasons would not change the site natural gas consumption. However, implementing gas-fired microturbine-based DG technology in place of PV could increase Site - B natural gas consumption by 94%.

With regard to electric energy consumption (kWh) and peak demand (kW), implementation of the "EE Package" approach would reduce site annual kWh by 5.8% and demand by 8.5% below the builder's baseline approach. Supplementing "EE Package" with the PV technology would result in a cumulative reduction of kWh by 42.6% and kW by 16.2%. Using DG technology with "EE Package" could reduce annual kWh by 30.5% and demand by 13.1%.

Given the reduction in energy consumption resulting from the use of the energy-efficient "EE Package" approach, energy-related air emissions are also significantly reduced. Specifically, Carbon Dioxide (CO2) emissions would be reduced by 7.2%, Sulfur Dioxide (SOx) emissions would be reduced by 5.9%, and Nitrogen Oxide (NOx) emissions would be reduced by 7.8% as compared to the emissions expected from the builder's baseline approach. Similar numbers for the "EE Package with PV" option show reduction of 39.7% (CO2), 42.5% (SOx), and 38.2% (NOx). The "EE Package with DG" option is not as effective in reducing emissions as the "EE Package with PV", however with the reductions of 16.1% (CO_2), 30% (SO_x), and 9% (NO_x) it is still better than the “EE Package” alone.

Annual utility costs savings associated with the use of the energy-efficient “EE Package“ approach are estimated to be 6.8% when compared with the builder’s baseline approach. Simple payback for the “EE Package” is estimated to be 9.8 years with ROI of 10.2%. The “EE Package with PV” option utility costs savings are 27.9%, simple payback is estimated at 14.8 years, and ROI 6.7%. Implementing “EE Package with DG” would result in annual utility cost savings of 19.8%, simple payback of 6.7 years, and ROI of 14.9%

District Cooling Analysis - Commercial, Mixed-Use, Residential Site-A

(See Chapter 3.4 of the Appendix A)

The annual electricity costs would be significantly lower for a district cooling system at Site-A than for the stand-alone alternatives with cooling production at individual buildings. These costs would be especially reduced for the district cooling alternative modeled with thermal energy storage (TES), due to its ability to shift cooling production from high-cost peak times, to lower cost semi-peak and off-peak times. Comparing the performance of the district cooling system to the stand-alone alternative for the Builder Baseline scenario, energy consumption was reduced by 4.11 million kWh and for the EE-PV scenario by 3.05 million kWh. Utilization of TES is particularly helpful in reducing environmental emissions, since chilled water production is shifted to off-peak times when electricity is produced by cleaner and more efficient base-load production facilities, versus peaking facilities.

Land Use Efficiency

(See Chapter 3.5.1 of the Appendix A)

Land Use Efficiency: Modeling results indicate that moderate-density development would reduce land consumption by up to 70% in the case of Site-A and nearly 78% in the case of Site-X. Additionally, the diversity in housing in a moderate-density development results in a per-household energy savings of nearly 50% at Site-A and 20% at Site-X. These savings are produced as a result of smaller housing units, shared walls and heating, air conditioning and ventilation systems.

Stormwater Runoff Mitigation and Carbon Sequestration

(See Chapter 3.5.2 of the Appendix A)

Modeling results indicate that modest increases in tree canopies and decreases in impervious surfaces will produce energy and stormwater facility construction costs savings and emissions reductions for large-scale development sites. Specifically a 10% increase in tree canopy resulted in a 48% increase in stormwater diversion for Site-A and a 64% increase in stormwater diversion for the Site-X. These diversions would save the developers of the two sites $122,300 and $387,440 respectively, in costs associated with the construction of these stormwater pond systems.

Modest increases in tree canopy led to significant storage and sequestration of carbon and other pollutants in both Site-A and the Site-X. The modeling revealed that a 10% increase in tree canopy in Site-A would result in the additional storage of 1,099 tons of CO_2 and the sequestration of 8.56 tons annually, over what could be expected from a business-as-usual development approach to site plantings. In the case of the Site-X, a 10% increase in tree coverage would produce the additional storage of 2,174 tons of CO2 and the sequestration of an additional 16.93 tons per year. Significant tailpipe emission reductions would also be achieved through these modest increases in tree canopies at both development sites.

Urban Heat Island Mitigation

(See Chapter 3.5.3 of the Appendix A)

Modeled application of urban heat island mitigation measures produced a 5-14% in kWh energy savings for residential and commercial structures in both development sites. In the case of Site-A, a 10% increase in vegetation and a 0.09 increase in albedo (reflectance of surfaces) resulted in a temperature decrease ranging from 1.3 degrees F to 2.8 degrees F. For Site-X a 10% increase in vegetation and a 0.11 increase in albedo resulted in a temperature decrease ranging from 1.1 to 2.4 degrees F. These lower temperatures produced annual energy cost savings for Site-A of $903,443 and savings for the Site-X totaling $2,254,377.

Passive Solar Building Orientation

(See Chapter 3.5.4 of the Appendix A)

Researchers determined that an east-west building orientation resulted in energy usage savings of about 2.8% annually for electricity and 2.2% annually for natural gas. These are modest savings, but result merely from changing the direction of the building without any additional design or mechanical features. In the case of electricity, the lower energy use produced a cost savings of 4.1% annually. For natural gas, there was an annual cost savings of 1.8%.

Acceptable Incremental Costs

(See Chapter 3.6.1 of the Appendix A)

The average maximum incremental cost the California building industry will accept for energy-efficient structures is between $1.59 and $7.41 per square foot of construction, depending on the technology enhancement. Given the range calculated for the modeled enhancements in this research project ($2.00 to $15.00 per square foot), the researchers conclude that significant economic incentives will be necessary to encourage their adoption in today's market.

The market surveys and construction industry interviews conducted indicate that developers are the most price-sensitive occupational subgroup in the industry and the most conservative in their estimation of what constitutes acceptable incremental costs. By marked contrast, design professionals were the least price-sensitive among all surveyed subgroups and did find the modeled incremental costs more acceptable. This finding leads the researchers to conclude that specific economic incentives need to be targeted to developers in order to accelerate adoption of energy-efficient technologies by the building industry.

With regard to the cost of integrating all of the modeled technologies and enabling community design features into a large-scale, energy-efficient development projects, the researchers estimate that their inclusion will add approximately 20-30% to the developer's total project costs.

Needed Financial and Business Models and Public Policy Incentives

(See Chapter 3.6.2 of the Appendix A)

The researchers conclude that widespread adoption of these advanced energy technologies and community design features by the development industry will not be realized without a fundamental transformation of the real estate development marketplace. Additionally, this transformation will not take place until at least seven principal economic, informational and procedural barriers to energy-efficient community development are adequately addressed.

The market and policy analysis conducted in the project identified the following barriers that must be addressed to advance this form of development:

1. Need for direct and indirect financial support for developers and builders;
2. Split Incentive Dilemma - a misalignment between investment costs and benefits;
3. Lack of knowledge among municipal officials inhibiting approval of EECD projects;
4. Lack of uniform municipal procedures and related incentives for EECD projects;
5. Lack of municipal investments in enabling green infrastructure;
6. Lack of consumer willingness to pay for the value of energy efficient features;
7. Investment risks that inhibit capital market entities from financing EECD projects.

The researchers conclude that the two essential changes necessary for this transformation to be realized are that:

- The value of energy-efficient building technologies and community design features is recognized by all entities in the real estate development transaction chain (lenders, investors, developers, builders, design professionals, appraisers and brokers); and that
- This recognition results in market transactions that enable developers to capture capital investments in energy-efficient design features through real estate sale prices that are acceptable to consumers.

State and local government- and utility-funded intervention will be necessary to produce these changes over the near-term (5-10 years). This report provides a detailed description of these interventions that include a combination of market push and market pull mechanisms to transform the market to the point where public and utility intervention will no longer be necessary to sustain energy-efficient community development in California.

APPENDIX A

Energy-Efficient Community Development in California; Chula Vista Research Project

This document was prepared by the National Energy Center for Sustainable Communities using research reports and materials developed by the team members of the Chula Vista Research Project. The report contains detailed technical findings that are the results of a research project intended to determine how advanced building energy technologies and land use, transportation and urban design features can be integrated to produce energy-efficient development projects in California. The researchers modeled the application of these technologies and design features on two development sites in Chula Vista, California and assessed their impact on the environment and the existing electric and natural gas utility infrastructure. Additionally, the researchers examined the market and institutional barriers preventing the adoption of this form of development by municipalities and the development industry.

APPENDIX B

Creating Energy-Efficient Communities in California: A Reference Guide to Barriers, Solutions and Resources

This document prepared by the National Energy Center for Sustainable Communities using research reports and materials developed by the team members of the Chula Vista Research Project is intended as a guide to the State, regional and local government agencies as well as the partnering utilities and private development industry to help optimize energy-efficiency at the community scale. It introduces these prospective partners to the existing economic, informational and procedural barriers that currently prevent the adoption of energy-efficient community development projects in California, and to some of the solutions to resolve them. The Reference Guide to Barriers, Solutions and Resources also provides valuable resources they can use to formulate their own initiatives to contribute to the statewide challenge of reducing energy-related global greenhouse gas emissions.

APPENDIX C

Creating Energy-Efficient Communities in California: A Technical Reference Guide to Building and Site Design

This document prepared by the National Energy Center for Sustainable Communities using research reports and materials developed by the team members of the Chula Vista Research Project is intended as a guide to the private development industry as well as the State, regional and local government agencies to help optimize energy-efficiency at a single building and ultimately at a community scale. In the case of the advanced building energy technologies, three alternative development options were modeled for each distinct building prototype on each site. These included the use of: advanced, highly efficient building envelope features, appliances and space conditioning equipment (the EE option); the EE option with the addition of solar photovoltaic panels (the EE-PV option); and the use of the EE option with the addition of distributed generation technologies (the EE-DG option).

The Technical Reference Guide to Building and Site Design summarizes the key findings of the energy technology and community design modeling.

GTI PROJECT NUMBER: 20144/20543

Energy efficient Community Development in California: Chula Vista Research Project

APPENDIX A

Arnold Schwarzenegger
Governor

ENERGY-EFFICIENT COMMUNITY DEVELOPMENT IN CALIFORNIA: CHULA VISTA RESEARCH PROJECT

PIER INTERIM PROJECT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
National Energy Center for Sustainable Communities at San Diego State University

January 2009
CEC-500-06-004

Prepared By:
National Energy Center for Sustainable Communities
at San Diego State University
Project Manager: Doug Newman
Primary Author: Doug Newman
San Diego, California 92182-1934
Commission Contract No. 500-06-004

Prepared For:
Public Interest Energy Research (PIER)
California Energy Commission

Elaine Hebert
Contract Manager

Norm Bourassa
Program Area Lead
Buildings

Vacant
Office Manager
Energy Efficiency

Martha Krebs, Ph.D.
PIER Director

Thom Kelly, Ph.D.
Deputy Director
ENERGY RESEARCH & DEVELOPMENT DIVISION

Melissa Jones
Executive Director

Acknowledgments

The author is grateful to following individuals for their significant contributions to the research project:

- Marek Czachorski – Gas Technology Institute
- Tim Kingston – Gas Technology Institute
- Bryan Kleist – FVB Energy
- Mark Spurr – FVB Energy
- Ken Synder – PlaceMatters
- Jason Lally – PlaceMatters
- Jocelyn Hittle – Place Maters
- Denny Stone – City of Chula Vista, California
- Craig Ruiz – City of Chula Vista, California
- Brad Remp – City of Chula Vista, California
- Larisa Dobriansky – National Energy Center for Sustainable Communities
- Lou Galuppo – Burnham Moores Center for Real Estate, University of San Diego
- Dr. Charles Tu - Burnham Moores Center for Real Estate, University of San Diego
- Meghan Bokath - Burnham Moores Center for Real Estate, University of San Diego
- George Burmeister – Colorado Energy Group
- Dr. Ken Walsh – San Diego State University
- Dr. David Rohy – San Diego State University
- Dr. Alan Sweedler – San Diego State University
- Julie Marini – San Diego State University
- Jim Corlette – San Diego Gas and Electric
- Joe Frani – San Diego Gas and Electric
- Thomas Saunders – San Diego Gas and Electric
- Tom Blessent – Otay Land Company
- Curt Nolan – Otay Land Company
- Todd Galreneau –McMillin Development
- Nick Lee – Corky McMillin Development

Citation

Please cite this report as follows:

Newman, Doug, George Burmeister, Marek Czachorski, Louis Galuppo, Bryan Kleist, , Jason Lally, , Ken Snyder, Dr. Charles Tu, Dr. Ken Walsh. 2009. *Energy-Efficient Community Development in California: The Chula Vista Research Project.*. California Energy Commission, PIER Program. CEC-500-06-004.

Preface

The California Energy Commission's Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program conducts public interest research, development, and demonstration (RD&D) projects to benefit California.

The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grants
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

Energy-Efficient Community Development in California is the interim report for the Chula Vista Research Project, contract number 500-06-004, conducted by the National Energy Center for Sustainable Communities at San Diego State University. The information from this project contributes to PIER's Buildings End-Use Energy Efficiency Program.

For more information about the PIER Program, please visit the Energy Commission's website at www.energy.ca.gov/research/ or contact the Energy Commission at 916-654-4878.

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Abstract and Key Words

This report contains the results of a research project intended to determine how advanced building energy technologies and land use, transportation and urban design features can be integrated to produce energy-efficient development projects in California. The researchers modeled the application of these technologies and design features on two development sites in Chula Vista, California and assessed their impact on the environment and the existing electric and natural gas utility infrastructure. Additionally, the researchers examined the market and institutional barriers preventing the adoption of this form of development by municipalities and the development industry.

The research findings suggest that the integrated use of these technologies and features can reduce aggregate energy consumption and CO_2 emissions of a large-scale development project by as much as 45% and 33% respectively, as compared to a Title-24 compliant project. However, the researchers conclude that a fundamental market transformation will be necessary to achieve these gains and that State agencies and the utilities must take a leadership role in facilitating the transformation. Additional research is also needed to improve modeling tools, further evaluate the carbon reduction potential of various technologies and design features and to resolve economic and policy barriers impeding this form of development in California.

Keywords: Low-carbon communities, energy-efficiency, community-scale development, advanced energy technologies, land use, urban design, transportation, density, mixed-use development, urban heat island effect, stormwater runoff, carbon sequestration, 4D analysis, building energy modeling, Chula Vista, distributed generation, district energy, public policy, development industry, green buildings

Executive Summary

Introduction

Within the next 20-25 years, the United States will design, construct, and remodel more than half of all structures in the country. This equates to 213 billion square feet of built space, half of it in new homes, which have yet to be designed and constructed.[1] This presents an unprecedented opportunity to design and build our homes, offices, public facilities and whole communities to a new level of energy and resource efficiency. Although technologies exist that can improve the energy efficiency of individual buildings and processes, little research has been conducted on how to optimize the efficiency of these technologies in relation to one another or in the aggregate, to achieve community-scale energy efficiency. Further, little or no research has sought to determine how to maximize the performance of energy efficiency, demand response, renewable energy, and distributed energy technologies and strategies through energy-efficient community planning, design and development.

Given the scarcity of engineering research in this area, there has been little social science research conducted to identify potential institutional (legislative and regulatory) and market barriers and solutions associated with energy-efficient community development. Research of this nature will be essential to fully engage the private sector in the investment, design and construction of energy-efficient residential, commercial, industrial, institutional and mixed-use development projects in California.

Purpose

The purpose of the research project was to determine which actions and technologies in the California loading order can be combined with enabling community design options to increase the energy efficiency and air quality of California communities, as well as providing additional environmental benefits.

Project Objectives

The primary objective of the project was to resolve, through research and the development of new knowledge, outstanding technical, market and policy barriers to the creation of more sustainable communities in California. The six supporting research objectives were to: 1) Estimate the relative energy efficiency and emissions reduction performance of individual energy efficiency, demand response , renewable energy, and distributed generation technologies in typical development projects; 2) Determine the extent to which the application of these technologies reduce peak demand and result in better utilization of existing utility infrastructure; 3) Determine the market-feasible combinations of energy technology and design options that will increase building energy efficiency by more than 25% above existing Title-24 2005 standard; 4) Estimate the degree to which enabling community design options (i.e., mixed-

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[1] *Toward A New Metropolis: The Opportunity to Rebuild American*, Arthur C. Nelson, Virginia Polytechnic Institute and State University - A Discussion Paper Prepared for The Brookings Institution Metropolitan Policy Program. December 2004

use/ moderate density/transit-oriented development; stormwater runoff and carbon sequestration measures; urban heat island reduction measures; and passive solar building orientation can improve energy technology performance or reduce energy consumption of a site; 5) Determine the maximum incremental cost that the California building industry and consumers will accept for energy-efficient residential, commercial, industrial and institutional structures; 6) Determine which financial and business models and associated public policies and incentives will lead to accelerated deployment of advanced energy technologies in typical development projects throughout the State of California.

Project Approach

To achieve the project objectives, the application of a number of building energy technologies and urban design features were modeled on two large-scale development sites on the eastern side of Chula Vista, California. The sites are referred to as Site-A, a predominantly commercial mixed-use development on 290-acres of land; and Site-B, a predominantly residential mixed-use development on 418-acres of land. The modeling was designed to estimate the aggregate energy consumption and energy-related emission reductions that resulted from the application of the advanced technologies and features as compared to the developer/builder's proposed baseline (BPB) approach to developing the sites.

In the case of the advanced building energy technologies, three alternative development options were modeled for each building prototype on each site. These included: the *EE* option, use of advanced, highly efficient building envelope features and internal appliances; the *EE-PV* option, use of the EE option with the addition of solar photovoltaic panels; and the *EE-DG* option, use of the EE option with the addition of distributed generation technologies. In addition to building energy technologies, the researchers also examined the technical and economic feasibility of a district cooling system to serve the majority of the cooling loads in Site-A.

In the case of the advanced urban design features, four alternative options were modeled for the two development sites. These included the use of: moderate-density/mixed-use development; stormwater runoff mitigation measures; carbon sequestration measures; and urban heat island mitigation measures. Additionally, passive solar building orientation was also modeled for one of the sites.

Once the incremental costs of the energy technology options were determined, the researchers conducted online surveys with developers, builders and brokers to determine if they were deemed acceptable in today's marketplace. Additionally, the researchers surveyed capital market and development industry practitioners to determine the perceived barriers and risks associated with the use of these technologies and design features in large-scale development projects, and needed financial and business models and public policy incentives that would accelerate their adoption.

Conclusions and Supporting Research Results

Conclusions - Energy Technology Options

The strategic integration of EE, EE-PV and EE-DG building energy technologies and district cooling produced significant reductions in aggregate energy consumption, peak demand and emissions, compared to the developer/builder's proposed baseline approach. However, the central power plant emission reductions achieved through use of the EE-DG option would significantly increase local emissions. The utility infrastructure impacts associated with the use of the EE and EE-PV options were deemed relatively insignificant while use of the EE-DG option would result in a significant reduction of necessary electric distribution facilities to serve a large-scale development project.

Supporting Site-A Research Results

The building energy modeling indicated that use of the EE option would reduce Site-A electrical energy consumption (kWh) by 11 % and peak demand (kW) by ~17%, as compared to the BPB approach. Use of the EE-PV option would reduce consumption by ~34% and peak demand by ~29%. Use of the EE-DG option would reduce consumption by ~31% and peak demand by ~45%. With regard to central power plant emissions reductions, the EE option would reduce CO_2 by ~12%, SO_x by 11% and NO_x by 12.6% as compared to the emissions expected from the BPB approach. Similar numbers for the EE-PV option show reductions of 30.8% in CO_2, 34.2% in SO_x, and 29.3% in NO_x. The EE - DG option is not as effective in reducing emissions as the EE-PV option, however with the reductions of 6.7% in CO_2, 30.3% in SO_x, and 38.5% in NO_x it is still better than the builder's baseline approach.

With regard to natural gas, use of the EE option would achieve a 16.6% reduction in annual consumption (MMBtu/year). Adding PV technology to the EE option would not alter the natural gas consumption at the site. However, using DG technology instead of PV could result in a significant increase in the consumption of natural gas at the site, and specifically by 106.5% as compared with the builder's proposed baseline approach.

Associated annual utility cost savings were 11.3% for the EE options as compared to the BPB approach, with a simple payback of 5.9 years and a return on investment (ROI) of 16.9%. Cost savings for the EE-PV option were 32.3% with a 12.4 year payback and a ROI of 8.1%. Cost savings for the EE-DG option were 16% with a 7 year payback and a ROI of 14.3% (assuming the reinstatement of the 2007 Self Generation Incentive Program).

In terms of the electric utility impact analysis conducted on the three development options, only the EE-DG option would result in a significant reduction in the electric utility distribution system to serve the site (a reduction of 1 circuit and associated substation facilities), and only if sufficient system redundancy was assured. With regard to the natural gas utility system, none of the modeled development options would significantly impact what the utility would design and install for either of the two sites site assuming a conventional approach to development. However, the EE-DG option would entail the addition of a regulator station to accommodate the increased pressures required for the distributed generation units serving the sites.

Site-A District Cooling System Analysis: The researchers found that annual electricity costs would be significantly lower for a district cooling system at Site-A than for the stand-alone alternatives with cooling production at individual buildings. These costs would be especially reduced for the district cooling alternative modeled with thermal energy storage (TES), due to its ability to shift cooling production from high-cost peak times, to lower cost semi-peak and off-peak times.

In addition to cost savings, the reduced consumption of electricity from the grid associated with the district cooling alternative over the stand-alone cooling approach will reduce central power plant greenhouse gases and the emission of priority pollutants. Comparing the performance of the district cooling system to the stand-alone alternative for the Builder Baseline scenario, energy consumption was reduced by 4.11 million kWh and for the EE-PV scenario by 3.05 million kWh. Utilization of TES is particularly helpful in reducing environmental emissions, since chilled water production is shifted to off-peak times when electricity is produced by cleaner and more efficient base-load production facilities, versus peaking facilities.

With regard to annual operating costs, the analysis indicated that the district cooling alternative without TES has a moderate annual operating cost advantage over stand-alone cooling production at individual buildings. Once TES is introduced to the district cooling configuration, the economic advantage of the district cooling alternatives over the stand-alone alternatives is more significant, due to substantially reduced electricity costs and a minor reduction in plant capital costs.

Supporting Site-B Research Results

The building energy modeling indicated that use of the EE option would reduce Site-B electrical energy consumption (kWh) by 5.8% and peak demand (kW) by 8.5%, as compared to the BPB approach. Use of the EE-PV option would reduce consumption by ~42% and peak demand by ~16%. Use of the EE-DG option would reduce demand by 30.5% and peak demand by ~13%. With regard to central power plant emissions reductions, the EE option would reduce CO_2 by ~9%, SO_x by 6% and NO_x by 10.5% as compared to the emissions expected from the BPB approach. Similar numbers for the EE-PV option show reductions of ~35% in CO_2, ~29% in SO_x, and ~49% in NO_x. However, the CO_2 emission of the EE-DG option is 5.2% higher than the builder's baseline approach. This is because the CO_2 emissions of the DG option deployed at Site-B entails a mix of microturbine-based power generation and heat recovery technologies that release more CO_2 than is released during production of an equivalent amount of electricity at a central power plant in California.

With regard to natural gas, use of the EE option would achieve a 17.4% reduction in annual gas consumption (MMBtu/year). Adding PV technology to the EE option, would not change the natural gas consumption at the site. However, implementing gas-fired microturbine-based DG technology in place of PV would increase Site-B natural gas consumption by 94%.

Associated annual utility cost savings were 6.8% for the EE options as compared to the BPB approach, with a simple payback of 9.8 years and a ROI of 10.2%. Cost savings for the EE-PV option were ~30% with a ~15 year payback and a ROI of 6.7%. Cost savings for the EE-DG option were ~20% with a 6.7 year payback and a ROI of 14.9% (assuming the reinstatement of the 2007 Self Generation Incentive Program).

Conclusions - Community Design Options

Mixed-use/moderate density development, stormwater runoff mitigation, carbon sequestration and urban heat island mitigation measures all produce significant reductions in energy consumption and energy-related emissions in large-scale development projects. The mixed-use/moderate density option also facilitates the cost-effective performance of combined cooling heat and power technologies and district cooling systems and significantly reduces vehicular petroleum consumption and emissions and increases land use efficiency.

Supporting Research Results - Mixed-Use/Moderate Density Development

CCHP: The research results showed that mixed-use, moderate-density development did enable the economical performance of distributed generation-CCHP technologies in Site-A and resulted in a 68% reduction in central power plant electricity consumption and associated CO2, Sox and NOx emissions. However, these reductions were produced at the expense of significantly increased local emissions. Specifically, CO2 associated with the use of CCHP would increase by 79%, and NOx would increase by 152% above the emissions expected from a central power plant meeting the same load requirements for a low-density (baseline) development scenario for Site-A. However, use of natural gas-fueled CCHP would result in a 64% reduction in central power plant SOx emissions.

District Cooling: This design option also enabled the economical use of district cooling technologies in Site-A and resulted in a significant reduction of central power plant energy consumption and emissions as noted above. The modeling results indicate that the costs associated with a district cooling system designed to serve a moderate-density, mixed-use development are 181% lower than the costs of a system designed to serve the same load in a conventional low-density development. Additionally, the research findings indicate that the cost of a system to serve a low-density development would be economically prohibitive.

Petroleum Consumption: Mixed-use, moderate-density development significantly reduced vehicle miles traveled (VMT) in both Site-A and the surrogate for Site-B and resulted in a significant reduction of vehicular petroleum consumption and emissions. Specifically, the design option reduced VMT, petroleum consumption and emissions by 12.5% in Site-A and by 15% in the Site-B surrogate. 2

Land Use Efficiency: Modeling results indicate that moderate-density development would reduce land consumption by up to 70% in the case of Site-A and nearly 78% in the case of Site-X. Additionally, the diversity in housing in a moderate-density development results in a per-

[2] The Site-B surrogate was developed as a replacement for the actual development site in the modeling of community design options. The replacement was necessary due to the advanced stage of site planning at Site-B that precluded further consideration of the modeled options. In the body of the report the surrogate is referred to as Site-X.

household energy savings of nearly 50% at Site-A and 20% at Site-X. These savings are produced as a result of smaller housing units, shared walls and heating, air conditioning and ventilation systems.

Supporting Research Results - Stormwater Runoff Mitigation

Modeling results indicate that modest increases in tree canopies and decreases in impervious surfaces will produce energy and stormwater facility construction costs savings and emissions reductions for large-scale development sites. Specifically a 10% increase in tree canopy resulted in a 48% increase in stormwater diversion for Site-A and a 64% increase in stormwater diversion for the Site-X. These diversions would save the developers of the two sites $122,300 and $387,440 respectively, in costs associated with the construction of these stormwater pond systems.

Supporting Research Results - Carbon Sequestration

Modest increases in tree canopy led to significant storage and sequestration of carbon and other pollutants in both Site-A and the Site-X. The modeling revealed that a 10% increase in tree canopy in Site-A would result in the additional storage of 1,099 tons of CO_2 and the sequestration of 8.56 tons annually, over what could be expected from a business-as-usual development approach to site plantings.[3] In the case of the Site-X, a 10% increase in tree coverage would produce the additional storage of 2,174 tons of CO_2 and the sequestration of an additional 16.93 tons per year. Significant tailpipe emission reductions would also be achieved through these modest increases in tree canopies at both development sites.

Supporting Research Results - Urban Heat Island Mitigation

Modeled application of urban heat island mitigation measures produced a 5-14% in kWh energy savings for residential and commercial structures in both development sites. In the case of Site-A, a 10% increase in vegetation and a 0.09 increase in albedo (reflectance of surfaces) resulted in a temperature decrease ranging from 1.3 degrees F to 2.8 degrees F. For Site-X a 10% increase in vegetation and a 0.11 increase in albedo resulted in a temperature decrease ranging from 1.1 to 2.4 degrees F. These lower temperatures produced annual energy cost savings for Site-A of $903,443 and savings for the Site-X totaling $2,254,377.

Supporting Research Results - Passive Solar Building Orientation

Researchers determined that an east-west building orientation resulted in energy usage savings of about 2.8% annually for electricity and 2.2% annually for natural gas. These are modest savings, but result merely from changing the direction of the building without any additional design or mechanical features. In the case of electricity, the lower energy use produced a cost savings of 4.1% annually. For natural gas, there was an annual cost savings of 1.8%.

[3] Storage refers to the amount of carbon stored in the biomass of trees on planting. Sequestration refers to the additional amount of carbon stored every year the trees grow.

Conclusion – Incremental Costs

The average maximum incremental cost the California building industry will accept for energy-efficient structures is between $1.59 and $7.41 per square foot of construction, depending on the technology enhancement. Given the range calculated for the modeled enhancements in this research project ($2.00 to $15.00 per square foot), the researchers conclude that significant economic incentives will be necessary to encourage their adoption in today's market.

Supporting Research Results - Incremental Costs

The market surveys and construction industry interviews conducted indicate that developers are the most price-sensitive occupational subgroup in the industry and the most conservative in their estimation of what constitutes acceptable incremental costs. By marked contrast, design professionals were the least price-sensitive among all surveyed subgroups and did find the modeled incremental costs more acceptable. This finding leads the researchers to conclude that specific economic incentives need to be targeted to developers in order to accelerate adoption of energy-efficient technologies by the building industry.

With regard to the cost of integrating all of the modeled technologies and enabling community design features into a large-scale, energy-efficient development projects, the researchers estimate that their inclusion will add approximately 20-30% to the developer's total project costs.

Conclusions – Needed Financial and Business Models and Public Policy Incentives:

The researchers conclude that widespread adoption of these advanced energy technologies and community design features by the development industry will not be realized without a fundamental transformation of the real estate development marketplace. Additionally, this transformation will not take place until at least seven principal economic, informational and procedural barriers to energy-efficient community development are adequately addressed.

Supporting Research Results - Models and Public Policy Incentives

The market and policy analysis conducted in the project identified the following barriers that must be addressed to advance this form of development:

1. Need for direct and indirect financial support for developers and builders;
2. *Split Incentive Dilemma* - a misalignment between investment costs and benefits;
3. Lack of knowledge among municipal officials inhibiting approval of EECD[4] projects;
4. Lack of uniform municipal procedures and related incentives for EECD projects;
5. Lack of municipal investments in enabling green infrastructure;
6. Lack of consumer willingness to pay for the value of energy efficient features;

[4] EECD – Energy Efficient Community Development

7. Investment risks that inhibit capital market entities from financing EECD projects.

The researchers conclude that the two essential changes necessary for this transformation to be realized are that:

- The value of energy-efficient building technologies and community design features is recognized by all entities in the real estate development transaction chain (lenders, investors, developers, builders, design professionals, appraisers and brokers); and that
- This recognition results in market transactions that enable developers to capture capital investments in energy-efficient design features through real estate sale prices that are acceptable to consumers.

State and local government- and utility-funded intervention will be necessary to produce these changes over the near-term (5-10 years). This report provides a detailed description of these interventions that include a combination of *market push* and *market pull* mechanisms to transform the market to the point where public and utility intervention will no longer be necessary to sustain energy-efficient community development in California.

Recommendations

The authors view this research as merely a limited first-step toward a better understanding of the potential that energy-efficient community development has to assist the State in meeting its near-, mid- and long-term energy efficiency and emissions reductions goals. Additional research is recommended to conduct a more sophisticated examination of this potential in the coming years. Specifically, the researchers recommend a comprehensive assessment of the energy-efficiency and emissions reduction potential of all available land use, infrastructure, transportation and urban design features and a more thorough examination of their impact on the performance of building and infrastructure energy technologies.

Second a comprehensive, state-wide examination of the same potential for district energy systems in California. Third, the translation of this research into a set of improved modeling tools, methods and site development guidelines to help guide local communities and their private development industry partners in advancing energy-efficient development projects in the state. Finally, the researchers recommend a comprehensive review of relevant State, regional and local public policies to ascertain where policy innovations are needed to facilitate this form of development throughout California.

Benefits to California

The results of this research project, and those expected from the proposed research will produce benefits for California's electricity and natural gas rate payers by enabling public and private development practitioners to significantly contribute toward the improvement of community-scale energy efficiency, affordability and reliability. These contributions will also significantly decrease both local and global environmental impacts associated with end-use energy and resource consumption.

This report has provides specific quantification of the energy and emission reduction gains that can be achieved by even the most sophisticated/smart growth-oriented development projects as modeled in this research. The proposed research would move beyond this work and chart a feasible pathway to even more substantial gains, potentially reducing aggregate energy consumption of large-scale, mixed-use, residential, commercial and institutional development sites (500-2,000+ acre) by as much as 50% and CO_2 emissions by 50% or more. Additional benefits for California from this practical research will include further peak demand reduction, increases in system reliability, and enhanced consumer comfort, convenience and affordability.

Chapter 1. Introduction

1.1 Background and Overview

Opportunity Statement - Within the next 20-25 years, the United States will design, construct, and remodel more than half of all structures in the country. This equates to 213 billion square feet of built space, half of it in new homes, which have yet to be designed and constructed.[5] This presents an unprecedented opportunity to design and build our homes, offices, public facilities and whole communities to a new level of energy and resource efficiency. Although technologies exist that can improve the energy efficiency of individual buildings and processes, little research has been conducted on how to optimize the efficiency of these technologies in relation to one another or in the aggregate, to achieve community-scale energy efficiency. Further, little or no research has sought to determine how to maximize the performance of energy efficiency, demand response, renewable energy, and distributed energy technologies and strategies through energy-efficient community planning, design and development.

Given the scarcity of engineering research in this area, there has been little social science research conducted to identify potential institutional (legislative and regulatory) and market barriers and solutions associated with energy-efficient community development. Research of this nature will be essential to fully engage the private sector in the investment, design and construction of energy-efficient residential, commercial, industrial, institutional and mixed-use development projects in California.

Historically, California has been one of the leading states promoting energy efficiency and resource conservation, and has now become the lead state in the emerging national effort to reduce greenhouse gas emissions and global warming. The California Energy Action Plan, the Integrated Energy Policy Report of 2007, the "Global Warming Solutions Act of 2006 (AB 32) and Executive Order S-3-05 all contain strategies and goals that will continue to move the state forward in each of these key areas of sustainable energy management. However if the State is to reach the ambitious goals contained in these documents, it must determine how to optimize energy-efficient community development. It must also engage the private sector, and in particular the development industry, in the pursuit of this supporting objective.

Research Goal - The goal of the research project was to determine which actions and technologies in the California loading order[6] can be combined with enabling community design

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[5] *Toward A New Metropolis: The Opportunity to Rebuild American*, Arthur C. Nelson, Virginia Polytechnic Institute and State University - A Discussion Paper Prepared for The Brookings Institution Metropolitan Policy Program. December 2004

[6] The California Energy Action Plan, adopted in 2003 by the California Energy Commission, the Public Utilities Commission, and the Consumer Power and Conservation Financing Authority, envisioned a "loading order" of energy resources to guide decisions made by these same agencies. This loading order is as follows:

1. optimize all strategies for increasing conservation & energy efficiency to minimize increases in electricity & natural gas demand;
2. meet generation needs first by renewable energy resources & distributed generation;
3. support additional clean, fossil fuel, central-station generation.

options to increase the energy efficiency and air quality of California communities, as well as providing additional environmental benefits.

1.2 Project Objectives

The primary objective of the project was to resolve, through research and the development of new knowledge, outstanding technical, market and policy barriers to the creation of more sustainable communities in California.

The 6 supporting research objectives were to:

1. Estimate the relative energy efficiency and emissions reduction performance of individual energy efficiency (EE), demand response (DR), renewable energy (RE) and distributed generation (DG) technologies (advanced energy technologies) in typical development projects (residential, commercial, industrial, institutional);
2. Determine the extent to which the application of these technologies, in typical development projects, will reduce peak demand and result in better utilization of existing utility infrastructure;
3. Determine the market-feasible combinations of energy technology and design options that will increase building energy efficiency by more than 25% above existing Title-24 2005 standards;
4. Estimate the degree to which enabling community design options (i.e., mixed-use/ moderate density/transit-oriented development; stormwater runoff and carbon sequestration measures; urban heat island reduction measures; and passive solar building orientation) can improve energy technology performance in typical development projects;
5. Determine the maximum incremental cost that the California building industry and consumers will accept for energy-efficient residential, commercial, industrial and institutional structures;
6. Determine which financial and business models and associated public policies and incentives will lead to accelerated deployment of EE, DR, RE and DG technologies in typical development projects throughout the State of California.

Chapter 2. Project Methods

2.1 Summary

This chapter describes in detail the methods, tasks and assumptions employed to address the project research objectives. The research team assembled for the project included energy technology and urban design modelers, construction process engineers and municipal planners and building officials, real estate market analysts and developers.

To explore the potential economic and environmental costs and benefits of alternative energy technology and community design options in large-scale development projects, two planned development sites located in the City of Chula Vista were selected as the primary case studies (Sites-A and –B). An additional hypothetical site (Site-X), was generated from the building and land use attributes of the two sites, to enable the examination of certain community design options that could not be considered in the sites given that certain spatial elements had become fixed in their development plans.

Detailed building engineering modeling was then conducted on the two primary sites to compare the energy efficiency and emissions reduction performance of the technology alternatives to the performance expected from a set of conventional building features for the sites. Next, the modeling results were examined to determine the impact of the use of these alternatives on the building construction processes and to identify additional costs associated with process altercations. The modeling results were also examined by the electric and gas utility to determine the extent to which use of these alternatives could reduce peak demand and result in better utilization of the existing utility infrastructure. Similarly, planning and design modeling was conducted to quantify the comparative performance benefits of a set of alternative development options for the sites.

With regard to the social science research objectives, a series of workshops were held with real estate development experts, public officials and utility representatives to identify solutions to barriers that prevent the use of energy-efficient development alternatives/options in California. Online surveys of the development and capital market industries were also conducted to examine the market's sensitivity to costs associated with this form of development and to deepen the researchers' understanding of the associated investment risks. Additional telephone interviews were conducted with developers and building industry leaders to enable researchers to ask follow-up questions on the workshop and survey results and to solicit input from the industry on what they need most to engage this form of development.

Figure-1 provides a schematic depiction of the specific research focus areas and the approximate sequence of the analysis.

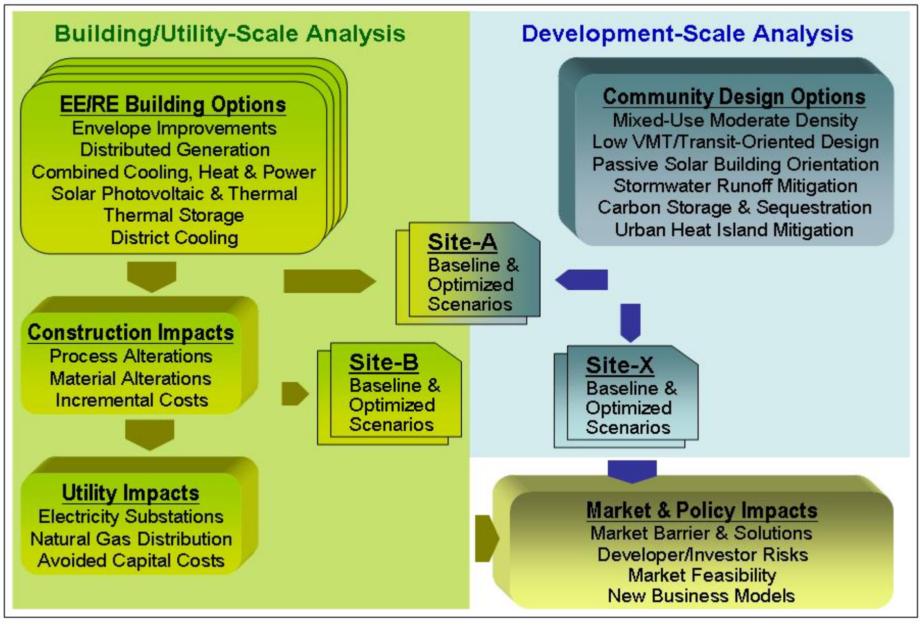

Figure 1. Schematic of the Research Focus & Sequence

2.2 Case Study Sites

The two planned community development projects selected as case studies for this research are located on a 6,000-acre parcel of land known as the Otay Ranch, in Chula Vista, California. The projects are the next to be built on this greenfield parcel that will accommodate 27,389 residents in 10,306 dwelling units upon completion in 2015. The sites were selected to represent two of the development types common to California communities. Figure-2 is an aerial photograph of the development sites (circled).

Figure 2. Otay Ranch Development Site

The first site is referred to as *Site-A* in this report and consists of a 290-acre mixed-use commercial development. The site will contain 180 commercial, residential and mixed-use residential/ commercial structures with various configurations of six space-use types: restaurant, retail, hotel, office, library, and residential. Considered together, there will be a total of 6,600,719 square feet (s.f.) of new development in Site-A, with residential applications representing approximately 41% of the total (2,711,980 s.f.).

The second site is referred to as *Site-B* and consists of a 418-acre mixed-use residential and institutional development. The site will contain 866 residential and mixed-use residential/commercial structures with 4,270 living units for a total of 6,776,027 s.f. of living space, and 357 retail store/commercial units for a total of 296,259 s.f. of commercial space.

As stated in the methods summary, the hypothetical development site generated for this research is referred to as *Site-X* and is designated as a 418-acre mixed-use residential and institutional development quite similar to Site-B but incorporating several building prototypes from Site-A as well. Again, this hypothetical site allowed the researcher to examine the energy and emissions performance of the full suite of community design options that could not be modeled in either of the actual development sites.

2.3 Modeling Tools

Six building and district energy technology and urban design modeling tools were used in the research. These included:

- Building Energy Analyzer™ (BEA), - a proprietary product of the Gas Technology Institute (GTI);
- Energy-10™ - a proprietary product of the Sustainable Building Industry Council (SBIC);
- City Green™ - a proprietary product of the American Forests organization;
- Mitigation Impact Screening Tool (MIST) – a product of the U.S. Environmental Protection Agency;
- CommunityViz™ - a proprietary product of the Orton Family Foundation; and
- TERMIS – a proprietary product of 7-Technologies.

BEA was used to model energy, economic and environmental parameters for 15 types of commercial, institutional and commercial-residential mixed-use structures. Energy-10™ was used to model 5 types of single and multi-family residential buildings. City Green was used to model alternative landscape design elements and to support evaluation of the urban heat island effect. MIST was used to assess the impact of increasing urban albedo (reflectance) and/or urban vegetation in reducing the urban heat island effect.

CommunityViz was used to model potable water and wastewater treatment infrastructure, urban runoff, alternative land-use configurations and transportation infrastructure, patterns and strategies. CommunityViz was also used to co-register and synthesize data inputs from the other software tools and to produce 360-degree visualizations and real-time impact simulations for stakeholder meetings in which alternative design options were evaluated.

Modeling of transportation infrastructure, patterns, and strategies for energy consumption and emission impacts entailed estimating average daily vehicle-miles traveled (VMT) using both quantitative factors such as housing density and road patterns, and qualitative factors such as the probability that residents will choose alternative modes of transportation. Based on the estimated VMT, potential savings in energy consumption and air emissions were then calculated using generally accepted averages.

Termis is a hydraulic modeling tool used for the design and analysis of district energy systems.

2.4 Building Energy Technology Modeling

This modeling task entailed analyzing and selecting an optimal mix of energy-efficient building materials and advanced energy technologies for building prototypes representative of the building stock planned for Site-A and Site-B. The criteria used to make these selections were maximum energy savings and a realistic and acceptable payback on investment.[7]

<u>Modeling Assumptions & Prototypes</u> - The research team initiated this task by compiling a building design, construction and equipment *Technical Assumptions Manual* for each site that was used to guide the modeling work (Appendix A and B).

The manuals provide details on building envelope geometry, construction materials, and HVAC equipment specifications for all the prototypical structures similar to those planned for each site. The manuals also provide specific details on the specific modeling approach used and itemize the Title-24, 2005 mandatory and prescriptive features for the modeled buildings as well as all evaluated alternative energy-efficient (EE) building materials and equipment, and their installed costs.

The economic assumptions necessary to calculate EE measure paybacks, such as local utility rate structures and applicable rebates (e.g.: PV system rebates), are provided in these manuals. The Technical Assumption Manuals were reviewed and approved by the developers of each site and by municipal officials prior to their use to ensure that a realistic set of “real world” assumptions were used as the basis for the building modeling.

Site-A was the first of the two sites analyzed. As noted above, the site will contain 180 commercial, residential and mixed-use residential/commercial structures with various configurations of six space-use types. Considered together, there will be a total of 6,600,719 s.f. in Site-A, with residential applications representing approximately 41% of the total or 2,711,980 s.f.

Fifteen prototypical buildings were modeled for the site which are described in detail in the Site-A Technical Assumptions Manual and listed below in Table-1. Figure-3. provides the location for the prototypes on the developer’s site utilization plan.

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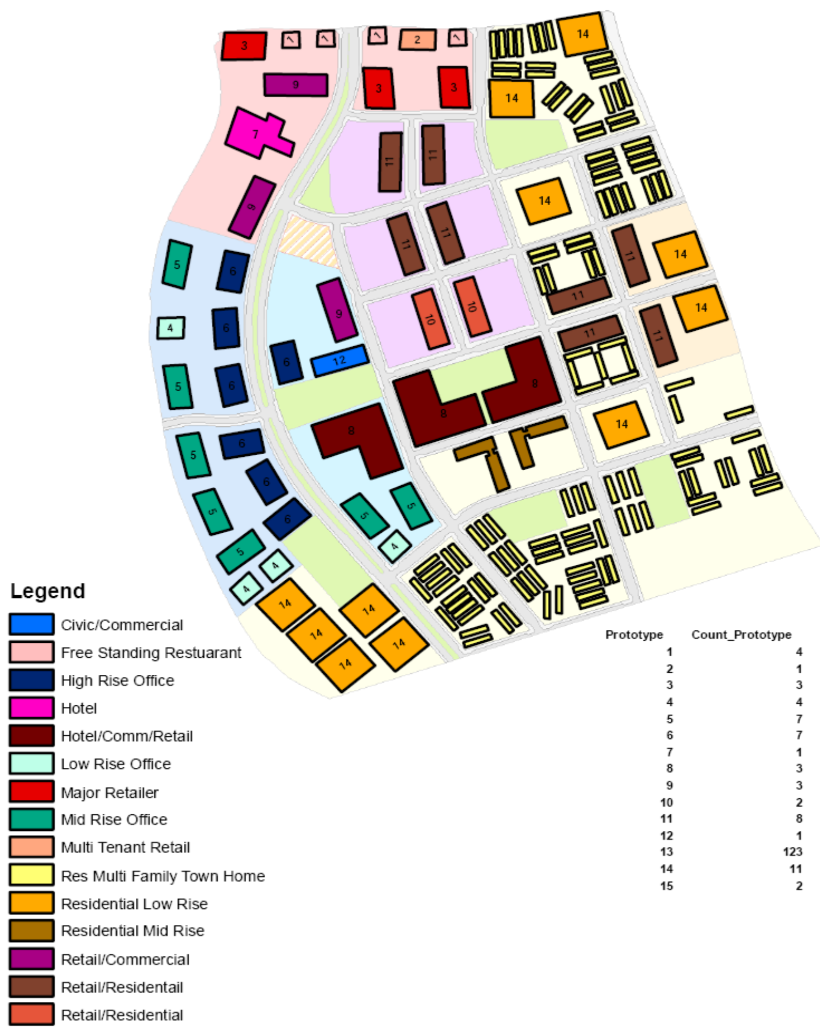
[7] Paybacks = < than useful life of the measure (material, equipment, feature) being implemented

1	Freestanding Full Service Restaurant	FSR
2	Multi-Tenant Retail Shop	MTR
3	Major Retailer Store	MRS
4	Office Building Low-Rise	LRO
5	Office Building Mid-Rise	MRO
6	Office Building High-Rise	HRO
7	Large Hotel	LGH
8	Small Hotel	SMH
9	Retail/Commercial Mixed Use	RCM
10	Retail/Residential Mixed Use Mid-Rise	RRM
11	Retail/Residential Mixed Use Low-Rise	RRL
12	Civic/Commercial Mixed Use	CCM
13	Residential Multi-Family Townhome	RTH
14	Residential Low-Rise	RLR
15	Residential Mid-Rise	RMR

Table 1. Site-A: Prototypical Buildings



Prototype	Count_Prototype
1	4
2	1
3	3
4	4
5	7
6	7
7	1
8	3
9	3
10	2
11	8
12	1
13	123
14	11
15	2

Figure 3. Site-A: Utilization Plan & Prototypical Building Placement

In contrast to the predominantly commercial character of Site-A, Site-B is planned to be a predominantly residential and mixed-use residential/commercial development. The site will contain 866 buildings featuring 4,270 residential units with a total of 6,776,027 s.f. of living space and 357 retail store/commercial units representing a total of 296,259 s.f. of commercial space. Five distinct building prototypes were selected to represent these structures in the modeling and are described in Table-2. The Site-B Technical Assumptions Manual provides the building geometry, floor plans, materials, equipment and other relevant details for the prototypes. Figure-4. provides the location for the prototypes according to the developer's site utilization plan.

Building Name	**Luminara**	**Chambray**	**Artisan**	**Artisan**	**Studio Walk**	**Studio Walk**	**Studio Walk**	**Gateway**	**Gateway**	**Gateway**	**Gateway**	**Gateway**
Space Usage	Residential	Residential	Residential	Retail	Residential	Retail	Retail	Residential	Retail	Retail	Retail	Retail
Building Prototype #	**01**	**02**	**03**	**03**	**04**	**04**	**04**	**05**	**05**	**05**	**05**	**05**
Model	RES	RES	RES	RSCSM	RES	RSCSM	RSISM	RES	RSCSM	RSISM	RSCLG	RSILG
Residential Units	1	2	5	0	10	0	0	84	0	0	0	0
Model Qty per Building	1	1	1	2	1	1	4	1	2	5	1	3
Model Length	42	49	72	19	172	19	19	198	39	39	44	44
Model Width	30	31	50	27	50	27	27	153	26	26	58	29
Stories	2	2	2.5	1	2	1	1	4	1	1	1	1
Floor-to-floor Ht.	11	11	11	14	11	14	14	11	14	14	14	14
Total sqft	2,540	2,982	9,091	510	17,215	510	510	121,309	1,003	1,003	2,528	1,242
Bedrooms	4	3	3	-	4	-	-	206	-	-	-	-
People per Unit	6	5	5	-	6	-	-	-	-	-	-	-
People Per Building	6	10	25	13	60	13	13	332	26	26	67	33
Sqft per Person	423	298	364	38	287	38	38	365	38	38	38	38
Roof Sqft	1,778	2,087	3,636	510	8,608	510	510	30,327	1,003	1,003	2,528	1,242
Roof Available %	0%	0%	45%	0%	45%	0%	0%	45%	0%	0%	0%	0%
Window %	18%	12%	7%	16%	11%	16%	10%	8%	10%	10%	16%	10%
Door % (3.5'x8')	3%	1%	6%	0%	4%	0%	0%	4%	0%	0%	0%	0%
Adiabatic Wall %	0%	0%	8%	50%	0%	50%	79%	0%	50%	70%	50%	70%
Average Orientation deg	212	178	201	201	206	206	206	171	171	171	171	171
Building Count	**265**	**99**	**47**	**47**	**80**	**80**	**80**	**33**	**33**	**33**	**33**	**33**

Table 2. Site-B: Prototypical Buildings

Figure 4. Site-B: Utilization Plan & Prototypical Building Placement

The research team used the BEA and Energy-10 modeling tools described above to analyze the variable energy, economic and environmental impacts of both development sites relative to conventional and alternative approaches to building design and construction utilizing a variety of alternative energy-efficient measures.

The alternative EE measures included:

- Energy-efficient glazing;
- Alternative framing and improved envelope insulation (roof, floors, walls, and doors);
- Energy-efficient lighting;
- High efficiency space cooling equipment;
- High efficiency heating, domestic hot water equipment;
- *EnergyStar* appliances;
- Thermal storage;
- Solar thermal heating;
- On-site power generation using solar photo-voltaic (PV) systems; and
- On-site power generation with heat recovery using internal combustion (IC) engines and a microturbine system.

The modeling entailed detailed analysis of building envelope energy loses and internal energy loads for occupants and all fixtures and equipment, including space conditioning and ventilation systems. Specifically, the modeling included 8,760, hour-by-hour consumption of five types of building energy uses including:

- Electricity;
- Natural gas;
- Cooling;
- Heating;
- Domestic hot water.

<u>Modeling Scenarios</u> – There were four alternative development scenarios modeled for each of the sites. A brief description of each scenario is provided below.

***Builder Proposed Baseline* (BPB) *Scenario*:** Defined as one in which the construction materials, lighting and operating equipment for each structure are designed to meet the California Title-24, 2005 energy efficiency standard or to exceed it if specified as such in the building plans provided by the developers/builders. Detailed descriptions of the builder's proposed plan for each prototypical structure are contained in the Technical Assumption Manuals for both sites in the *Modeling Scenario* tables, under the column heading *Proposed Baseline*.

***EE Package* (EE) *Scenario*:** Defined as one in which advanced energy efficiency measures are employed in all structures to achieve increased energy efficiency, economic savings and air emission reductions. These measures included alternative grades of wall and roof insulation, windows, doors, lighting, HVAC equipment including thermal storage, appliances, and implementation of solar thermal technology. Detailed descriptions of the EE measures modeled for each prototypical structure are again contained in the Technical Assumptions Manual in the *Modeling Scenario* tables, under the column headings *Alternative 1 to 3* and in the sections titled *Thermal Storage* and *Solar Thermal*.

EE Package with DG* (EE-DG[8]) *Scenario: Defined as one in which advanced energy efficiency measures are employed with a fossil fuel-based (natural gas) onsite power generation units with heat recovery technology on all suitable structures within the development site. Details of these Combined Heat and Power (CHP) systems are described in the Technical Assumptions Manual section titled *On-Site Combined Heat and Power – Microturbine CHP*.

***EE Package with PV* (EE-PV) *Scenario*:** Defined as one in which advanced energy efficiency measures are employed with solar photovoltaic onsite power generation technology on all suitable structures within the development site. Details of the solar photovoltaic systems are described in the Technical Assumptions Manual section titled *On-Site Power Generation – Photovoltaics*.

Once these four scenarios were modeled for the two development sites, the findings were analyzed to determine the energy efficiency, economic savings and emissions reduction potential of the alternative development approaches. Additionally, individual structure and aggregate development-wide load duration curves were generated for each site and then evaluated by San Diego Gas and Electric (SDG&E) to determine the extent to which the alternative scenarios reduced peak demand and resulted in a better utilization of the existing utility infrastructure.

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[8] It should be noted that the economics component (simple payback and ROI analysis) of the EE-DG option analysis presented in this report may have at this point in time more hypothetical than practical value. At the time the CVRP study analysis was initiated (Spring of 2007) the DG analysis was based on applicable 2007 California Self-Generation Initiative Program (SGIP) guidelines which provided a rebate of $600/kW for IC-engine based CHP systems and a $800/kW for microturbine based CHP systems. Preliminary calculations showed a very long payback of 17 years for the Site-A microturbines based DG option and consequently microturbines were not considered as a valid technology for larger commercial buildings, even as they qualified from the emissions point of view. On the other hand, the paybacks for IC engines based DG system were acceptable (7.5 years) and considering the fact that the units were to be run in a CHP configuration with heat recovery, an assumption was made to take advantage of SGIP permitted heat recovery credit to qualify IC installations from the emissions point of view. However, the l2008 SGIP eliminated all DG rebates except for the wind and fuel cell applications. That makes the Site-A DG analysis more a "what if" case than a practical deployment target as the payback is not acceptable without the rebates. Nonetheless, this analysis was included in this report to illustrate the potential energy efficiency and environmental gains that can be obtained through the use of targeted CHP deployment.

2.5 Utility Impact Analysis

The objective of the utility impact analysis was to determine the extent to which the application of the modeled building technologies, in typical development projects, would reduce peak demand and result in better utilization of existing utility infrastructure.

Once the building energy loads were calculated for each building prototype, they were aggregated for the Site-A and Site-B development sites and then provided to the electric and gas utility distribution planning departments at San Diego Gas and Electric (SDG&E) for analysis.

In the case of the electric utility impact analysis, the utility planners estimated the aggregate distribution system demand associated with each of the modeled technology enhancement scenarios and assessed the associated electrical facilities necessary to meet those demands (i.e. circuits, substations, transformer banks and related facilities).

In the case of the natural gas utility impact analysis, the utility planners estimated the design day pressures for piping and regulator facilities needed to meet the gas demand of the builder proposed baseline and the EE and EE-DG scenarios modeled for each development site.

<u>An Important Note</u>: Natural gas distribution systems in this area are planned for an extreme 24-degree heating day design point, or the worse-case heating day scenario that the system must have capacity to serve. Therefore, natural gas distribution systems are *conventionally* designed with much greater capacity than a development site would demand in a typical year or in some cases a typical decade. Additionally, distribution systems are designed with additional capacity for future load additions within existing developments (e.g.: the addition of a cogeneration unit at a commercial site or swimming pools in residential complexes), and unless a planned site is landlocked, for adjacent sites that may be developed in the future.

Given these factors, the impact analysis was designed to estimate the degree to which the modeled builder proposed baseline (BPB) and EE-DG scenario loads would impact the capital infrastructure requirements and costs for each development site. This impact was considered under both a conventional approach to distribution pipe planning and an optimized approach, or one specifically designed to meet only the loads modeled. To determine the piping, pressure and regulator requirements needed to meet these loads, the utility planners used Advantica's SynerGEE gas modeling software and the site utilization plans to generate alternative distribution systems for analysis. Five distribution systems were designed and analyzed including:

1. A conventionally designed distribution system for the development area <u>without</u> the the Site-A and Site-B natural gas loads (Appendix-C);
2. A conventionally designed distribution system for the area <u>with</u> the builder proposed baseline (BPB) scenario loads for sites A and B (Appendix-D);
3. An optimally designed (optimized) distribution system serving the BPB scenario loads (Appendix-E);
4. An optimally designed distribution system serving the EE-DG scenario loads (Appendix-F);

5. An optimally designed distribution system serving the EE-DG scenario loads with the addition of a new regulator station (Appendix-G).

The schematic plans for each of these systems can be found in Appendices E-I.

There were a number of key cost assumptions used in this analysis. They include the following:

- Gas service line and metering costs would be the same for all scenarios. All the customers who use gas need gas services and meters. It was expected that all the services and meters would be the same in all scenarios. The only exception to this would occur with the metering required for the EE-DG scenario, but even those locations would require standard meter sets and services and therefore would not result in significant additional gas system costs.
- All gas pipe is assumed to be polyethylene and installed in a joint trench with other utilities in a "greenfield"/ all-dirt environment with no existing pavement.
- Installed, greenfield gas pipe cost estimates are based on the following unit costs:

Pipe Size	Cost $/ft
2-Inch	$38.60
3-Inch	$44.10
4-Inch	$55.13
6-Inch	$65.15

Note: These are order-of-magnitude values and are not to be used for detailed cost estimating. SDG&E's smallest gas main is a 2-inch polyethylene pipe. Gas mains then step up in size to a 3-, 4- and 6-inch pipe with capacity doubling with each incremental increase in size.

2.6 Technology Construction Impacts & Economic Evaluation

Although the modeling method described above did consider the installed cost of the alternative EE measures and technologies in its economic evaluation, additional analysis was necessary to evaluate the impact of their installation on overall construction processes and operations and to estimate the cost of that impact.

Measurement of potential impact in this case was measured through imputed cost impacts associated with the energy efficiency technologies. Cost impacts could be positive or negative. Estimates of the cost to install individual technologies (and by summation, packages) were produced as part of the energy analysis, in order to estimate simple payback as described under building modeling above. However, increases to these costs could accrue due to potential disruptive impacts or on and altercations in the construction process. To enable the reader a better understanding of the implications of such alterations, the following paragraphs provide background on, and describe the varied dynamics considered in this analysis.

Because construction processes are linked chains of specialized operations conducted, by and large, by separate companies, modifications to the process can have unintended and disruptive consequences for the larger process. Therefore, process analysis tools were used to model the potential impacts of required process changes and to map potential cost impacts over and above the direct cost of the installation work. Utility incentive programs also impact costs by offsetting the first cost or impacting cash flows more than simply the amount indicated by the energy efficiency gains themselves. Therefore, the economic feasibility assessment included consideration of utility incentive programs as well.

Assessment of the construction process was conducted by considering the overall construction process and the perturbations that would be introduced by substitution or insertion of different materials into the building, thereby requiring alternate construction operations. The construction process to produce a structure, particularly with the complexity of the building prototypes modeled in this project, consists of a complex, fragmented supply chain of owners, contractors, subcontractors, and suppliers. The industry is typified by temporary, contract-driven relationships between the participants in a given project. Furthermore, a given project operates under a range of external influences on the constructed product, primarily at the project level.

This complexity in the project organization and function induces the development of relatively entrenched practices and production approaches that are collectively referred to as the "culture" of the construction industry. These include the relationship between designers and contractors, the contracting and contractor selection procedures, and the development of a subcontractor-driven approach to the construction process that typify US construction projects at the present time. Looking specifically at the production phase, production assets are deployed in the form of primarily subcontracted labor to complete installations, with the dividing lines between subcontractors developed largely (and traditionally) along distinctions between trades. Thus, the subcontracts are devised primarily based on the particular type of materials being installed and the classes of work being conducted, rather than based on some other consideration such as space within the structure.

The selection of general contractor, subcontractors, and suppliers for a given project is accomplished along a number of dimensions, chief among them are cost, availability, and reputation. A typical building project might include 80 or more different companies including designers, the general contractor, subcontractors, and suppliers. Given the number of companies which exist in a region, especially in the subcontractor community, the odds do not support repeated work by exactly the same team on multiple projects. As a consequence, the production system constantly has to adjust to a new set of "handoffs" or interfaces from one trade-based subcontractor to the next. In this context, the word "handoff" is intended to mean the transition from one subcontractors work to the next in the project chain.

For example, once the interior framing is completed in a building or portion of a building, the plumbing subcontractor might begin work pulling pipes through the just framed walls in that building or portion of a building. Thus the work of the framing subcontractor is "handed off" to the plumbing subcontractor, and this handoff is both physical in terms of holding up the pipes and temporal in the sense that the project logic requires that the frame be built first. The handoff is analogous to the movement of a part from one machine to the next in a manufacturing assembly line, but in the case of the construction project the part stays stationary and the workers move on to the site.

Handoffs like this are repeated dozens of times over the course of a project. The work of the following subcontractor usually depends on the work done by the preceding subcontractor, either for structural support (such as the relationship between drywall and framing), collision potential (such as between plumbing and mechanical systems), or tolerance and finish condition (such as between drywall and electrical service trim). Because these dependencies exist and the set of subcontractors involved differs from one project to the next, there is strong pressure for relatively established traditions to develop, at least in a given geographic area, governing the sequence of operations and the characteristics of the work at time of handoff.

In this research project, the proposed modifications to the final building conditions consist of tinkering with these established processes. The final product completed according to the proposed energy-efficient alternate designs is different than the “normal” product. As a result, there exists the potential for problems to arise during construction activities that disrupt established practices for handoffs by changing the nature of the product, the condition of the product at the time of handoff, or the number and sequence of handoffs that take place.

In general, such disruptions can be expensive to accommodate in the production process, and can introduce expenses beyond the difference in cost associated with just the additional materials themselves. The research team therefore analyzed these cost implications in order to distinguish the cost implications for the overall process from the basic projected cost implications for materials and labor itself. Furthermore, those energy-efficient technologies which are significantly disruptive are unlikely to be adopted by the construction community, because aside from the predictable process and cost implications unpredictable variations can be introduced by a reduced set of interested or qualified bidders. These dramatic disruptions have the potential of rendering the option practically infeasible.

The construction process cost analysis consisted of the following generic steps:

1. Evaluate the process implications of the various building component alternates described in the Site-A Technical Modeling Assumptions as compared to the base case, and characterize these implications by their impact on the processes;
2. From this characterization, select alternates that potentially have implications for process disruption;
3. For those cases, develop a process map of the base case and the alternate(s) of interest;
4. Using the process maps, identify potential cost implications of disruptions noted.

Following this process, for all packages and technologies determined to be practically feasible, an assessment was made of potential cost savings that might enhance market adoption arising from energy efficiency incentive programs. This analysis was completed using the building modeling described above as input. In the building modeling, the modeling team completed a detailed analysis of the energy performance of a wide range of energy efficiency upgrades and distributed generation equipment including both photovoltaic and internal combustion engines for the prototype structures at Site-A.

As noted in the footnote above, subsequent to the completion of modeler's analysis, the internal combustion engine option had been eliminated from incentive programs because of persistent emissions control concerns, and so this option is not considered further in this section. The modeler's analysis included estimation of the cost difference between the builder baseline and the modified case for individual technologies. Furthermore, they considered packages of energy-efficient technologies that could combine cost effectively. The cost effectiveness was estimated using the simple payback period. In general, simple payback was calculated using Equation (1)

$$PB = \frac{\Delta C_{EE}}{AS_{EE} - OM_{EE} + R_{EE}} \quad (1)$$

where: PB = simple payback period (years);

ΔC_{EE} = estimated difference in first cost of energy efficiency technology (or package) over the builder baseline ($);

AS_{EE} = estimated annual savings in energy utility expenditures resulting from the energy-efficient technology (or package) over the builder baseline case ($/year), calculated as the estimated annual utility cost using the builder baseline technology minus the estimated annual utility cost using the energy efficiency technology (or package);

OM_{EE} = estimated cost of operations and maintenance of the photovoltaic system if part of the energy-efficient package, estimated as 0.12% of the installation cost for photovoltaic systems and zero otherwise; and

R_{EE} = estimated revenue for electricity over-production from photovoltaic system if part of the energy-efficient package, estimated from the energy simulation with a blended electric rate of $0.l141/kWh and zero otherwise.

Technologies were deemed to be cost effective if the simple payback period was less than the useful life of the technology. The modeling team analyzed energy efficiency upgrades to the envelope, lighting, and mechanical systems, and chose the most cost-effective combination for each prototype in a package referred to as the optimal energy efficiency package or EEopt. A corresponding cost differential over the builder baseline for EEopt was also developed. For cases where photovoltaics were cost effective and practical, they also developed a cost for the same system including photovoltaics, referred to as EEopt+PV. Because the California Solar Initiative is so fundamental to the economics of photovoltaics, the payback period for the photovoltaic systems already include government incentives.

To assess the impact of incentives on the payback period, SDG&E incentives under the Sustainable Communities Program were estimated. The incentives were incorporated into the payback calculation as indicated in Equation (2)

(2) $$PB = \frac{\Delta C_{EE} - I_U}{AS_{EE} - OM_{EE} + R_{EE}}$$

where: I_U = estimated utility incentive to offset the first cost of the system.

The estimation of the incentives available from SDG&E's Sustainable Communities Program was completed in accordance with the Participant Handbook (SDG&E 2008). SDG&E describes the program as a means to promote green building design practices by incenting construction practices that significantly exceed the Title-24 requirements. Builders can become eligible for incentives by demonstrating that energy efficiency alternatives well in advance of Title-24 requirements have been incorporated into the building. Additional incentives are available for satisfying sustainability criteria.

Different incentive structures exist for nonresidential and residential structures. For nonresidential structures, the incentive is calculated for both the electric and gas performance of the structure (Equations (3) through (5) SDG&E 2008).

(3) $$I_{elec} = \left[0.10 + \frac{\left(Perf_{T24} - 10\right)}{100}\right] AS_{kWh}$$

where: I_{elec} = electric incentive ($);
$Perf_{T24}$ = performance of the structure better than Title-24 requirements in percent, maximum of 25; and
AS_{kWh} = annualized electrical savings in kWh.

(4) $$I_{gas} = \left[0.34 + \frac{4.4\left(Perf_{T24} - 10\right)}{100}\right] AS_{therms}$$

where: I_{gas} = gas incentive ($);
AS_{therms} = annualized gas savings in therms.

$$I_U = I_{elec} + I_{gas}$$

An additional 20% is available for projects that also obtain the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) or equivalent certification and perform an on-site renewable energy evaluation. The maximum incentive payable for nonresidential projects is $150,000.

For residential projects, the incentive is calculated at $165 per dwelling unit, with a $50,000 maximum per project.

These incentives were applied in Equation (2) for each prototype. An example calculation is presented for Prototype 4 to illustrate the process.

Example Calculation

The data contained in Table 3. below, is derived from the from the modeler's analysis for Prototype 4 (a low-rise office structure) which is summarized in the Site-A: Modeling Results document – Tables-27 and -28, (Appendix A.).

Variable	Builder Baseline	Optimum EE Package	Optimum EE and PV
Package Cost	n/a	$90,874	$532,195
Annual Utility Cost	$60969	$51631	$31,914
Annual Electrical Usage	332,469 kWh	285,304 kWh	140,418 kWh
Annual Gas Usage	249 MMBtu	215 MMBtu	215 MMBtu
Total Annual Energy	1384 MMBtu	1188 MMBtu	694 MMBtu
Payback Period Eqn (1)	n/a	9.7 years	17.2 years

Table 3. Analytical Results from Building Energy Analysis

The calculation for the optimum EE package proceeds as follows:

Estimated energy improvement over the builder baseline is

$$Perf = \frac{\text{Energy Saved}}{\text{Builder Baseline Energy}} \times 100\% = \frac{1384\text{ MMBtu } - 1188\text{ MMBtu}}{1384\text{ MMBtu}} \times 100\% = 14.1\%$$

The builder baseline is the set of construction practices proposed by the developer and the building community as standard practice in the region. This set of practices is recognized to be above the requirements of Title-24. Previous modeling by the research team in the area found that the builder baseline would exceed the Title-24 requirements by an amount from 8 to 13%. Detailed energy modeling would be required for the final buildings that could demonstrate exactly what the right number is. But, for purposes of this estimate of the incentive effect only an unbiased estimate of the result compared to Title-24 is needed. Therefore, a moderate assumption that the builder baseline is about 10% better than Title-24 was used. Accordingly, $Perf_{T24} \approx 14.1\% + 10\% = 24.1\%$. Using this value, the incentives can be calculated.

$$\begin{aligned} I_{elec} &= \left[0.10 + \frac{(Perf_{T24} - 10)}{100} \right] AS_{kWh} \\ &= \left[0.10 + \frac{(24.1 - 10)}{100} \right] (332,469 - 285,304) \\ &= (0.241)(47,165) = \$11,362 \end{aligned}$$

$$I_{gas} = \left[0.34 + \frac{4.4\left(Perf_{T24} - 10\right)}{100}\right] AS_{therms}$$

$$= \left[0.34 + \frac{4.4\left(24.1 - 10\right)}{100}\right]\left(2490 - 2150\right)$$

$$= \left(0.96\right)(340) = \$327$$

$$I_U = I_{elec} + I_{gas} = \$11,362 + \$327 = \$11,689$$

Substituting the necessary values in Equation (2),

$$PB = \frac{\Delta C_{EE} - I_U}{AS_{EE} - OM_{EE} + R_{EE}}$$

$$= \frac{90,874 - 11,689}{\left(\$60,969 - \$51,631\right) - 0 + 0} = 8.5 \text{ years}$$

For the optimum EE package, this means the incentive package reduces the payback period by approximately 1.2 years, from 9.7 years to 8.5 years.

The calculation for the combined optimum EE-PV package proceeds as follows:

Estimated energy improvement over the builder baseline is

$$Perf = \frac{\text{Energy Saved}}{\text{Builder Baseline Energy}} \times 100\% = \frac{1384 \text{ MMBtu } - 694 \text{ MMBtu}}{1384 \text{ MMBtu}} \times 100\% = 49.8\%$$

Using the same assumption as before, $Perf_{T24} \approx 49.8\% + 10\% = 59.8\%$. Using this value, the incentives can be calculated as before. However, the maximum value of the incentive in each case is controlled by the maximum energy savings of 25%.

$$I_{elec} = \left[0.10 + \frac{\left(25 - 10\right)}{100}\right]\left(332,469 - 140,418\right)$$

$$= \left(0.25\right)(192,051) = \$48,013$$

$$I_{gas} = \left[0.34 + \frac{4.4\left(25 - 10\right)}{100}\right]\left(2490 - 2150\right)$$

$$= \left(1.00\right)(340) = \$340$$

$$I_U = I_{elec} + I_{gas} = \$48,013 + \$340 = \$48,353$$

In this case, the payback is affected by operations and maintenance costs and revenue from electricity generated by the PV system and sold back to the utility. As explained below Equation (1), the annual O&M expense is estimated using 0.12% of the (pre-CSI incentive) first cost of the system, or OM_{EE} = (0.12%)(740,608) = \$889/yr. The electrical revenue was provided by the modeling effort, and for this prototype R_{EE} = \$2826/yr. The revised payback period is then estimated using Equation (2).

$$PB = \frac{\Delta C_{EE} - I_U}{AS_{EE} - OM_{EE} + R_{EE}}$$

$$= \frac{532{,}195 - 48{,}353}{(\$60{,}969 - \$31{,}914) - 889 + 2826} = 15.6 \text{ years}$$

For the combined optimum EE-PV package, this means the incentive package reduces the payback period by approximately 1.6 years, from 17.2 years to 15.6 years.

An additional 20% incentive is also available for each case for adoption of sustainable practices in the projects (including LEED certification or equivalent). This additional incentive reduces the payback period another 0.3 years for both packages. All results are provided in the next chapter.

Once these analyses were completed, the assessment of market feasibility for construction could proceed. Based on the process analysis, additional costs could be attributed to activities found to have disruptive influences on the process. Then, cash flow improvements arising from the utility-based incentives could be calculated, along with their potential impact on simple payback. In the results section in the next chapter, the lowest payback periods corresponding to the most feasible alternatives will be presented based on these analyses.

2.7 District Cooling System Evaluation

In addition to modeling the energy, economic and environmental performance of alternative EE measures and technologies, the research team also examined the efficacy of a district energy system for Site-A. This special, expanded study was made possible through co-funding provided by the International District Energy Association (IDEA). In the study the researchers evaluated the incorporation of a district cooling system in an effort to determine if further energy efficiency and environmental benefits could be obtained while remaining cost competitive with "stand-alone" cooling production at individual buildings. To perform this evaluation, the researchers used the individual and aggregate 8760 hourly building energy data generated for both the BPB and the EE-PV development scenarios described above.

The evaluation of district cooling under each of these scenarios, which produce different peak loads and annual cooling consumption, was conducted with and without Thermal Energy Storage (TES) technology. An analysis of the hourly data generated: annual peak loads for sizing of the district cooling plant and infrastructure; monthly peak loads for calculation of electricity demand charges; and cooling consumption for each of the SDG&E utility rate periods (on-peak, semi-peak, and off-peak) for calculation of electricity energy charges.

For the district cooling configurations with TES technology, the researchers developed daily load profiles for different times of the year, and utilized analysis of these profiles in order to size the TES tank for optimal "peak shaving", and to estimate annual plant cooling production (ton-hours) at each of the SDG&E utility rate periods with the optimal use of the TES facility. For both scenarios, capital costs were developed for the district cool plant with and without TES, for the chilled water system and for Energy Transfer Stations (ETS) at individual buildings.

To size the distribution piping for capital cost estimation, a hydraulic model of the distribution network was prepared using TERMIS, a hydraulic modeled software package specifically designed for analysis of district energy systems. District cooling plant electricity consumption, for input to the economic analysis, was calculated by acquiring detailed manufacturer performance data for chiller selections for both baseline & optimum plant configurations and by binning wet bulb temperature data for San Diego to calculate estimates for peak and average plant kW/ton for the 3 utility rate periods.

Monthly peak electricity demand and the utility rate period electrical consumption were then applied against the SDG&E rate tariff to calculate electricity costs. Water consumption was calculated for each alternative using a cooling tower water balance tool, and water costs determined using applicable local water utility rates.

Annual operating costs were then calculated for capital recovery, electricity, water & water treatment chemicals, maintenance and operating labor. For both of the development scenarios, total annual operating costs for the district cooling alternatives were then compared against total annual operating costs for the *stand-alone* alternatives with cooling production at individual buildings.

<u>Technical and Economic Modeling/Analytical Assumptions</u>

<u>Building Scenarios</u> - The economic feasibility of district cooling generally hinges on load density, and is most feasible when serving high-density areas. Larger buildings that are close together make the best candidates for district cooling. The cost of chilled water distribution pipe mains is lower when buildings are close together, and the cost of chilled water service lines and energy transfer stations are lower, on a unit cost per ton basis, for larger buildings. Conversely, small buildings, or buildings requiring a long extension of piping to reach, can be prohibitively expensive to serve with a district cooling system.

The researchers performed an initial evaluation of the stock of buildings proposed for the Site-A development and decided to eliminate building Type 13 (townhomes) and Type 14 (low-rise residential) from the detailed district cooling economic analysis, due their small cooling loads, and the location of these buildings on the fringes of the development. Therefore, the assumption for the researcher's economic analysis was that building Types 13 and 14 will remain stand-alone buildings with cooling production equipment at each individual building (split system heat pumps).

Table-4 lists building prototypes, the quantity of buildings in the proposed Site-A development, and peak cooling loads for each building type for the two development scenarios. This table lists building and peak cooling load totals for all the buildings in the development, and also for *All buildings less Types 13 & 14,* the set of buildings that are served with district cooling for this analysis. Note that this set of buildings is only 25% of the total buildings in the development, but accounts for 90% of the peak load.

Detailed information on each of the building prototypes is contained in Appendix-H for the BPB and the EE-PV/optimum scenarios, including: building prototype cooling system (Stand-alone cooling production); building square footage; annual cooling consumption; annual space cooling related electric consumption, including heat rejection; average unit electric cost for buildings; annual cost of space cooling related electric consumption including heat rejection.

Building Prototype ID	Building Prototype Description	# of Bldgs	Builder Baseline Scenario Peak Cooling Load (tons)	EE-PV Configuration Scenario Peak Cooling Load (tons)
1	Free Standing Restaurant	4	127	120
2	Multi Tenant Retail	1	74	44
3	Major Retailer	3	278	254
4	Low Rise Office	4	297	236
5	Mid Rise Office	7	1,600	1,348
6	High Rise Office	7	3,650	3,143
7	Hotel	1	199	197
8	Hotel/Comm./Retail	3	1,117	969
9	Retail/Commercial	3	788	630
10	Retail/Residential	2	314	265
11	Retail/Residential	8	1,006	808
12	Civic/Commercial	1	322	271
13	Res Multi Family Town Home	123	734	610
14	Residential Low Rise	11	357	323
15	Residential Mid Rise	2	143	123
TOTAL - "All bldgs"		180	11,006	9,341
TOTAL - "All bldgs less Types 13 & 14"		46	9,916	8,408

Table 4. Site-A: Development Buildings & Cooling Loads

Plant Configurations - The researchers developed four conceptual plant configurations that are compared to stand-alone cooling production at individual buildings within the scope of this evaluation. These configurations are as follows:

- District Cooling without TES for Builder Proposed Baseline (BPB) scenario
- District Cooling with TES for Builder Proposed Baseline (BPB) scenario
- District Cooling without TES for EE-PV scenario (EE-PV)
- District Cooling with TES for EE-PV scenario (EE-PV)

For the BPB scenarios, the district cooling plant is assumed to be configured with chillers in a parallel arrangement (not in series), and chillers are not equipped with variable frequency drives (VFDs). The researchers considered this the baseline configuration, which has lower first cost but is not optimized for maximum efficiency.

For the EE-PV scenarios, the district cooling plant is assumed to be configured with chillers in a series-counterflow arrangement, and chillers are equipped with variable frequency drives (VFDs). Arranging chillers in a series-counterflow configuration reduces chiller lift, thereby increasing efficiency of the chiller pair. Figure-5 illustrates the reduction in lift that is achieved with chillers in series-counterflow configuration. Installing VFDs on chillers provides substantially higher efficiencies at lower than design entering condenser water temperatures (ECWT). Installing VFDs on chillers, therefore, is highly beneficial to district cooling plants with evaporative cooling towers and significant seasonal and daily variability in wet bulb temperatures. For plant configurations with TES, the researcher's analysis assumes that the type of TES will be an unpressurized, stratified chilled water storage tank. A stratified chilled water storage tank is one where supply and return water reside in the same tank, separated only by a thermocline. Chilled water storage has substantially lower capital costs than other methods of TES, such as ice storage.

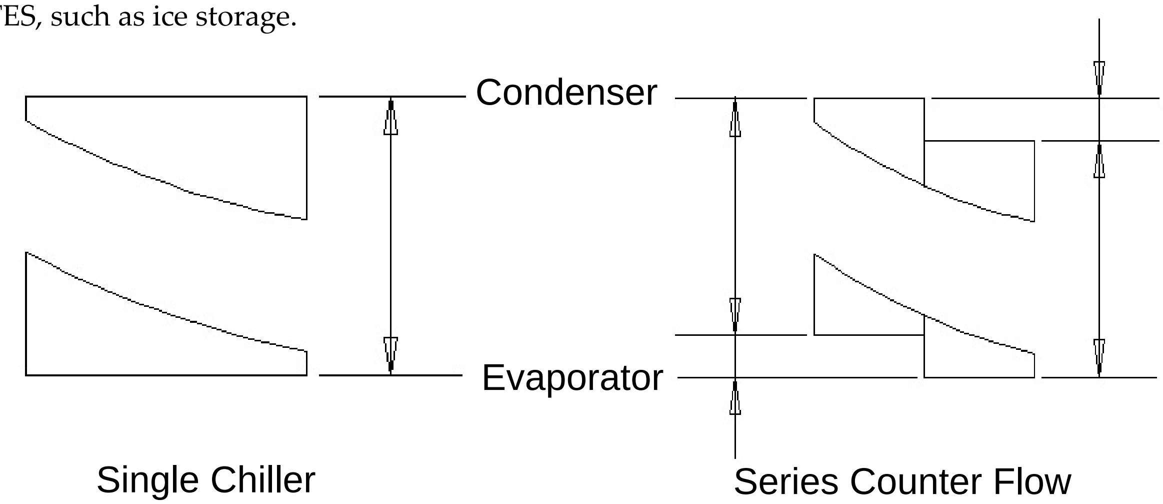

Figure 5. Series-Counter Flow Lift Reduction

In fact, the installed cost of chilled water TES capacity is typically less than the installed cost of chiller capacity. Additionally, if a very tall chilled water storage tank can be installed, then the tank can also maintain static pressure in the system and protect the system from surge or the water-hammer effect. Chilled water storage has the additional advantage of not needing to be located in close proximity to the chiller plant, which can improve system hydraulics and reduce distribution pipe size. For this evaluation, however, the researchers have assumed that the chilled water TES tank will be located adjacent to the plant, and have not accounted for potential distribution piping capital cost savings associated with a more hydraulically beneficial location for the tank.

The downside to chilled water TES is that the tank is very large relative to other TES technologies, such as ice storage, and could be difficult to site due to zoning or architectural limitations. Another potential downside to stratified chilled water TES is that the supply temperature cannot be lower than approximately 40°F or the balance of the thermocline will be disrupted.

<u>Annual Cooling Production</u> - Annual cooling production (ton-hrs) for the stand-alone alternatives, with cooling production at individual buildings, is assumed to be equal to the aggregate building cooling consumption provided for the BPB and EE-PV/optimum scenarios. This data is provided in Appendix-H, and is as follows:

- BPB = 14,814,215 ton-hrs;
- EE-PV = 12,305,738 ton-hrs.

For the district cooling alternatives, the total annual plant cooling production is assumed to be the aggregate cooling consumption above, plus 0.5% additional for distribution thermal losses.

In order to properly calculate electricity costs for the district cooling alternatives, it was necessary to identify the quantity of cooling production (ton-hrs) generated in each of the six electric utility rate periods, as defined in SDG&E Schedule AL-TOU. For the district cooling scenarios without TES, the cooling consumption totals for each of the rate periods could be extracted directly from the 8760 hourly data for the aggregate building cooling consumption and then scaled up to account for thermal losses.

For the district cooling scenarios with TES, more in-depth analysis was required to determine the quantity of cooling production (ton-hrs) generated in each of the six SDG&E utility rate periods, since TES "peak shaving" shifts production from peak times to off-peak times.

For the TES alternatives, the researchers developed daily load profiles for different times of the year, and analyzed these profiles in order to size the TES tank for optimal peak shaving, and to estimate annual plant cooling production at each of the utility rate periods. Figure-6 is the peak day profile for the BPB scenario, generated from the 8760 hourly data. The dashed red line indicates the average load for the peak day. Plant compressions (chillers) for this TES plant alternative were sized to produce the tons below the red line (52% of diversified peak) and TES was sized to produce the tons above the red line (48% of diversified peak).

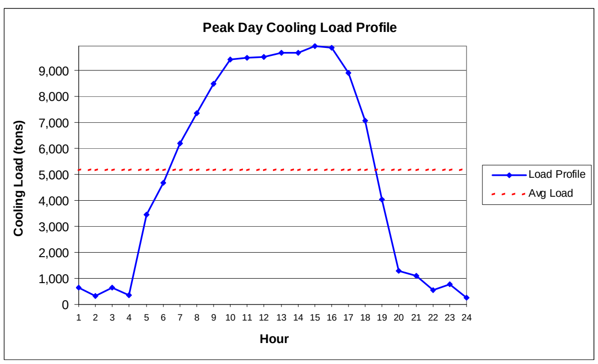

Figure 6. Peak Day Load Profile for BPB scenario

Appendix-I contains several example load profiles for the BPB scenario for different times of the year. Note that these profiles illustrate aggregate system peak load, before application of the diversity factor for the district cooling alternatives. Also included in Appendix-I are the TES charge and discharge tables that researchers constructed to determine the amount of compression that is required during on-peak, semi-peak, and off-peak utility rate periods throughout the year. Note, for example, that on the May 1st cooling day, plant compression (chillers on) can be confined to the off-peak period, which dramatically reduces plant electricity cost. The other significant benefit of shifting compression to off-peak time periods is that the electricity produced by utilities during these time periods is cleaner and more efficient, resulting in reduced emissions and greenhouse gases.

Appendix-J contains load profiles and TES analysis for the EE-PV/optimum scenario. Table-5 below lists the plant annual cooling production by utility rate period that was developed for each of the district cooling alternatives using 8760 hourly data and TES analysis.

Utility Rate Period	BPB Scenario		EE-PV Scenario	
	District Cooling Without TES (ton-hrs)	District Cooling With TES (ton-hrs)	District Cooling Without TES (ton-hrs)	District Cooling With TES (ton-hrs)
Summer On-Peak	4,165,532	1,071,891	3,454,835	904,894
Summer Semi-Peak	2,650,251	2,781,059	2,296,368	2,314,849
Summer Off-Peak	2,216,744	5,179,577	1,877,736	4,409,197
Winter On-peak	615,551	0	477,385	0
Winter Semi-Peak	4,141,244	142,212	3,406,085	118,444
Winter Off-Peak	1,099,024	5,713,607	854,907	4,619,933
Total, Plant Annual Cooling Production	14,888,346	14,888,346	12,367,316	12,367,316

Table 5. Plant Annual Cooling Production by Utility Rate Period

<u>Stand-alone Building Production Equipment Sizing & Capital Cost Assumptions</u> - The capacity of production equipment installed in individual buildings will be higher than the calculated production requirements for the buildings for the following reasons:

- For individual split system heat pumps and unitary packaged air-conditioners, units must be sized to meet the cooling requirements of individual zones within the buildings, and therefore, do not take advantage of diversity at the building level;
    - Building central chiller plants are typically designed with a level of production equipment redundancy, to limit lack of cooling availability if a piece of equipment is out of service (but building chiller plants have fewer chillers than district plants);
- Building HVAC system designers typically oversize production equipment, relative to actual capacity requirements, to avoid the risk of under sizing equipment.

To determine individual building production equipment installed capacity for capital cost estimation purposes, the researchers applied the following factors to individual building peak cooling loads to account for over sizing, redundancy and/or diversity considerations: Central chiller plant = 1.4, Heat pumps / unitary packaged = 1.6. In the researcher's experience, these factors are quite low. If higher factors were used for installed individual building production equipment, the economics for district cooling alternatives would be more favorable.

The capital cost assumption for stand-alone building chiller plants for the BPB scenario was $2,090/ton. This is considered a total installed cost that includes chillers, cooling towers, all piping and mechanical equipment, electrical equipment, controls and instrumentation, the structure, engineering, and project management. The capital cost assumption for split system heat pumps was $1,000/ton. This is considered total installed cost, and based on ~60% of installed heat pump cost apportioned to cooling. In addition, buildings with heat pumps were credited with $500/ton against capital costs to account for the higher cost of a hydronic HVAC system compatible with district cooling service. Capacity and installed capital cost of plant / cooling production equipment for all alternatives is presented in Table-6 below.

District Cooling Plant Sizing & Capital Cost Assumptions - For district cooling systems, the total production capacity required for the peak system load is typically less than the total of the peak loads for the individual buildings in the system. This is primarily due to differences in building usage type (e.g. office vs. residential), but may also be influenced by differences in solar loading and occupancy. For the analysis of the district cooling configurations a system diversity factor of 0.94 was assumed which, based on researcher's experience, is appropriate for the mix of building types included in the district cooling system analyzed.

For the district cooling chilled water plant, capital cost estimates are based on inclusion of one fully redundant chiller and associated plant auxiliaries. In many cases, district cooling systems have been able to operate at acceptable levels of reliability without the need for a redundant production unit due to the operating flexibility achieved by serving a large number of buildings, so the inclusion of a redundant chiller in the economic analysis is a conservative assumption with respect to the feasibility of district cooling for Site-A.

Table-6 presents a breakdown of quantity of chillers, and capacity of chillers and thermal storage that the researchers assumed for the plant concept for each of the district cooling alternatives, and used as the basis for plant capital cost development.

	BPB Scenario			EE-PV Scenario		
	District Cooling Without TES	District Cooling With TESS	Stand-alone (Cooling Production Individual Buildings)	District Cooling Without TES	District Cooling With TES	Stand-alone (Cooling Production Individual Buildings
Undiversified peak cooling demand (tons)	9,916	9,916	9,916	8,408	8,408	8,408
Load diversity factor	0.94	0.94	1.00	0.94	0.94	1.00
Diversified peak cooling demand (tons)	9,321	9,321	9,916	7,904	7,904	8,408
Thermal storage peak capacity (tons)	-	4,487		-	3,710	
Chiller firm capacity (tons)	9,321	4,834		7,904	4,194	
Number of chillers for firm capacity	6	4		6	4	
Chiller size (tons)	1,554	1,208		1,317	1,048	
Installed chiller capacity for N+1 (tons)	10,875	6,042		9,221	5,242	
Installed plant/equip capacity (tons)	10,875	10,530	14,341	9,221	8,952	12,139
Installed plant/equip cost ($)	$ 19,435,000	$ 18,290,000	$ 24,828,000	$ 17,354,000	$ 16,220,000	$ 23,088,000
Installed plant/equip cost ($/ton)	$ 1,787	$ 1,737	$ 1,731	$ 1,882	$ 1,812	$ 1,902

Table 6. Plant Capacity & Capital Cost

Land Cost Assumptions - Land requirements for each of the four district cooling plant alternatives were estimated, and land cost estimates calculated based on $22/SF, which is the average land cost on the east side of the City of Chula Vista where Site-A is located. Note that for this preliminary economic evaluation land costs were incorporated into overall capital cost for the district cooling alternatives, which will overstate annual operating costs for the district cooling scenarios by a small amount. While there is certainly a cost associated with the space occupied by individual building central plants for the Stand-alone analyses, due to difficulty of quantifying and valuing this space, the researchers did not include land costs for the Stand-alone alternatives in this evaluation.

Chilled Water Distribution System Assumptions & Capital Costs - Based on the customer base assumption for the analysis (All buildings less Types 13 & 14), the researchers developed a preliminary chilled water distribution system routing for the district cooling network, for use in developing capital cost estimates. A hydraulic model for this distribution routing was developed using TERMIS. Figure-7 is the nodal map from the model, which shows the assumed distribution pipe routing for the system. The pipe sizes and associated trench feet of piping that were determined via hydraulic modeling and used as the basis for capital cost estimation for the BPB scenario are presented in Table-7 below.

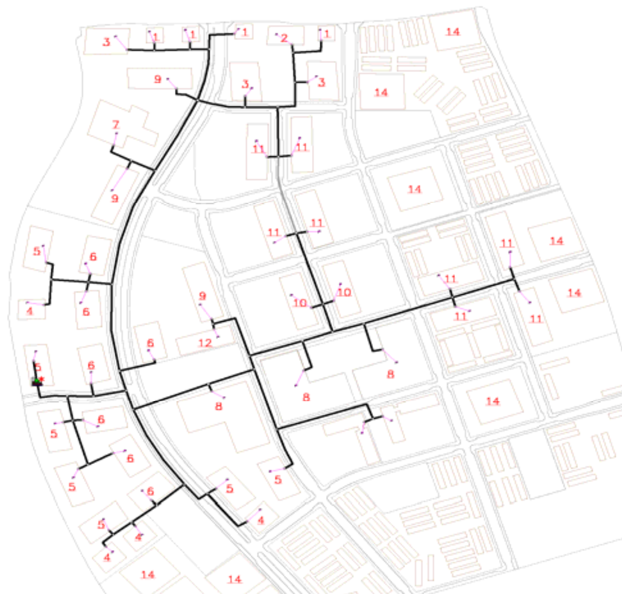

Figure 7. Chilled Water Distribution Piping System

Nominal Pipe Size	Trench Feet of Piping
3	485
4	1,806
5	3,589
6	1,679
8	2,356
10	2,244
12	495
14	733
16	629
20	296
24	227
Total	14,540

Table 7. Distribution System Pipe Sizes & Trench Feet

Building numbers on the piping map in Figure-7 comport with the building prototype identification numbers. The plant is assumed to be located on the west side of Site-A (and there may be an opportunity to locate the plant within a parking ramp for office buildings). Appendix-K contains a larger copy of this pipe routing map and Appendix-L contains a summary of distribution piping system capital costs.

For capital cost estimates, the researchers assumed that the distribution system would be constructed of pre-insulated, welded steel piping. If insulation is not required for some or all of the distribution piping, then distribution capital cost would be reduced. Whether or not insulation is economically justified and/or technically required depends on a variety of factors, such as climate, bury depth, supply water temperature maintenance requirements, and system phasing. A technical evaluation of insulation requirements was not undertaken within the scope of this evaluation, so current capital cost assumptions for distribution piping may be conservative, with respect to the feasibility of district cooling for Site-A.

Building Energy Transfer Station (ETS) Assumptions & Capital Costs - Energy Transfer Station (ETS) is a term used for the facility installed at a customer building where cooling is transferred from the district cooling system to the building's internal HVAC systems. The ETS installation typically consists of the following components:

- 1+ plate and frame heat exchangers transferring heat to the building's hydronic space heating system;
- A control valve or valves to regulate hot water flow through the heat exchangers;
- An energy meter to measure customer hot water demand and consumption;
- Piping, strainer(s), and isolation valves;
- Pressure and temperature gauges and/or transmitters;
- For larger ETS, controls integrated with overall system.

Energy transfer station capital costs were estimated for each of the prototype buildings in both of the development scenarios and are presented in Table-8 below.

Building Prototype ID #	Building Prototype Description	# Bldgs	Builder Baseline ETS Capital Costs	EE-PV Configuration ETS Capital Costs
1	Free Standing Restaurant	4	$79,200	$74,800
2	Multi Tenant Retail	1	$35,600	$25,500
3	Major Retailer	3	$123,800	$116,900
4	Low Rise Office	4	$142,600	$125,200
5	Mid Rise Office	7	$607,800	$512,300
6	High Rise Office	7	$1,186,300	$1,037,300
7	Hotel	1	$75,400	$75,000
8	Hotel/Comm./Retail	3	$374,100	$329,500
9	Retail/Commercial	3	$275,900	$239,200
10	Retail/Residential	2	$127,300	$112,500
11	Retail/Residential	8	$432,600	$359,700
12	Civic/Commercial	1	$109,600	$94,700
15	Residential Mid Rise	2	$71,700	$65,300
TOTAL - "All bldgs less Types 13 & 14"		46	$3,642,000	$3,168,000

Table 8. ETS Capital Costs

Building Energy Transfer Station (ETS) Assumptions & Capital Costs – Table-9 below summarizes capital cost estimates that were used in the economic analysis for this evaluation.

Capital Cost Item	Builder Baseline Scenario			EE-PV Configuration Scenario		
	District Cooling Without Thermal Storage	District Cooling With Thermal Storage	Stand-alone (Cooling Production at Individual Buildings)	District Cooling Without Thermal Storage	District Cooling With Thermal Storage	Stand-alone (Cooling Production at Individual Buildings)
DC plant / Building production equip.	$ 19,435,000	$ 18,290,000	$ 24,828,000	$ 17,354,000	$ 16,220,000	$ 23,088,000
Distribution piping system	$ 9,751,000	$ 9,751,000	$ -	$ 9,263,000	$ 9,263,000	$ -
Energy transfer stations (ETS)	$ 3,642,000	$ 3,642,000	$ -	$ 3,168,000	$ 3,168,000	$ -
Land purchase cost	$ 467,000	$ 515,000	$ -	$ 396,000	$ 437,000	$ -
Total	$ 33,295,000	$ 32,198,000	$ 24,828,000	$ 30,181,000	$ 29,088,000	$ 23,088,000

Table 9. ETS Capital Cost Summary

Operating & Maintenance Costs

Electricity Cost: Stand-alone Alternative - Electricity costs for the stand-alone alternatives were calculated for each building prototype using: annual space cooling related electric consumption including heat rejection (kWh) and the average unit electric cost for the building ($/kWh). Since electricity costs for the stand-alone alternatives were calculated using average unit cost for the overall building, building cooling production costs used in the analysis could potentially be overstated or understated, to the extent that average unit electricity cost for cooling production differs from average electricity unit cost for the balance of the building.

Electricity Cost: District Cooling Alternatives - For the calculation of electricity costs for the district cooling alternatives, the researchers obtained detailed manufacturer performance data for chiller selections specific to the City of Chula Vista's climate conditions. The chiller selections were made based on the following key criteria: 80°F design entering condenser water temperature (ECWT) *and* 40°F supply & 56°F return water temperature. ECWT of 80°F was selected based on an ASHRAE 0.4% design wet bulb temperature of 73°F and a 7°F cooling tower approach at design conditions.

Chiller performance data was obtained for district cooling plant configurations under both development scenarios. Performance data was obtained for peak conditions and also for a full range of part load and reduced ECWT conditions. Appendix-M lists performance data for the chiller selections utilized for the analysis, and demonstrates the dramatic improvement in efficiencies that can be achieved with chillers in series-counterflow arrangement and driven with VFDs.

Utilizing this chiller performance data, the researchers made estimates, for both the configurations under both development scenarios of: peak plant kW/ton for each month of the year, and average plant kW/ton for each of the six utility rate periods. These plant kW/ton estimates were generated by considering each of the following factors:

- Chiller EWTC, based on peak and average wet bulb temperatures extracted from binned temperature data for San Diego;

- Percent loading on individual chillers;
- Percent loading for overall plant (for estimating plant auxiliaries).

All of these kW/ton estimates were then used, in conjunction with the following items, to calculate annual electricity costs for each district cooling alternative:

- Utility electrical tariff;
- Plant monthly peak demand figures (tons);
- Plant cooling production figures (ton-hrs) for each utility rate period.

The rate tariff used for electricity cost calculations was SDG&E's Schedule AL-TOU. Secondary service was selected since the cost difference between primary and secondary service was very small and chiller selections were for low voltage units due to availability of low cost, unit mounted VFDs. Appendix-N lists rate tariff figures used in the analysis, including EECC and DWR-BC charges. To the researcher's understanding, there was a new demand and energy charge rate structure for the EECC commodity charge issued in May, 2008. Per discussions with SDG&E personnel prior to issuance of the new rate, its structure should be beneficial to large customers such as district energy plants. This new rate structure is not currently incorporated into the economic analysis for this evaluation.

Plant monthly peak demand figures used for electricity cost calculations were extracted from the aggregate 8760 data. Plant cooling energy production figures were developed as discussed above, and were presented earlier in Table-5. The electricity use and costs that the researchers calculated using the methodology are presented in the evaluation results contained in the next chapter of this report.

Other O&M Costs - Operating and maintenance costs for all items but electricity are presented in Table-10 below.

Operating cost assumption	Builder Baseline Scenario		EE-PV Config. Scenario	
	District Cooling	Stand-alone	District Cooling	Stand-alone
Water, monthly meter fee (US$/month)	$ 342	$ 342	$ 342	$ 342
Water, consumption rate (US$/HCF)	$ 2.614	$ 2.614	$ 2.614	$ 2.614
Water consumption (HCF per 1000 ton-hours)	2.67	2.76	2.62	2.72
Water treatment chemicals cost (US$/HCF)	$ 1.70	$ 1.70	$ 1.70	$ 1.70
Production equip. maintenance (% of capital)	1.50%	2.20%	1.50%	2.26%
Distrib. & ETS equip. maintenance (% of capital)	0.80%	N/A	0.80%	N/A
Operating labor (Full-Time-Equivalents)	6	9	6	9
Labor costs ($/FTE)	$ 65,000	$ 65,000	$ 65,000	$ 65,000

Table 10. Operating Cost Assumptions (except electricity)

Water consumption was calculated for each alternative based on chiller efficiency, using a cooling tower water balance tool. Water costs were determined using San Diego Water Authority commercial rates.

Annual maintenance costs were estimated as a percentage of capital cost. The production equipment maintenance costs in Table-10 for the stand-alone alternatives are based on figures of 2.0% for individual building chiller plants and 4.0% for heat pumps.

Operating labor full-time-equivalent (FTE) positions for the district cooling alternatives are based on the researcher's experience for a system of this size. FTEs for the stand-alone alternatives assumes approximately 1/3 of an FTE for each of the 26 buildings with chilled plants and no operating labor for the 20 buildings with individual split system heat pumps or unitary packaged AC.

Cost of Capital Assumptions - Cost of capital assumptions for the economic analysis are presented in Table-11. The district cooling alternatives have been assigned a longer term due to the fact that these are longer lived assets and investors in district cooling utilities generally have a longer term view than developers and builders.

Assumption Item	District Cooling	Stand-alone
Debt as % of total financing	70%	70%
Equity as % of total financing	30%	30%
Debt interest rate	5%	5%
Equity return on investment	15%	15%
Weighted average cost of capital	8%	8%
Term (years)	20	15
Capital recovery factor	0.102	0.117

Table 11. Cost of Capital Assumptions

Technical Considerations Regarding Assumptions

The assumptions carried for district cooling plant efficiency in this analysis presume that the system is operated efficiently, in a manner that maximizes the investment in district cooling infrastructure. One key requirement for efficient operation of a district cooling plant is that the district cooling developer work with designers of the customer buildings to ensure that they are designed and operated to provide desired return water temperature back to the district cooling plant, so that the plant does not suffer from the *low delta T syndrome*. The high-efficiency building HVAC systems planned for Site-A will already include the key features required to ensure high return water temperature (such as variable volume systems with 2-way valves at coils). Nonetheless, it will be important for compatibility of building HVAC designs with the district cooling system to be confirmed at an early stage in their development.

2.8 Community Design Option Modeling

Development Sites - At the time this research project was first proposed to the Commission (April of 2006), the researchers intended to: model the energy and emissions performance of developer-proposed land use, urban design, infrastructure and transportation elements for Site-A and Site-B; and to compare it to the performance of an enhanced set alternatives for each site.

However, by the time the research was initiated (April of 2007), Site-A had advanced to a stage in the development planning process where most of these spatial elements had become fixed, thereby precluding the modeling of alternatives for these elements. Fortunately many of these fixed elements incorporated the best of the Smart Growth design principles[9], so the research team elected to estimate the degree to which the developer's proposed plan for Site-A exceeded the efficiency and emissions performance expected of a conventional development plan for the site. Under this approach, the developer's plan for Site-A was considered the optimized scenario and the conventional plan was considered the baseline scenario.

For Site-B, a similar situation existed as many of its spatial elements had become fixed by the time the research team could model them. However, given the need to model the full array of alternative community design options, including transportation elements, the researchers elected to work with the Site-B developer to formulate a hypothetical site. The hypothetical site, labeled Site-X, was similar to Site-B in many respects, and incorporated building prototypes used in both Site-A and Site-B. Consistent with the modeling approach for Site-A, a conventional baseline scenario was also formulated to serve as the basis for comparison to the advanced alternatives modeled in Site-X. Figures-8 and -9 depict the two site utilization plans.

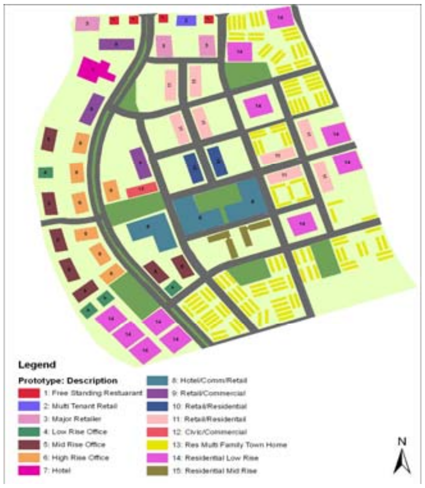

Figure 8. Site-A: Utilization Plan

Figure 9. Site-X: Site Utilization Plan

General Modeling Data, Tools & Assumptions - In order to model the energy and emissions impacts of alternative community design options, the researchers assembled and integrated a

[9] Smart Growth best practices can be found at: http://www.smartgrowth.org/about/principles/default.asp?res=1280

suite of land use planning, urban design and impact analysis tools. The objective of the modeling scenarios was to determine which options enabled the use of advanced energy-efficient technologies and which would significantly reduce energy consumption, related emissions, vehicle-miles traveled (VMT), stormwater runoff and the urban heat island (UHI) effect.

The databases imported into the community-scale modeling included:

- BEA and Energy10™ building energy and emission profiles for prototypical buildings from Sites-A and -B;
- Potable water, wastewater and infrastructure data from the City, developer and utilities;
- Grading and stormwater management data from the developer;
- Transit study data from the regional transportation planning agency (SANDAG).

As stated in the methods summary, the tools used for community-scale modeling included:

- CITYgreen™ – used to assess the impact of alternative green infrastructure elements;
- Mitigation Impact Screening Tool (MIST) – used to assess the impact of increasing urban albedo (reflectance) and/or urban vegetation in reducing the urban heat island effect;
- CommunityViz™ - used to model alternative land-use configurations; alternative transportation infrastructure, patterns and strategies; potable water and wastewater treatment infrastructure; and urban runoff. CommunityViz™ was also used to co-register and synthesize data inputs from the other software tools and to produce 360° visualizations and real-time impact simulations for stakeholder meetings in which alternative design options were evaluated.

Additional modeling inputs, outputs and assumptions for the modeling of sties A and X are contained in Appendices-P and -Q, respectively.

Community Design Options

The research team examined the energy efficiency and related emissions performance of five alternative community design options. These included:

- Mixed-Use, Moderate-Density Development;
- Urban Runoff Mitigation Measures;
- Carbon Sequestration Measures;
- Urban Heat Island Mitigation Measures;
- Passive Solar Building Orientation.

As stated earlier, the researchers modeled two scenarios for each site. The first was the baseline scenario that entailed a conventional approach to site development, without the aid of the alternative community design options. The second was the optimized scenario in which four of the five design options were applied to the two development sites. The fifth option, passive solar building orientation, was a limited examination and applied only to Site-X. A description of the methods used to model each of the design options is provided below.

Mixed-Use, Moderate-Density Development

Mixed-use, moderate-density development is characterized by the co-location of residential uses with commercial-office, commercial-retail and often public/institutional uses. Residents of a mixed-use community development typically have access to a variety of employment, shopping, recreational and entertainment amenities all within a quarter-mile walking distance from their homes. Mixed use developments often include a range and mix of housing options including single-family detached homes, attached townhomes, and multifamily condominium complexes, often with commercial retail and office space at ground- level or the second floor.

Moderate-density for this research project was defined as 11.2 dwelling units per-acre, whereas conventional development in the City of Chula Vista is typically 3.3 dwelling units per-acre. Moderate-density development encourages the use of public transportation and typically places the highest density housing options closest to transit corridors, station facilities and transit stops. Moderate-density developments will include a variety of structures that generally do not exceed 10-stories in height.

In addition to offering a variety of housing options and easy pedestrian access to amenities and rapid transit, moderate-density developments are believed by community planners to be more energy- and resource-efficient than lower density developments. To examine this belief further, the researchers sought to quantify the benefits of moderate-density development relative to the performance of advanced energy-efficient technologies and district energy systems at Site-A. The researchers also sought to quantify the benefits of moderate-density development vs. low-density development relative to petroleum consumption and vehicular air emissions and to land use efficiency for sites A and X. The methods and assumptions for each examination follow.

CCHP Technologies – Multi-story commercial office and retail buildings typically found in moderate to higher density developments are ideal candidates for the use of the advanced energy-efficient technology known as combined cooling, heating and power (CCHP) technologies, referenced earlier in this report. These technologies make more efficient use of energy resources by capturing waste heat produced in power generation for use in space conditioning (cooling or heating) and for the generation of domestic hot water. In the case of Chula Vista's climate, recaptured heat is best converted and utilized to meet commercial building cooling demands as heating and domestic hot water loads are generally insufficient to warrant use of the recaptured heat for those purposes.

To quantify CCHP energy efficiency and emissions performance in a moderate-density site and to compare it to the performance of the conventional approach to energizing and conditioning commercial buildings in a lower density site, the researchers conducted a two-part analysis.

Part one of the analysis entailed modeling the energy and emissions performance of CCHP systems at Site-A in a set of commercial buildings with sufficient thermal loads to make their use economical – the *optimized* scenario. Building prototype 6 (P6) was selected as the test building for the analysis as its size and associated cooling loads were substantial enough to warrant a central chiller plant based cooling system. This configuration entails substitution of some of the buildings' electric chillers with absorption chillers that can be driven by heat recovered from onsite distributed generation (DG) systems. In this case the prime mover in the system was an internal combustion (IC) reciprocating engine.

In the moderate-density, optimized scenario for Site-A, seven P6 prototype buildings were sited along with a mix of residential, retail and other commercial buildings. The P6 prototype is a nine-story office building with approximately 225,000 square feet floor area. The seven P6 buildings represent 1.5 million square feet of commercial space and when clustered together, promote adjacent residential, commercial retail and transit development as well.

Part two of the analysis focused on the low-density development scenario for Site-A (the baseline scenario) and the performance of a set of commercial buildings equivalent in square footage to the seven P6 buildings, but utilizing conventional space conditioning systems and no onsite power generation. The commercial building prototype common to lower density developments is prototype 4, a two- story office building of approximately 30,000 sq ft.   Figure-10 below provides a visual comparison of the two building prototypes used in the analysis.

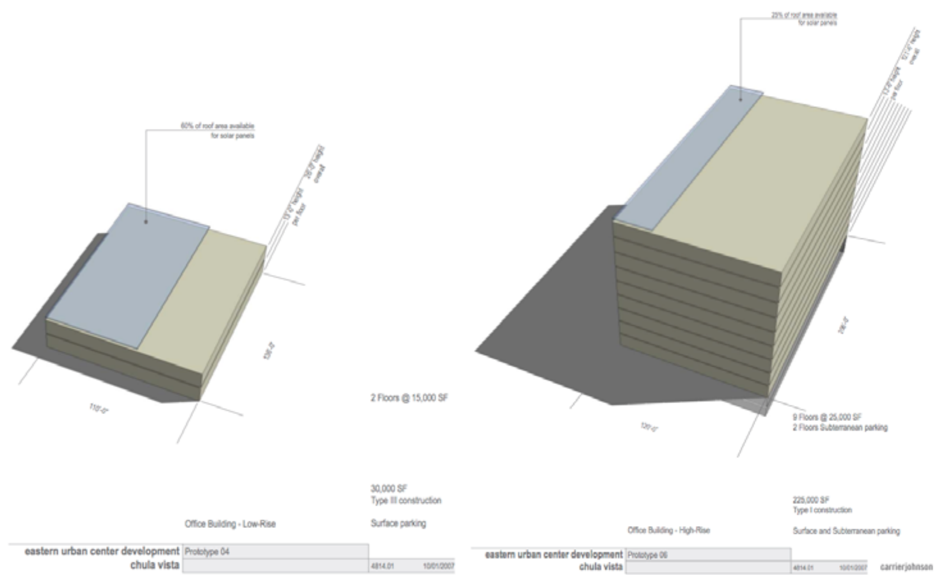

Figure 10. Comparison of Building Prototypes 4 (left) and 6 (right)

To determine the number of P4 buildings required to match the equivalent amount of space contained in seven P6 buildings, the researchers calculated the total square footage of the P6 structures in the optimized scenario for Site-A and divided that number by the square footage of one P4 building. Given this simple calculation, approximately 53 P4 buildings were needed to equal the space of seven P6 buildings. Table-12 below provides the basis for this calculation.

Building Space Conversion Calculation

Individual P6 High Rise Office Square Footage		224,640
Total P6 Buildings in Plan	×	7
Total P6 Square Footage		1,572,480
Individual P4 Low Rise Office Square Footage	÷	29,920
Individual P4 / Total P6 Square Footage (rounded)		53

Table 12. Site-A: Building Space Conversion Calculation

The aggregated energy and emissions performance results for the two sites under these different technology scenarios are presented in the next chapter. They are based on the following individual building energy consumption figures and the emissions factors below.

The calculated annual energy consumption of a P6 building equipped with CCHP technology is 684,148 kWh of electric energy and 21,807 MMBtu of natural gas. The calculated annual energy consumption of a P4 building without CCHP technology is 285,304 kWh of electric energy and 215 MMBtu of natural gas energy. Aggregate figures were generated by multiplying the annual energy consumption for each prototype by the number of those prototypes for the two development scenarios. With regard to the associated air emissions for energy consumption under the two scenarios, the following conversion factors were used:

- **CO_2**: 700.4 lbs/MWh of electric energy produced and 117.6 lbs/MMBtu of gas energy used at the building level;
- **SO_x**: 0.128 lbs/MWh of electric energy produced and 0.00059 lbs/MMBtu of gas energy used at the building level;
- **NO_x**: 0.352 lbs/MWh of electric energy produced and 0.092 lbs/MMBtu of gas energy used at the building level.

<u>District Energy Systems</u> - As noted earlier in this chapter, the researchers conducted an extensive technical and economic feasibility analysis on the use of a district cooling system vs. stand-alone building technologies to serve Site-A. In addition to that analysis, the researchers were interested in examining the role that development density plays in the economic feasibility of a district cooling system. To pursue this interest, the researchers conducted a comparative economic analysis of two district cooling configurations – the one designed to serve the optimized, moderate-density scenario, and the other to serve the baseline, low-density scenario for Site-A.

The key factors that determine the economic feasibility of a district energy system include the aggregate load density of the buildings served by the system and the capital costs for distribution piping and the energy transfer stations (ETS) located at each building served. To determine the aggregate cooling load density for the optimized Site-A scenario, the researchers aggregated the hourly load profiles for each of the served building prototypes referenced in the district cooling evaluation described earlier. This included all prototypes except for P13, P14 and P15.

To determine the piping and ETS capital costs for a similar district cooling system for the baseline/low-density scenario, the researchers generated a piping distribution plan to serve approximately the same amount of square feet of building space as the optimized scenario but in lower density structures across the baseline site. To equal the aggregate cooling load of the optimized scenario and/or approximately the same amount of space, more than twice as many lower density buildings were required. Table-13 contains the building distribution list for the baseline and optimized scenarios used in this analysis.

		Baseline		**Optimized**	
Bldg. ID	Description	# in Plan	Total Commercial Space (sq ft)	# in Plan	Total Commercial Space (sq ft)
1	Free Standing Restaurant	17	125,800	4	29,600
2	Multi-tenant Retail	15	300,000	2	40,000
3	Major Retailer (Big Box)	13	422,500	3	97,500
4	Low Rise Office	53	1,590,000	4	120,000
5	Mid Rise Office	8	800,000	7	700,000
6	High Rise Office	0	-	7	1,575,000
7	Large Hotel	0	-	1	171,000
8	Small Hotel	4	608,000	3	456,000
9	Retail/Office Mixed Use	0	-	3	315,000
10	Retail/Residential Mixed Use Mid Rise	0	-	2	66,000
11	Retail/Residential Mixed Use Low Rise	0	-	8	256,000
12	Civic/Office Building	0	-	1	22,200
Total		110	3,846,300	45	3,848,300

Table 13.   Site-A: Building Distribution List for the District Energy Density Analysis

To calculate the distribution piping costs for the low density scenario, the researchers first calculated the total trench-feet of pipe per-square-mile for the optimized scenario derived from the earlier district cooling evaluation. This number was then multiplied by the total area of the low-density scenario. For the moderate-density scenario, the researchers assumed an average piping cost of $650.00 per-trench-foot (assuming a pair of cooling pipes), which includes construction management and engineering costs and a 10% contingency.

In the low-density scenario it is likely that the average pipe size for the additional piping will be somewhat less than the average pipe size for the moderate-density scenario. However, this is offset by the necessity of larger pipe mains to maintain the same distribution pressure. Given this offset, $650.00 per-trench-foot for additional piping provides a reasonable estimation of the piping capital cost required in the low-density scenario. The total distribution piping cost for this scenario is then determined by multiplying this unit cost by the total length of piping required by the distribution plan.

The researchers calculated the additional ETS costs as a percent increase over the moderate-density scenario based on the average cooling load for each of the buildings served in the low-density scenario. As expected, ETS costs increase as there are more buildings being connected to the system but this is somewhat balanced by smaller loads for each building. Pumping costs were ignored because researchers made a reasonable assumption about maximum pressure for the distribution system, within a 150 psi pressure class limitation. A lower density scenario would not require more pumping power in this case, although the piping sizes may be marginally bigger. Because all piping assumed in the moderate-density scenario was pre-insulated (a conservative estimate in Chula Vista's climate zone), the incremental heat gain losses were not deemed to be significant relative to the increased capital costs required. The results of this analysis are presented in the following chapter.

<u>Petroleum Consumption & Vehicular Air Emissions</u> - To quantify the benefits of moderate-vs. low-density development sites relative to petroleum consumption and vehicular air emissions, the researchers examined their design features that influence vehicle-miles-traveled (VMT).

Mixed-use, moderate-density development is generally considered to result in lower VMT than lower density developments given the co-location of residences, employment and retail centers and entertainment amenities and through street and sidewalk patterns that promote better pedestrian access/opportunities. By contrast, low-density developments are generally considered to result in higher resident VMT due to their use of more curvilinear streets and cul-de-sacs, the intentional separation of uses, and incomplete sidewalks.

The researchers used the 4D method to compare the relative vehicle-miles-traveled (VMT) savings due to design features linked to population and employment densities, diversity of housing and jobs, accessibility to regional destinations, and the design of streets and sidewalks. Using the 4D approach, the researchers estimated VMT associated with the use of integrated building, land use and transportation development options for Site-A and Site-X and calculated energy, emissions and cost savings using generally accepted averages.

The 4D method enables researchers to estimate changes in vehicle trips (VT) and VMT as a result of changes in these community design factors. This measurement is calculated from empirically derived elasticities indicating how much the dependent variables (VT and VMT) change as a result of a unit change in each factor. For example, every 1% increase in the diversity factor results in a 0.032% decrease in VMT. Therefore, its elasticity is said to be -0.032. The elasticities are derived from studies commissioned by the U.S. Environmental Protection Agency (EPA) in support of their development of the Smart Growth Index tool, produced in association with Criterion Planners; and further refined by Hubbard and Walters at Fehr & Peers in their work in the Sacramento region and in connection with Blueprint Sacramento.[10] The use of 4D elasticities has been undertaken in several locations within California including San Louis Obispo, Contra Costa County, Humboldt County, and the San Joaquin Valley.[11] The elasticities used by the researchers for this project are provided in Table-14.

Factors	Vehicle Trips	Vehicle-Miles Traveled
Density	-0.043	-0.035
Diversity	-0.051	-0.032
Design	-0.031	-0.039
Destinations	-0.036	-0.204

(Source: USEPA 2002)

Table 14. 4D Elasticities

The four factors are measured in the following way:

- Density = Percent change in population and employment density calculated as [(population + employment) per square mile];

- Diversity = Percent change in jobs and population calculated as {1 – [absolute value (b * population – employment) / (b * population + employment)]} where:

  b = regional employment / regional population;

[10] Hess et al. 1999; Cervero and Kockelman, 1997; Hubbard and Walters 2006

[11] Loudon et al. 2007

- Design = Percent change in the "Design Index" calculated as [0.0195 * street network density + 1.18 * sidewalk completeness + 3.63 * route directness] where:
    - 0.0195 = coefficient applied to street network density, expressing the relative weight of this variable compared to the other design index variables
    - street network density = length of street in miles/area of neighborhood in square miles
    - 1.18 = coefficient applied to sidewalk completeness, expressing the relative weighting of this variable compare to the other design index variables
    - sidewalk completeness = length of sidewalk / length of public street frontage
    - 3.63 = coefficient applied to route directness, expressing the relative weighting of this variable compared to the other design index variables
    - route directness = average airline distance to center / average road distance to center.
- Destinations = Percent change in Gravity Model denominator for study Transportation Analysis Zones (TAZs) *i*: Sum[Attractions(*j*)*Travel Impedance(*i*,*j*)] for all regional TAZs *j*

Each factor is then multiplied by the related elasticity to arrive at a percent change in Home Bound (HB) VMT attributable to that factor. The addition of the four percent changes results in the total percent change in HB VMT for the modeled scenario.

The variable assumptions required to complete this analysis are derived from the following sources:

1. Study Area Size
    a. Derived from the total area of the site plans
2. Persons per household
    a. Baseline: derived from latest census for the City of Chula Vista
    b. Optimized: based on conversations with developers (higher density areas tend to have fewer persons per household)
3. Density
    a. Baseline: 3.3 dwelling units/acre based on a typical suburban gross density
    b. Optimized: derived from site plan and building dwelling unit assumptions
4. Dwelling Units
    a. Baseline: density × study area size
    b. Optimized: derived from the number of buildings and units per building indicated in the site plans

5. Population
   a. Persons per household × Dwelling Units
6. Employment
   a. Baseline: based on conversations with Chula Vista planning staff
   b. Optimized: total commercial area / 823 sqft per employee[12]
7. Regional Employment
   a. From SANDAG's 2030 Long Range Forecast (2008)
8. Regional Population
   a. From SANDAG's 2030 Long Range Forecast (2008)
9. Transit Percentage
   a. From SANDAG's mobility tables (2007)
10. Sidewalk Completeness
    a. Baseline: Assumption based on conversations with Chula Vista planners
    b. Optimized: Derived from site plans
11. Street Network Density
    a. Total street length / study area size in sq miles
12. Pedestrian Route Directness
    a. Derived through spatial analysis measuring the straight line distance and network distance to the center of the site (the ratio of these two measures represents the route directness)
13. Average Auto Trip
    a. From SANDAG (Data Warehouse: Transportation 2000)
14. Average Transit Trip
    a. Baseline: Based on conversations with SANDAG staff
    b. Optimized: Based on conversations with SANDAG staff (a separate SANDAG transit study was not conducted for this research project)

Tables-15 and -16 below contain the variable assumptions for Site-A and Site-X.

Parameter	Baseline	Optimized
Size – Acres	215	215
Persons Per Household	2.5613	2.0614
Population	1814	4946
Dwelling Units	550	2401
Employment	451	4723
Regional Employment	1,573,740	1,573,740
Regional Population	3,245,280	3,245,280
Transit Percentage	6%	6%

[12] Average amount of commercial floor area that equates to one job based on Commercial Buildings. (EIA, 1999)

[13] Based on 2000 Census mean for Chula Vista.

[14] Assumed persons per household based on developer assumption that includes a diversity of residents that draws down averages seen in single-family communities.

Sidewalk Completeness	75%	100%
Pedestrian Route Directness	0.60	0.71
Average Auto Trip	28 min	28 min
Average Transit Trip	40 min	35 min
Street Network Density	15 length / sq mi	15.3 length / sq mi

Table 15. Site-A: 4D Analysis Parameter Assumptions

Parameter	Baseline	Optimized
Size – Acres	310	310
Persons Per Household	2.56	2.06
Population	2618	9342
Dwelling Units	1023	4535
Employment	651	4888
Regional Employment	1,573,740	1,573,740
Regional Population	3,245,280	3,245,280
Transit Percentage	6%	6%
Sidewalk Completeness	75%	100%
Pedestrian Route Directness	0.60	0.76
Average Auto Trip	28 min	28 min
Average Transit Trip	40 min	20 min
Street Network Density	15 length / sq mi	16.5 length / sq mi

Table 16. Site-X: 4D Analysis Parameter Assumptions

The vehicular petroleum and emissions assumptions used in the analysis are provided in Table-17 below. [15]

Pollutant/Fuel	Emissions and Fuel Consumption rate (per mile driven)
Hydrocarbons	1.36 grams (g)
Carbon monoxide	12.4 g
Nitrogen oxides	0.95 g
Particulate matter (PM_{10})	0.0052 g
Particulate matter ($PM_{2.5}$)	0.0049 g
Carbon dioxide (CO2)	369 g
Gasoline consumption	.0417 gallons (gal)

Table 17. Vehicular Petroleum and Emissions Assumptions

[15] Values derived from *Average Annual Emissions and Fuel Consumption for Gasoline-Fueled Passenger Cars and Light Trucks*, Office of Transportation and Air Quality, USEPA, 2005.

Land Use Efficiency –To examine the impact of moderate density development on land use efficiency, the researchers conducted a simple land consumption analysis on sites A and X. In the analysis, the researchers took the number of dwelling units from the optimized scenarios for each site and divided them by the gross density figure of 3.3 units per acre (considered low-density development by the City of Chula Vista in its General Plan Update). The product of that calculation is the number of acres required to accommodate those dwelling units for each site at the reduced density. Gross density was used for this analysis as it accounts for roads, parks, non-residential units, and other infrastructure. Additionally, researchers calculated the land acquisition costs for the lower density comparison assuming an average land cost of $22/sq. ft. The results of this analysis are presented in the next chapter.

Urban Runoff Mitigation and Carbon Sequestration Measures

Urban runoff mitigation is the process of diverting stormwater flows from collection, retention, detention and/or storm sewer processing facilities. These measures are pursued by communities interested in reducing costs associated with the construction of these facilities; and in the case of processing facilities, in reducing energy consumption and energy-related air emissions associated with their operation. Although these are a number of different measures for diverting stormwater, the measures considered in this research project were the use of increased tree plantings and open space. Increased tree plantings also provide another benefit to communities through carbon sequestration and pollutant removal, assisting them in meeting their carbon and pollutant reduction goals.

To quantify the stormwater diversion performance and cost savings, and the energy consumption and carbon reduction benefits of these measures, the researchers compared two scenarios for sites A and X. The baseline scenario entailed minimal tree coverage on each site, while the optimized scenario introduced an additional 10% of tree coverage. The primary indicator for urban runoff mitigation is stormwater diversion for a two-year, 24-hour peak rain event. The volume diverted during such an event is measured in cubic feet and an equivalent dollar value can be calculated for costs associated with the construction of facilities to handle the diverted stormwater. The primary indicator for carbon sequestration is the number of tons of CO_2 stored in the biomass of planted trees. This section describes the tools, methods and modeling assumption used by the researchers to analyze the impact of urban runoff and carbon sequestration measures applied to both sites.

Urban Runoff Mitigation Analysis - The researchers used CITYgreen™ to analyze the ecological and economic benefits of tree canopies and other green/open space features for the baseline and optimized scenarios for each development site. CITYgreen™, built on the ESRI ArcGIS platform, allows users to derive assumptions from spatial datasets. The primary input to CITYgreen™ is a classified land cover dataset for each development scenario. Land cover assumptions were derived from site plan data provided by the developers and datasets derived from a variety of sources including aerial photography, satellite imagery and GIS vegetation layers. The datasets were classified into land cover features such as tree canopies, open spaces, impervious surfaces, and water surfaces, and configured into feasible landscape plans by the researchers to conduct the CITYgreen™ analysis.

Stormwater runoff, concentrations and peak flow were calculated by the research team through the use of the Urban Hydrology for Small Watersheds model, also known as the Technical Release 55 (TR-55) model. This model is commonly used by civil engineers in the design of stormwater management facilities and was developed by the Natural Resource Conservation Service, a bureau of the U.S. Department of Agriculture. CITYgreen™ uses the TR-55 modeling results to calculate the volume of runoff from land cover based on the two-year 24-hour rain event. This calculation allows researchers to examine the impact of tree planting on urban runoff and to estimate savings attributed to diverted stormwater.

CITYgreen™ produces this calculation by first assigning a Curve Number to each classified land cover type. A Curve Number is a parameter used in hydrology for predicting runoff potential and varies by land cover type and soil type.[16] The number ranges from 30 to 100 and lower numbers indicate lower runoff potential. The calculation of diverted stormwater is estimated by taking a site-wide Curve Number, weighted by percentage of each land cover type, under different scenarios and comparing them to a baseline (for example, a site with canopy versus a site with no canopy). The difference in the Curve Number between two scenarios then drives the calculation of the stormwater volume diverted using the TR-55 methodology. The equations for calculating the stormwater savings are provided below.[17]

Site Wide Weighted Curve Number (CN):
CN (weighted) = Total product of (CN × Percent land cover area) / total percent area or 100

Potential Maximum Retention After Runoff Begins:
S = ((1000 / CN) – 10)

Runoff Equation:
Q = [P - .2 ((1000 / CN) – 10)]2 / P + 0.8 ((1000 / CN) – 10)

Flow Length:
F = (total study area acres × 0.6) × 209

Lag Time:
L = ((F×0.8) × ((S + 1.0) × 0.7) / (1900 × ((slope) × 0.5)))

Time of Concentration:
$T_c = 1.67 \times L$

[16] Curve numbers for land use and soil types is contained in Appendix-R

[17] Derived from the CITYgreen User Manual, 2000, References and Appendices, p. 84

Unit Peak Discharge:

$\log(q_u) = C_0 + C_1 \times \log(T_c) + C_2[\log(Tc)] \times 2$

Peak Flow:

$Peak = (q_u \times A_m \times Q \times F_p)$

Storage Volume (this is the key indicator of how much stormwater savings result from tree planting):

$V_s = V_r \times (C0 + (C1(q_o/q_i)) + (C2 \times ((q_o/qi)^2)) + (C3 \times (qo/qi)^3)) \times$ study area acres $\times 43560.17 / 12$

Variable Definitions:

P	=	Average rainfall for a 24 hour period (inches)
A_m	=	Study area acres / 640 to determine square miles
F_p	=	Swamp pond percentage adjustment factor (based on the percentage of open water and swamp that exist on the site)
q_o	=	Existing peak flow condition with trees (cubic feet per second)
q_i	=	Peak flow without trees (cubic feet per second)
C_0, C_1, C_2	=	TR-55 coefficients in accordance with rain type[18]

Output Values:

Peak	=	Peak flow (cubic feet per second)
V_s	=	Storage volume (cubic feet)
V_r	=	Runoff volume (inches)
CN	=	Runoff curve number (weighted)
Q	=	Runoff (inches)
F	=	Flow length (feet)
S	=	Potential maximum retention after runoff begins (inches)
L	=	Lag time (hours)
T_c	=	Time of concentration (hours)
q_u	=	Unit peak discharge (cubic feet per second per square mile per inch)

Carbon Sequestration Analysis - Using the same land cover assumptions generated for the stormwater analysis, the researchers used the CITYgreen™ tool to calculate the air pollution removal and carbon storage and sequestration potential of the tree canopies for the two development sites.

The CITYgreen™ tool incorporates the USDA's Urban Forest Effects Model (UFORE) to calculate tree canopy potential to remove five criteria pollutants from the atmosphere. In addition to calculating the annual pollutant levels reduced through the use of tree canopies, the

[18] See table of coefficients by rainfall type in Appendix-S

model also calculates the associated dollars saved on negative externalities due to these pollutants such as increases in asthma and other respiratory ailments and decreases in tourism. CITYgreen™ estimates the amount of pollution in a given area based on data from the nearest city, in this case, San Diego. The pollution removal rate or flux (F) is calculated by multiplying the deposition velocity (V_d) by the concentration of the pollutant (C):

$$F\ (g/cm^2/sec) = V_d(cm/sec) \times C\ (g/cm^3)$$

Annual flux values are summed by estimating the total pollutant flux by hour over a surface in periods where pollutants are known to exist. These numbers are pre-calculated in CITYgreen™ for 55 modeled regions, including San Diego, and are expressed as the weight of pollutant removed per square meter of canopy.

The UFORE model was also used by the researchers to calculate the amount of carbon stored in the trees represented on the land cover maps for each development site and to calculate their annual carbon sequestration. While storage and sequestration varies by tree species and maturity, the researchers assumed a weighted average of trees appropriate for urban plantings. Based on assumptions of average carbon storage and sequestration for trees used in a typical urban forestry program, CITYgreen™ calculates a carbon storage and sequestration weight per square meter of canopy. Table-18 below provides the averages used by the researchers for this analysis.

	Weight per Square Meter
Carbon Storage	96.46 g
Carbon Sequestration	0.75 g

Table 18. Carbon Storage and Sequestration Canopy Assumptions

Tables-19 and -20 below provide additional assumptions used in the stormwater runoff, carbon sequestration and air quality analysis of both development sites.

	Baseline		Optimized	
Land Cover Type	Acres	Percent	Acres	Percent
Impervious Surfaces: Buildings/structures all other buildings	57.2	27.80%	57.1	27.70%
Impervious Surfaces: Paved - drain to sewer	36.2	17.60%	36.3	17.60%
Meadow: (Continuous grass, generally mowed, not grazed)	1.4	0.70%	1.4	0.70%
Open Space: Grass/scattered trees and grass cover > 75%	10.9	5.30%	10.9	5.30%
Trees: Grass/turf understory ground cover > 75%	3.4	1.70%	24.1	11.70%
Trees: Impervious understory	1.5	0.70%	1.4	0.70%
Urban: Commercial/business	95.5	46.30%	74.8	36.30%
Total	206.119	100.00%	206.1	100.00%

Table 19. Site-A: Land Cover Assumptions

Additional Site-A Assumptions:

Stormwater Runoff Assumptions (for the TR-55 calculations, see previous subsection):

P = 1.75 inches

A_m = .32 sq mi

F_p = 1.0

Soil Type = D (very impervious)[20]

Raintype = I[21]

Electricity Multiplier for Stormwater Processing: 652 kWh per acre-foot of water[22]

Air Quality Assumptions (for San Diego region):

Weight of Pollutant Removed Per Square Meter of Canopy[23]

Ozone	7.6 grams
Particulate Matter	5.6 grams
Nitrogen Dioxide	2.8 grams

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[19] Number excludes a portion of unplanned land that is within the original site, explaining the difference between the total area in this analysis and the 4D and land area analysis

[20] Used to determine the curve numbers associated with each land cover type. These values are contained in Appendix-T.

[21] Used to determine coefficient values for the TR-55 calculations. Appendix-S contains the table of Rain Types and associated coefficient values.

[22] Multiplier derived from Hoffman, Alan R. 2004. *The Connection: Water and Energy Security.*

[23] From air quality data associated with San Diego and packaged with CITYgreen

Sulfur Dioxide	0.8 grams
Carbon Monoxide	0.7 grams
Total	17.4 grams

Dollar Value of Pollutants Removed Per Square Meter of Canopy

Ozone	0.006767
Particulate Matter	0.004518
Nitrogen Dioxide	0.006767
Sulfur Dioxide	0.001653
Carbon Monoxide	0.000940

Weight of Stored Carbon per Square Meter of Canopy[24]

Young Trees	72.31 grams
Mature Trees	99.15 grams
Even Mix	120.89 grams
Unknown Age	96.46 grams

Annual Rate of Carbon Sequestration per Square Meter of Canopy[25]

Young Trees	1.62 grams
Mature Trees	0.17 grams
Even Mix	0.34 grams
Unknown Age	0.75 grams

	Baseline		**Optimized**	
Land Cover Type	Acres	Percent	Acres	Percent
Impervious Surfaces: Buildings/structures all other buildings	78.2	23.20%	78.2	23.20%
Impervious Surfaces: Paved - drain to sewer	82.2	24.40%	82.2	24.40%
Open Space - Grass/Scattered Trees: Grass cover > 75%	19.2	5.70%	19.2	5.70%
Trees: Grass/turf understory ground cover > 75%	16.8	5.00%	50.5	15.00%
Urban: Commercial/business	140.5	41.70%	106.8	31.70%
Total	33726	100.00%	337	100.00%

Table 20. Site-X: Land Cover Assumptions

[24] Based on average for typical trees used in urban forestry. (McPherson, Nowak, Rowntree 1994, 201) Please also see Tree Guidelines for Coastal Southern California Communities. McPherson, Scott, Simpson, Xiao, and Peper. 2000. http://www.fs.fed.us/psw/programs/cufr/products/2/cufr_48.pdf

[25] ibid.

[26] Number includes streets on the perimeter of the site.

Additional Site-X Assumptions:

Stormwater Runoff Assumptions:

P	=	1.75 inches
A_m	=	.53 sq mi
F_p	=	1.0
Soil Type	=	D (very impervious, based on the site's location)
Raintype	=	I (based on the site's location)

Electricity Multiplier for Stormwater Processing: 652 kWh per acre-foot of water

Air Quality Assumptions (for San Diego region):

Weight of Pollutant Removed Per Square Meter of Canopy

Ozone	7.6 grams
Particulate Matter	5.6 grams
Nitrogen Dioxide	2.8 grams
Sulfur Dioxide	0.8 grams
Carbon Monoxide	0.7 grams
Total	17.4 grams

Dollar Value of Pollutant Removed Per Square Meter of Canopy

Ozone	0.006767
Particulate Matter	0.004518
Nitrogen Dioxide	0.006767
Sulfur Dioxide	0.001653
Carbon Monoxide	0.000940

Weight of Stored Carbon per Square Meter of Canopy

Young Trees	72.31 grams
Mature Trees	99.15 grams
Even Mix	120.89 grams
Unknown Age	96.46 grams

Annual Rate of Carbon Sequestration per Square Meter of Canopy

Young Trees	1.62 grams
Mature Trees	0.17 grams
Even Mix	0.34 grams
Unknown Age	0.75 grams

Urban Heat Island Mitigation Measures

According to the U.S. EPA, the "the term "heat island" describes built up areas that are hotter than nearby rural areas. The annual mean air temperature of a city with 1 million people or more can be 1.8–5.4°F (1–3°C) warmer than its surroundings. In the evening, the difference can be as high as 22°F (12°C). Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality".[27]

The UHI effect can be mitigated through the use of lower-albedo (less reflective) materials on urban surfaces as well as through trees plantings. To quantify the impact of these measures on energy consumption for sites A and X, the researchers modeled two scenarios for each – one that included use of these measures and the other that did not include them. Site-wide albedo was then calculated for both scenarios. Using MIST, the average temperature reduction and percent reduction in energy for residential, office and retail buildings was then calculated and applied to the energy usage assumptions calculated for each prototype. This tool and the modeling approach is detailed below.

The Mitigation Impact Screening Tool (MIST) was developed by the U.S. EPA to analyze alternative urban heat island mitigation measures for development sites. MIST provides qualitative assessments of the likely impacts of heat island effect mitigation measures averaged at the city-scale[28]. Measures investigated include highly reflective construction and paving materials and urban vegetative cover. The researchers also used MIST to investigate average temperature reduction and to estimate the resulting impacts on ozone and energy consumption.

Once the research team examined a range of albedo, vegetation and combined albedo-vegetation scenarios for each site, MIST was used to extrapolate the results from a set of detailed meteorological model simulations for the San Diego region. These meteorological impacts were then combined with energy and tropospheric ozone air quality models to estimate the impact that the specified mitigation measure(s) may have on the development sites. It should be noted that the MIST results are intended only as a first-order estimate that urban planners can use to assess the viability of heat island mitigation strategies for their communities. Attachment-N contains a more detailed description of the atmospheric modeling, domain definitions, and control simulations components of MIST.

To establish the baseline for both Site-A and Site-X, the researchers applied a reflectance assumption to urban surfaces (roads, sidewalks, parks, roofs, etc.). The baseline represented the minimum requirements for roof albedo in California and typical developer paving choices for roads. The specific values are referenced later in this section.

[27] U.S.EPA Heat Island Home Page at: http://www.epa.gov/heatisland/index.htm

[28] MIST atmospheric modeling definitions and control simulations are contained in Attachment-I

An optimized scenario was then created for each site that included use of mitigation measures including "cool" roof coatings and road pavement. Because MIST uses a site-wide albedo differential as an input, the team developed a weighted measure of site-wide albedo for different types of surfaces. There were some challenges in estimating the different types of surface cover as these analyses were based on conceptual site plans that had no or little indication of parking, pathways, courtyards and other fine grained details. After removing roads, sidewalks, roofs, and parks that are specifically represented in the plan, there remained a large percentage of unclassified land cover in each site.

The researchers could not reasonably assume that all of the remaining land cover would be of one type. However, absent specific plans for these areas, estimating a large range of land cover types would not contribute significantly to the analysis. Instead, a general assumption was made that unclassified land would be divided into two categories: pavement and open space. Since these assumptions were applied equally to both sites, the relative differences still revealed impacts associated with the use of urban heat island effect mitigation measures.

To arrive at a reasonable mix of pavement and open space within the unclassified areas of each site, the team assumed a total pavement area coverage of 41%. This assumption was derived from analysis conducted of the Sacramento metropolitan region characterizing the urban fabric.[29] In the report, researchers found that approximately 41% of areas characterized as downtown/city center are comprised of pavement.

While the CVRP study areas are not as dense as a typical city center, they are more closely related in character to these areas than outlying residential, office or industrial areas. Therefore, the researchers believe that this is a reasonable estimate for the study areas, acknowledging that pavement cover varies widely from community to community. It is likely that the percentage of pavement would be lower in less dense areas, but these areas amount to little more than one-third of the total CVRP study area.

In each site, there is a specified amount of paved area classified as streets and sidewalks. The percent coverage of these areas was calculated and then subtracted from the target coverage of 41%. This remaining percentage represented the relative share of the unclassified land that was classified as paved. The remaining percentage of the unclassified land was classified as open space and assumed to be covered by grass and vegetation. Using these assumptions, a weighted albedo was calculated for the unclassified land and used in calculating the site's total weighted albedo.

The albedo assumptions are driven by the type of material covering each land cover type. The goal of this analysis was to illustrate how a change of materials can reflect more sunlight and lower the overall ambient air temperature in a development site. The optimized scenario featured higher albedo materials for key land cover types, and specifically roofs and streets.

The baseline scenario for both sites assumed the use of the following materials:

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29 See Rose, Akbari, Taha. 2003

- Streets: Asphalt (Albedo .04)
- Sidewalk: Gray Portland cement concrete (Albedo .45)
- Roof: Minimum required cool roof (Albedo .7)
- Park and Open Space: Grass and vegetation (Albedo .23)
- Parking Lots: Asphalt (Albedo .04)

The optimized scenario for both sites assumed the following materials:

- Streets: Asphalt with 6 inch whitetopping (Albedo .45)
- Sidewalk: Gray Portland cement concrete (Albedo .45)
- Roof: Double coat of cool roof coating (Albedo .85)
- Park and Open Space: Grass and vegetation (Albedo .23)
- Parking Lots: Asphalt (Albedo .04)

Site-A: Urban Heat Island Effect Analysis Assumptions

Site-A: is divided into the five main land cover types: street, sidewalk, roof, park, and unclassified cover as indicated in

Table below. The albedos described above were applied to the same area for the baseline and the optimized scenarios and then weighted according to the percent coverage. Tables-21 and -22 indicates how the unclassified area albedo was derived according to the approach described above. The resulting difference (delta) of 0.09 is the relative increase in albedo between the baseline and optimized scenarios. MIST uses this number to arrive at the relative energy savings attributable to the increase in albedo and vegetation.

			Surface Albedo		Weighted Albedo		
Land Cover	% Cover	Area (sq feet)	Baseline	Optimized	Baseline	Optimized	Delta
Street	10.93%	981,533	0.04	0.45	< .01	0.05	0.05
Sidewalk	7.35%	659,715	0.45	0.45	0.03	0.03	0
Roof	27.18%	2,440,558	0.7	0.85	0.19	0.23	0.04
Park	6.98%	627,038	0.23	0.23	0.02	0.02	0
Unclassified	47.56%	4,270,294	0.19	0.19	0.1	0.1	0.02
Total	100.00%	8,979,139			0.34	0.43	0.09

Table 21. Site-A: Albedo Assumptions Based on Surface Type

The researchers generated a set of variable assumptions for the site to be used in the MIST calculations. These included the following:

- Population: 4,946
- Latitude: 32.6
- Annual mean temperature: 63.7

- Annual cooling degree days (65F Base)[30]: 862
- Annual heating degree days (65F Base): 1,321

Site-A:	Parameter	%
	% Target Pavement Cover	41%
	% Pavement in Plan	18%
Unclassified Split	% Parking	23%
	% Open Space	77%
Weighted Albedo	Parking	0.01
	Open Space	0.18
	Total Weighted Albedo	0.19

Table 22. Site-A: Reflectance Assumptions for "Unclassified" Land cover

These assumptions and the relative albedo differences were then used as input for the MIST analysis of the site that produced a range and mean reduction in ambient air temperature and a related reduction in energy requirements for buildings in three general categories: residential, office, and retail. The team applied these percent reductions to the building modeling data for the baseline energy profile. The result was an aggregate energy reduction and related cost reductions that are provided in the results section of this report.

Site-X: Urban Heat Island Effect Analysis Assumptions

Site-X was also divided into the five land cover categories and weighted albedo values were calculated for the site. Tables-23 and -24 provide these values.

			Surface Albedo		Weighted Albedo		
Land Cover	% Cover	Area (sqft)	Baseline	Optimized	Baseline	Optimized	Delta
Street	17.91%	2,589,600	0.04	0.45	0.01	0.08	0.07
Sidewalk	6.12%	885,381	0.45	0.45	0.03	0.03	0
Roof	23.57%	3,408,049	0.7	0.85	0.16	0.2	0.04
Park	5.05%	730,516	0.23	0.23	0.01	0.01	0
Unclassified	47.35%	6,848,348	0.2	0.2	0.1	0.1	0
Total	100.00%	14,461,897			0.3	0.41	0.11

Table 23. Site-X: Albedo Assumptions Based on Surface Type

[30] Cooling Degree Days (CDD) are a measure of how many degrees above the base (65F) are experienced in a year. Subtracting 65 from the average temperature in a given day results in the number of CDDs. Summing all of these over the year produces the annual CDD number used here. Similarly, Heating Degree Days are a measure of how many degrees below the base are occur per year.

Site B	Parameter	%
	% Target Pavement Cover	41%
	% Pavement in Plan	24%
Unclassified Split	% Parking	17%
	% Open Space	83%
Weighted Albedo	Parking	0.01
	Open Space	0.19
	Total Weighted Albedo	0.2

Table 24. Site-X: Reflectance Assumptions for "Unclassified" Land cover

The relative difference in albedo became one of the variables entered into the MIST analysis as in Site-A: along with the following assumptions:

- Population: 9,342
- Latitude: 32.6
- Annual mean temperature: 63.7
- Annual cooling degree days (65F Base)[31]: 862
- Annual heating degree days (65F Base): 1,321

Again, the team applied MIST outputs to the building energy consumption data to arrive at approximate aggregate energy and emission reductions detailed in the results chapter of this report.

Passive Solar Building Orientation

The spatial modeling team also sought to quantify the impact that passive solar building orientation could have on energy consumption in a development project. It should however be noted that this analysis was of a very limited nature given that the National Renewable Energy Laboratory (NREL) is currently conducting an exhaustive study of the subject for the Energy Commission.

Passive solar building orientation entails the placement of a building on a site with the explicit intention of maximizing the sun and shade for heating and cooling in order to reduce energy use and cost. By facing the long side of a structure to the south and the short sides to the east and west and including overhangs or awnings over windows, the structure will capture solar heat in the winter and block solar gain in the summer. This can also be accomplished by

[31] The same CDD and HDD assumptions are made for Site-X as were made earlier for Site-A

minimizing the windows on the east and west sides of the structure and by increasing window cover on the south side. A true passive solar designed building will also make use of a thermal storage mass (thick dark walls that can absorb heat during the day and release it at night) and shading by trees to decrease heat in the summer. The single-family homes modeled in this limited study are not modeled with all of these features.

A building that is oriented toward the sun with more glazing on the south side (up to about 10 percent of floor area) is considered *solar tempered*. The single family homes modeled in this study more accurately fit within this category. Only one single family home was modeled for this analysis as the other residential buildings were multi-family buildings. These higher density buildings would see asymmetric benefits as some of the units would be unable to take full advantage of orientation being shaded by adjacent mid-rise or high-rise buildings. Also, glazing on these prototype buildings tends to be evenly distributed. Although it is possible to incorporate certain features of passive solar design into these buildings to take better advantage of natural light, these design features were not explicitly modeled.

To quantify the energy reduction potential of passive building orientation in Site-X, the researchers modeled a single-family home (Prototype 1 in Site-B) at thirty-degree intervals starting from north (0 degrees). This prototype has an attached garage in the front and is shorter on the entry side. Thus, when the building faces north, the long side of the structure faces east and west where most of the glazing is located. To reveal the impacts of orientation, the annual gas and electric usage are plotted against orientation in thirty-degree intervals. The results of this analysis are found in the next section.

Community Design Option Market Feasibility

Determining the market feasibility of the community design options modeled in this research was hampered by the lack of cost information associated with these options in the U.S. or abroad. As a surrogate for direct cost analysis of these options, the team examined the projected energy cost savings associated with the use of urban heat island mitigation measures on the two development sites and the cost of those measures. The energy and emissions savings from the building energy modeling work and the MIST calculations was used for the first half of this analysis while the incremental costs for whitetopping of streets, improved roof coatings and additional tree plantings were used for the second half of the analysis. These costs include the following:

- Whitetopping: $4.00 /sq yd./in[32]
- White roof coating: $0.20 /sq ft.[33]
- Tree: $445.00 per tree (including labor)[34]

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[32] US EPA 2005 *Cool Pavement Report*

[33] PG&E *Cool Roof Design*

[34] Costs derived from discussions with planning department personnel at the City of Chula Vista. The number of trees were estimated by dividing the total canopy area by the average tree canopy size, 1116 sq feet, estimated by Rosenzweig and Solecki, 2006

2.9 Market & Public Policy Analysis

In addition to modeling the performance, construction and utility impacts of building energy technologies, assessing the feasibility of a district energy system and examining the performance of community design options, the researchers also conducted a market and policy analysis to:

- Determine the maximum incremental cost that the California building industry and consumers will accept for energy-efficient residential, commercial, industrial and institutional structures; and to
- Determine which financial and business models and associated public policies and incentives will lead to accelerated deployment of EE, DR, RE and DG technologies in typical development projects throughout the State of California.

Several research methods were employed to pursue these objectives including: a literature review of related industry, government and utility research and policy initiatives; workshops with community development stakeholders; and surveys and interviews with practitioners and leaders of the real estate development and finance industries. A brief description of these methods is provided below.

Literature Review – The researchers conducted a review of recently published studies on both the incremental costs of energy-efficient buildings, and the barriers underlying the reluctance of developers and builders to invest in them. They also reviewed recent government and utility policy/planning documents to ensure that their evaluation of alternative financial, business and policy incentives was set within a relevant institutional context. During this review, the researchers paid particular attention to documents recently published by: the National Association of Industrial and Office Properties (NAIOP); the National Science and Technology Council Committee on Technology; the California Energy Commission; the California Air Resources Board; the California Public Utilities Commission and the California Investor-Owned Utilities. The most relevant publications reviewed are listed at the end of this report.

Stakeholder Workshops – The researchers conducted three stakeholder workshops during the course of the project to advance the second market and policy research objective listed above. Participants at the workshops included but were not be limited to, representatives of the: (1) real estate development transaction chain, including investors, lenders, developers and builders, design professionals, brokers and appraisers; (2) environmental organizations and community advocacy groups; and (3) local and state government agencies.

The first workshop was designed to further define the market and policy analysis task and to solicit input from the Chula Vista Research Project Advisory Committee[35] and from key members of the San Diego-area development industry and academic institutions. The input enabled the researchers to refine the definition of several key project terms that were used in the subsequent survey and interview sub-tasks, including the term - *Energy-Efficient Community*

[35] The Chula Vista Research Project Advisory Committee list is contained in Appendix-U

Development.[36] Input received during the first workshop also resulted in the generation of four subordinate questions the researchers were advised to consider in addressing the two primary research objectives for this task. These questions became the focus of the second workshop and included the following:

1. What are the most significant policy, regulatory and market barriers to investment in energy-efficient community development projects in California?
2. What are the perceived and real additional costs associated with the design and construction of energy-efficient community development projects? What potential public policies, incentives and other financial assistance could reduce these costs?
3. What are the perceived financial barriers and risks that prevent capital market entities from investing in energy-efficient buildings and community development projects?
4. What is the current market demand and/or acceptance level for energy-efficient development projects and what is necessary to increase that demand and acceptance?
5. What are the perceived benefits for developing energy-efficient homes, buildings, and communities? What are the effective means to increase those identified benefits?

During the second workshop, 55 representatives from the aforementioned organizations were divided into five discussion tables to explore each of the research questions developed in the first workshop. A discussion summary worksheet was completed by each table and was presented to all participants during a concluding plenary discussion.

During the third workshop, the list of barriers and solutions were prioritized[37] and the highest ranked barriers became the focus of strategic problem-solving break-out sessions among the participants. These sessions produced a preliminary strategy to address each barrier through collaborative action among government, industry, utility, academic and advocacy organizations. The strategies were then presented and discussed by the participants in a concluding plenary session.

<u>Capital Market Survey</u> – The researchers conducted an online capital market survey to determine the perceived risks and barriers associated with investment in energy-efficient buildings and community development projects. The target group for the survey was the real estate finance/investment/development industries (i.e. lenders, equity investors and developers). The survey instrument used by the researchers was Survey Monkey[38]. In addition to the research questions, additional information was also requested from the respondents to enable the research team to stratify and analyze their responses by market segment. A total of

[36] Defined as: Development of residential, commercial, and mixed-use structures and community infrastructure that integrate renewable and advanced energy-efficient technologies and performance enhancing urban design, to substantially reduce energy consumption and greenhouse gas emissions.

[37] Prioritization of the barriers and solutions was achieved through the use of a keypad voting system that enabled individual participants to vote anonymously, and simultaneous tabulation and presentation of the aggregate scores for all participants.

[38] Surveymonkey.com

120 respondents completed the surveys that were collected over a 15-day period, beginning on June 15, 2008 and ending on June 30, 2008.

Development Industry Survey – The researchers conducted an additional survey of the development, building and allied industries to directly advance the first market and policy analysis objective – to determine the maximum incremental cost their industries and consumers would accept for energy-efficient residential, commercial and industrial structures. Once gain, e-mail invitations to participate in the survey were sent to local members of the National Association of Industrial and Office Properties (NAIOP) and to members of the California Building Industry Association (CBIA).

The survey solicited participant responses to the incremental costs calculated for the three energy-efficient building measure/technology options modeled earlier in the research (i.e.: the EE, EE-PV and EE-DG options). These costs were expressed as an increment to the per-square foot building construction costs. The surveys utilized attitudinal questions and a Liker Scale to measure the degree to which the respondents agreed or disagreed with the market feasibility of the incremental costs modeled for each option. The survey also solicited estimates from the respondents on the maximum incremental costs they believed the current marketplace and consumers could sustain for buildings featuring these options. And again, information was also requested to enable the research team to stratify and analyze the responses by market segment. A total of 22 respondents completed the surveys on surveymonkey.com over a 19-day period, beginning on August 22, 2008 and ending on September 10, 2008.

Telephone Interviews – Findings from the stakeholder workshops and both surveys were the subject of follow-up telephone interviews with leaders of the CBIA, representatives from member companies and several of the leading "green" production homebuilders in the State. The interviews were designed to further examine incremental cost and risk factors associated with green building and development and to solicit needed public policies and incentives to support energy-efficient community development in California.

Chapter 3. Project Results

This chapter provides the results of the analytical methods employed to address each of the six research objectives in the project. These objectives are repeated below for reader convenience and then again independently of one another under the relevant section headings below.

1. Estimate the relative energy efficiency and emissions reduction performance of individual energy efficiency (EE), demand response (DR), renewable energy (RE) and distributed generation (DG) technologies (advanced energy technologies) in typical development projects (residential, commercial, industrial, institutional);
2. Determine the extent to which the application of these technologies, in typical development projects, will reduce peak demand and result in better utilization of existing utility infrastructure;
3. Determine the market-feasible combinations of energy technology and design options that will increase building energy efficiency by more than 25% above existing Title-24 2005 standards;
4. Estimate the degree to which enabling community design options (i.e., mixed-use/ moderate density/transit-oriented development; stormwater runoff and carbon sequestration measures; urban heat island reduction measures; and passive solar building orientation) can improve energy technology performance in typical development projects;
5. Determine the maximum incremental cost that the California building industry and consumers will accept for energy-efficient residential, commercial, industrial and institutional structures;
6. Determine which financial and business models and associated public policies and incentives will lead to accelerated deployment of EE, DR, RE and DG technologies in typical development projects throughout the State of California.

3.1 Building Energy Technology Performance

This section of the results addresses the following research objective:

- Estimate the relative energy efficiency and emissions reduction performance of individual energy efficiency (EE), demand response (DR), renewable energy (RE) and distributed generation (DG) technologies (advanced energy technologies) in typical development projects (residential, commercial, industrial, institutional).

Given that Site-A and Site-B are distinct from one another relative to their site utilization plans, mix of building types, and demand loads, the results of the energy technology performance modeling are presented below under separate sub-sections beginning with Site-A.

3.1.1 Site-A: Gas and Electric Utility Use Impacts

Figure-11 below presents the results of the four modeled development options relative to their impact on site-wide annual energy (gas and electric) consumption. Again the four options entailed development of Site-A utilizing: standard building materials and equipment - the builder's proposed baseline; buildings enhanced with energy efficiency features - the EE package; buildings enhanced with the EE package and solar photovoltaic panels – the EE package w/PV; and buildings enhanced with the EE package and distributed generation technologies/the EE package w/DG.

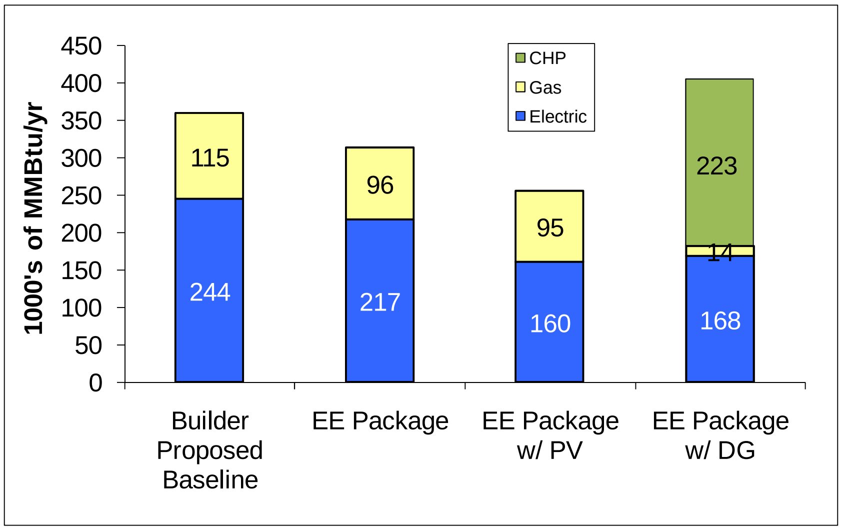

Figure 11. Total Annual Energy Consumption (all buildings)

The analysis of the results indicate that implementation of all applicable and economically feasible EE options on all suitable buildings can lower Site-A annual energy consumption from the builder proposed baseline of 359,000 MMBtu to 313,000 MMBtu, or by 12.8%. Implementation of the EE-PV option on all suitable buildings could further reduce electric grid and natural gas utility consumption to 255,000 MMBtu or by 27.8% compared to builder's baseline option. Deployment of the EE-DG option on all suitable buildings would not be as effective in reducing Site-A consumption of grid-provided electric energy as the EE-PV option, however it can still lower that consumption to 168,000 MMBtu from the 217,000 MMBtu expected from use of the EE option alone. On the other hand natural gas consumption will increase significantly reaching 237,000 MMBtu as compared with 95,000 MMBtu for the EE option. The increase results in the highest natural gas consumption of any of the modeled development scenarios.

It should be noted that Figure-11 shows consumed electric and natural gas energy expressed as Btu or the heat content of equivalent utilities. Although often used, a strict Btu analysis doesn't reflect other important factors associated with the value of energy imported/consumed by a community at different times of the day and year. Therefore, the results of the Site-A energy efficiency analysis are also presented using the Title-24 prescribed *Time Dependant Valuation*

(TDV[39]) approach. However, to further enhance the accuracy of the modeling, the researchers included appliances and other internal loads in their analysis not accounted for by a standard Title-24 TDV approach. This enhanced modeling method is termed the *Time Dependant Valuation Inclusive* approach (TDVI[40]).

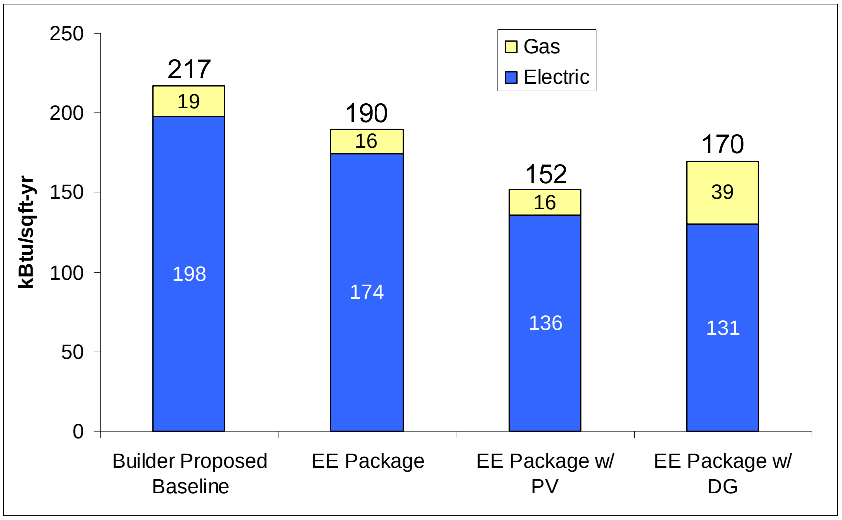

Figure 12. TDVI Energy Consumption (all buildings)

Figure-12 indicates that implementation of the EE option can lower Site-A TDVI energy consumption from the builder proposed baseline of 217 kBtu/sf-year to 190 kBtu/sf-year, or by 12.1%. Implementation of the EE-PV option could further reduce TDVI energy consumption to 152 kBtu/sf-year or by a total of 31.3% compared with the builder proposed baseline. Similar to the results shown in Figure-11, deployment of the EE-DG option would not be as effective in reducing Site-A TDVI energy consumption as the EE-PV option. However in contrast to Figure-11, where energy is expressed in Btu and EE-DG shows the highest use (at TDVI energy

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[39] Time-Dependent Valuation (TDV) is the method for valuing energy in the performance approach contained in the 2005 Building Energy Efficiency Standards, aka Title-24, 2005. Under TDV the value of electricity differs depending on time-of-use (hourly, daily, seasonal), and the value of natural gas differs depending on season. TDV is based on the cost for utilities to provide the energy at different times. For more information visit:

http://www.energy.ca.gov/title24/2005standards/archive/rulemaking/documents/tdv/index.html

[40] Time Dependent Valuation Inclusive (TDVI) energy consumption accounts for all building energy uses including energy consumed by appliances, plug loads and lights. Use of TDVI in calculating building energy efficiency differs from the use of TDV calculations conducted for Title-24 building compliance certification where the energy used for cooling, heating and domestic hot water is used as indicator of residential building energy efficiency. The Title-24 commercial building TDV method does however account for lights and receptacles load. Use of TDVI in the modeling enabled the researchers to gain a better understanding of the impacts of various EE measures on overall building energy consumption than was possible using Title-24 certification software such as Energy PRO 4.3 or Micropas7 v. 7.3.

consumption of 170 kBtu/sf-year), the EE-DG option is 33.8% better than the builder proposed baseline TDVI energy consumption. This illustrates the benefit of DG technology which, while increasing consumption of a low TDVI valued fuel like natural gas, can significantly decrease consumption of high TDVI valued electricity from the grid.

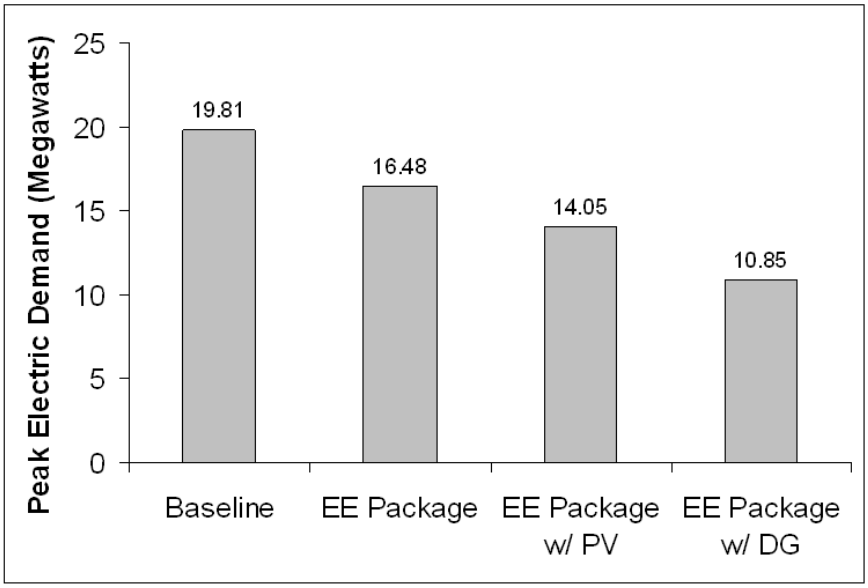


Figure 13. Peak Electric Demand (all buildings contributions)

	Peak MW	Total Cost	$/kW for Reduced Peak Demand
Baseline	19.809	-	-
EE Package	16.478	$10,068,880	$3,023
EE Package w/ PV	14.045	$55,372,374	$9,607
EE Package w/ DG	10.851	$15,795,566	$1,763

Table 25. Specific Cost of Electric Peak Demand Reduction

Peak demand reduction is an essential objective of community-scale energy efficiency and integrated energy technology and urban design. Figure-13 presents the impact on peak demand of the four modeled development options and Table-25 lists their implementation costs. Implementation of the EE option would result in lowering Site-A electric peak demand from the builder proposed baseline of 19.81 MW to 16.48 MW, or by 16.8%. At $3,023 / kW this is also the second least expensive of the three analyzed options to lower peak demand. Implementation of the EE-PV option could further reduce electric peak demand to 14.05 MW or by a total of 29.1% compared with the builder proposed baseline. At $9,607 / kW this is the most expensive of the three analyzed options to lower peak demand. Implementation of the EE-DG option could reduce Site-A electric peak demand to 10.85 MW which is better than EE-PV option and 45.2% less compared with the builder proposed baseline. The specific cost of implementing this option is $1,763 / kW reduced.[41]

3.1.2 Site-A: Environmental Impacts

Figures-14 through -16 present the cumulative annual air emissions associated with the Site-A annual electricity and natural gas consumption under the four development options. The calculations are based on the conversion factors contained on page-190 of Appendix-A and assume end-use delivery efficiency of 92% for electricity and 98.4% for natural gas.

Figure-14 indicates that implementation of the EE option can lower Site-A annual CO_2 emissions from the builder proposed baseline of 30,924 metric tons/year to 27,174 metric tons/ year, or by 12.1%. Implementation of the EE-PV option could further reduce CO_2 emissions to 21,403 metric tons/ year, or by 30.8%. Deployment of the EE-DG option would be less effective in reducing Site-A CO_2 emissions as the EE-PV option, however at 28,865 metric tons/year it is still 6.7% lower than the builder proposed baseline CO_2 emissions.

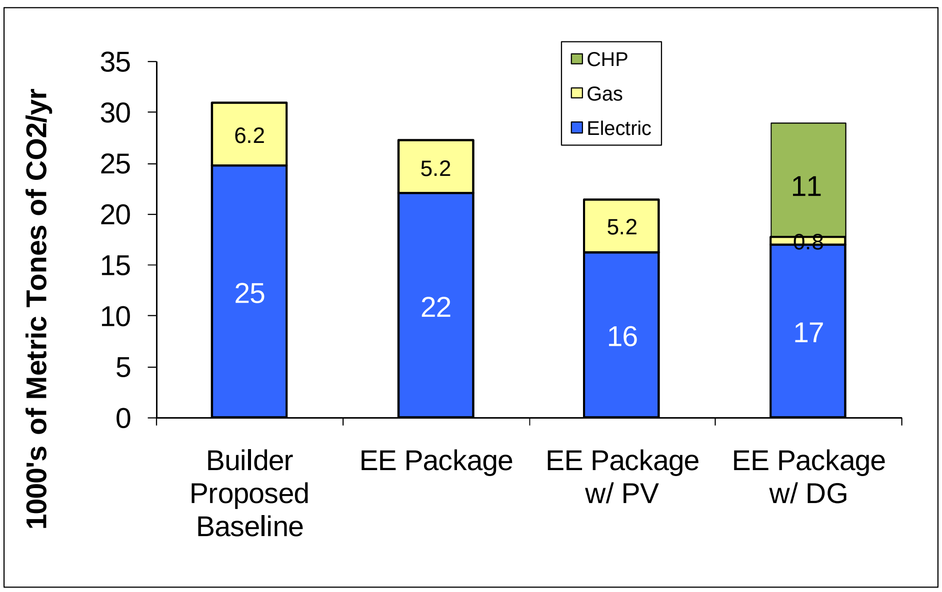
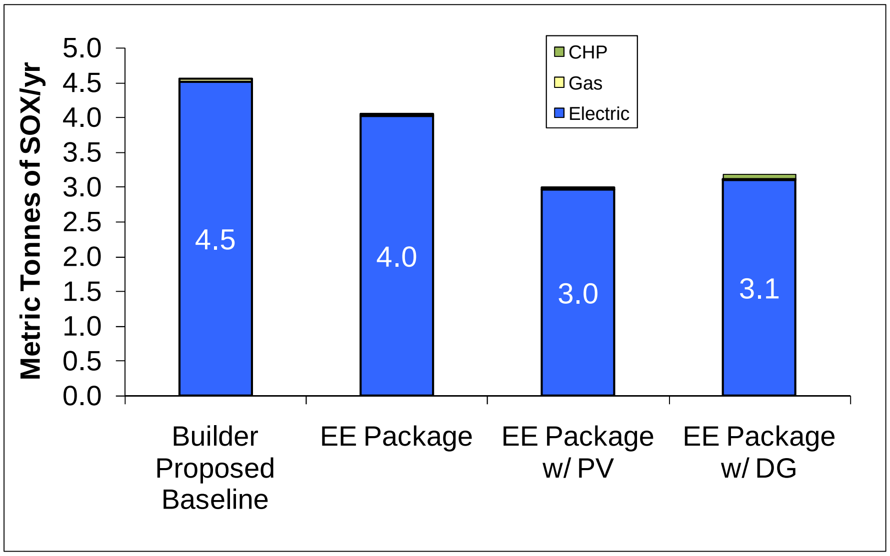


Figure 14. Total Annual CO_2 Emissions (all buildings contributions)

Figures-15 and -16 show SO_x and NO_x emissions impacts. Use of the EE option can lower Site-A annual SO_x emissions to 4.05 metric tons/year from the builder proposed baseline of 4.55 metric tons/year, or by 11%. NO_x emissions would be 14.79 metric tons/ year with EE option implemented vs. 16.93 metric tons/year for the builder proposed baseline, a reduction of 12.6%.

[41] Based on incentives of $600/kW of installed DG. See footnote 4 on page 11 of this report for additional explanation.



Note: Gas and CHP contributions to SO_x emissions are too small to illustrate on this chart given the scale.

Figure 15. Total Annual SO_x Emissions (all buildings contributions)

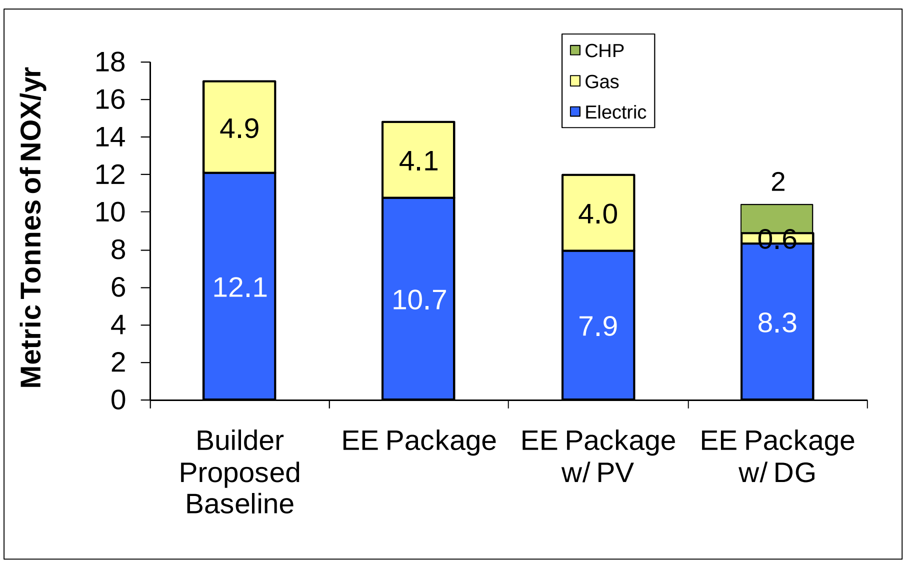


Figure 16. Total Annual NO_x Emissions (all buildings contributions)

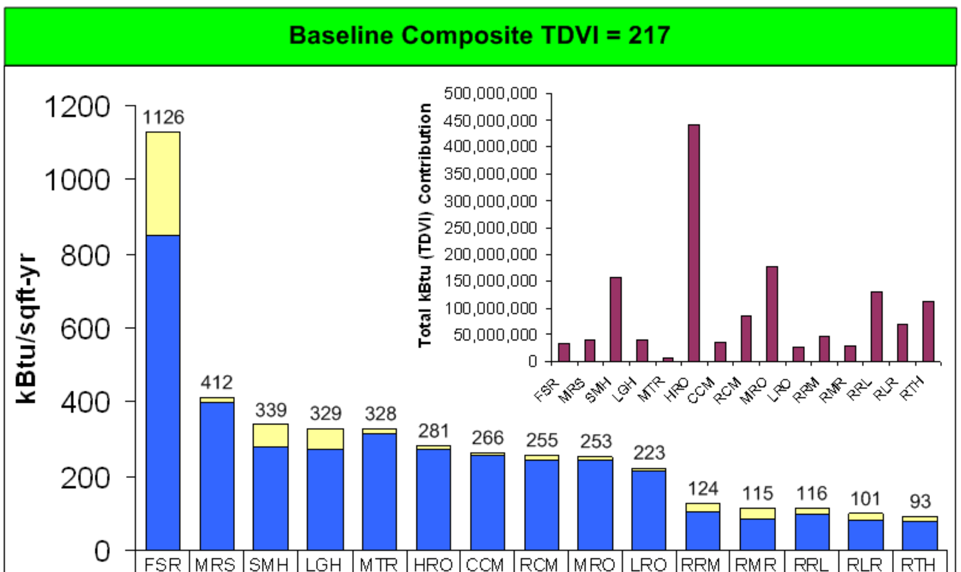
Implementation of the EE-PV option could further reduce SO_x emissions to 2.99 metric tons/ year or by 34.2%, and NO_x emissions to 12 metric tons/ year or by 29.3% as compared to the builder proposed baseline. Implementation of the EE-DG option could reduce Site-A SO_x emissions to 3.17 metric tons/ year or by 30.3% and NO_x emissions to 10.40 metric tons/ year or by 38.5% as compared to the builder proposed baseline option.

3.1.3 Site-A: TDVI Impacts by Building Prototype

To assist the reader in better understanding which building prototypes are the most energy intensive and the degree to which they contribute to Site-A annual energy consumption, a number of charts and tables are presented below. The charts shown in Figures-17 to -20 provide the TDVI energy density for each of the 15 building prototypes modeled in the research as well as the total annual TDVI – based energy consumption for all the buildings of the same type (shown as a chart insert).

Table-26 indicates the relative contribution that each building prototype makes toward the total TDVI energy consumption for Site-A. The results are expressed as a utility-specific percentage (electric and gas) as well as a utility-specific percentage per total site TDVI. In the builder proposed baseline configuration the freestanding Full Service Restaurant (FSR) prototype has the highest TDVI consumption of 1,126 kBtu/sf-year (Figure-17), however all FSR buildings contribute only 2.4% to Site-A total TDVI energy consumption (Table-26).

As shown in Figures-17 to -20 and in Table-24, High Rise Office (HRO) buildings contribute the most to Site-A total TDVI energy consumption, therefore they should be considered the prime target for uniform implementation of selected energy efficiency measures.



	FSR	MRS	SMH	LGH	MTR	HRO	CCM	RCM	MRO	LRO	RRM	RMR	RRL	RLR	RTH
Gas	278	14	59	59	14	10	10	10	9	9	20	30	19	19	18
Electric	848	398	280	270	314	271	256	245	244	214	104	85	97	82	75

Figure 17. Site-A: Builder Baseline - TDVI per Building Type

Baseline		Elec. TDVI as % of Total Elec. TDVI	Gas TDVI as % of Total Gas TDVI	Elec. TDVI as % of Total Site TDVI	Gas TDVI as % of Total Site TDVI
1	Freestanding Full Service Restaurant	1.9%	6.6%	1.8%	0.6%
2	Multi-Tenant Retail Shop	0.5%	0.2%	0.4%	0.0%
3	Major Retailer	3.0%	1.1%	2.7%	0.1%
4	Office Building Low-Rise	2.0%	0.9%	1.8%	0.1%
5	Office Building Mid-Rise	13.1%	5.1%	11.9%	0.4%
6	Office Building High-Rise	32.6%	12.7%	29.8%	1.1%
7	Hotel - Large	2.5%	5.8%	2.3%	0.5%
8	Hotel - Small	10.3%	16.7%	9.4%	1.4%
9	Retail/Commercial Mixed Use	6.3%	2.8%	5.8%	0.2%
10	Retail/Residential Mixed Use Mid-Rise	3.3%	4.1%	3.0%	0.4%
11	Retail/Residential Mixed Use Low-Rise	9.1%	8.5%	8.3%	0.7%
12	Civic/Commercial Mixed Use	2.6%	1.0%	2.4%	0.1%
13	Residential Multi-Family Townhome	6.9%	17.5%	6.3%	1.5%
14	Residential Low-Rise	4.3%	10.6%	3.9%	0.9%
15	Residential Mid-Rise	1.7%	6.3%	1.5%	0.5%

Table 26. Site-A: TDVI per Building Type (composite for prototype end-use areas)

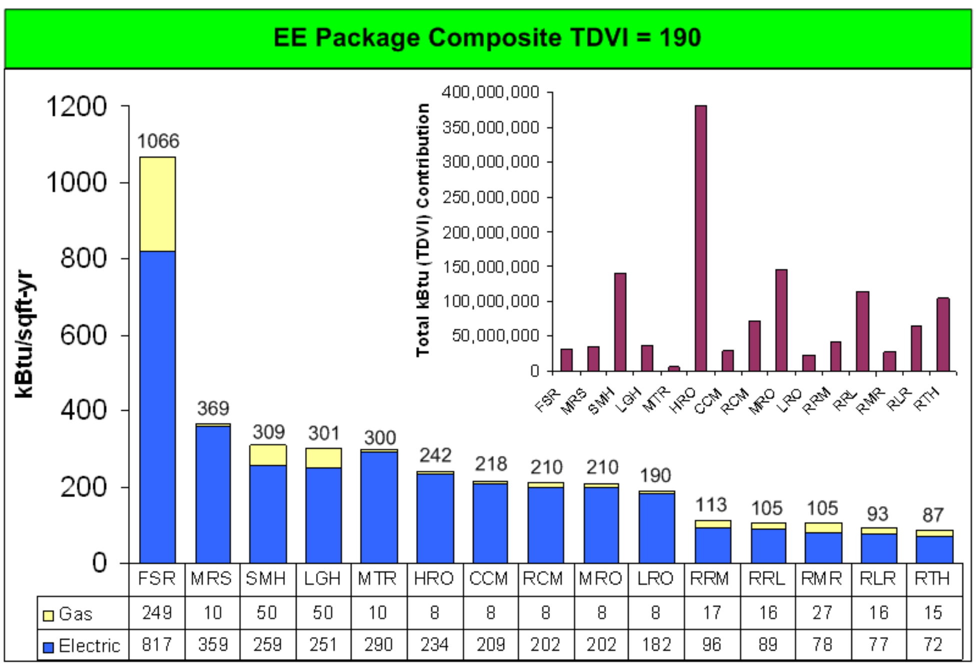
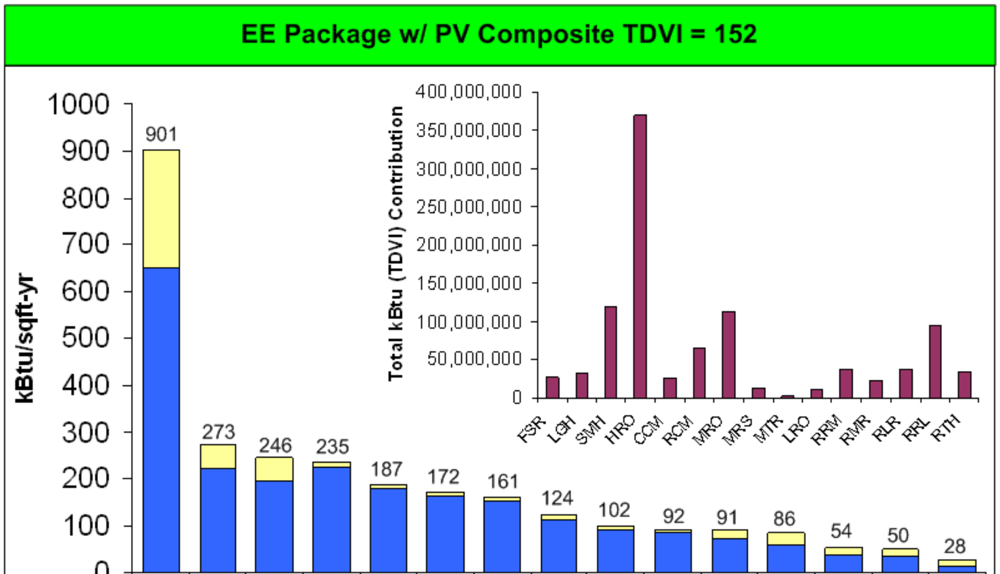
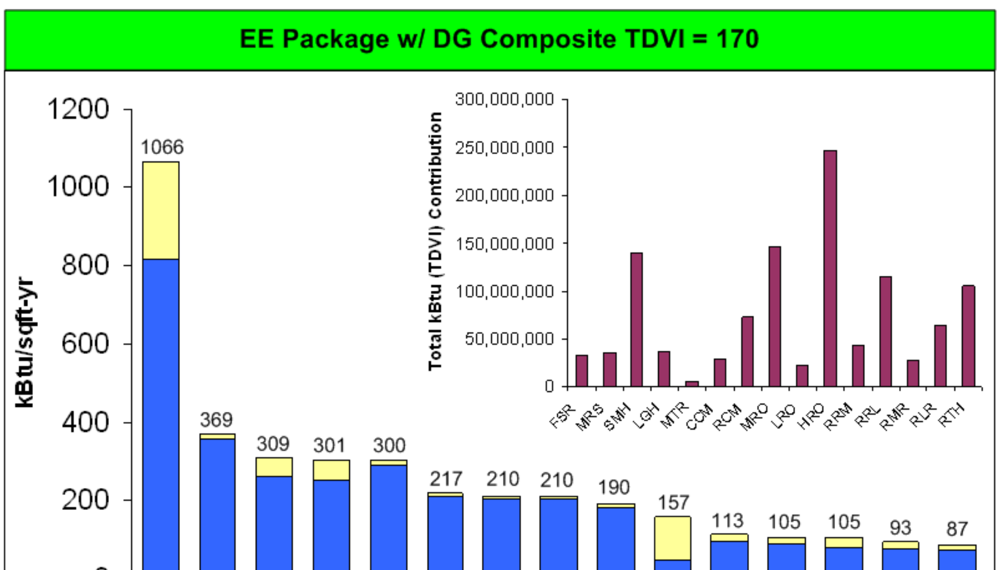


Figure 18. Site-A: EE Packages Only Option - TDVI per Building Type



	FSR	LGH	SMH	HRO	CCM	RCM	MRO	MRS	MTR	LRO	RRM	RMR	RLR	RRL	RTH
Gas	249	50	50	8	8	8	8	10	10	8	17	27	16	16	15
Electric	652	223	196	227	179	164	153	114	92	84	73	59	38	34	13

Figure 19. Site-A: EE Package with PV Option - TDVI per Building Type



	FSR	MRS	SMH	LGH	MTR	CCM	RCM	MRO	LRO	HRO	RRM	RRL	RMR	RLR	RTH
Gas	249	10	50	50	10	8	8	8	8	107	17	16	27	16	15
Electric	817	359	259	251	290	209	202	202	182	50	96	89	78	77	72

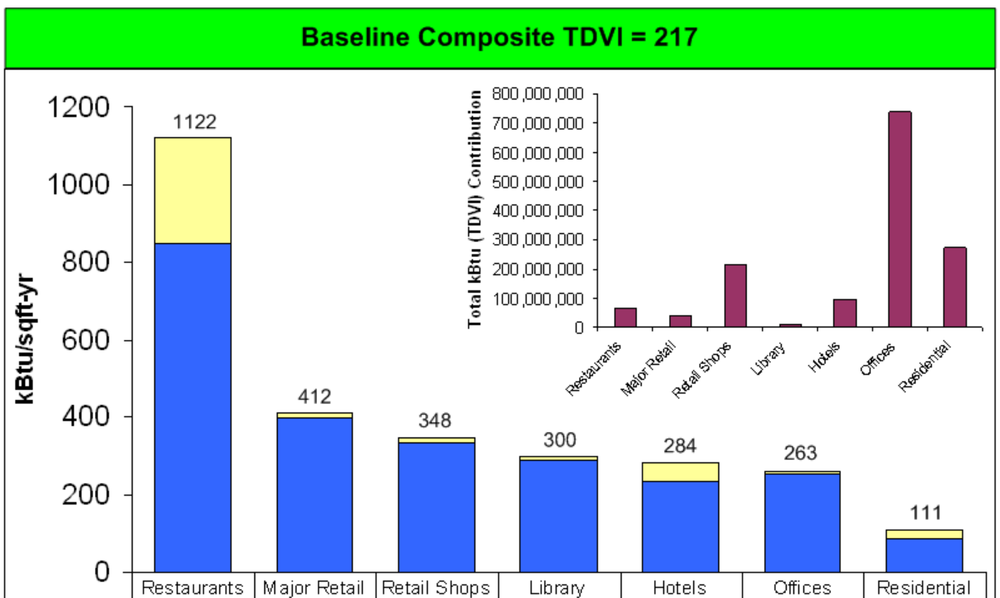
Figure 20. Site-A: EE Package with DG Option - TDVI per Building Type

3.1.4 Site-A: TDVI Impacts by Space-Use Type

Figures-21 to -24 illustrate which of the six building space end-uses are the most energy intensive and the degree to which they contribute to Site-A's total annual energy consumption. The charts provide TDVI energy density for various end-use floor plans as well as the total annual TDVI – based energy consumption for all the buildings space end-uses of the same type (shown as a chart insert).

As in the previous table, Table-27 indicates the relative contribution that each space end-use makes toward the total TDVI energy consumption for Site-A. The results are expressed as a utility-specific percentage (electric and gas) as well as a utility-specific percentage per total site TDVI.

As seen in Figure-21 (the builder proposed baseline), restaurants have the highest TDVI of 1,122 kBtu/sf-year. However the total square footage of office space exceeds the amount of any of the five remaining space end-uses and contributes to more than 51% of the total Site-A TDVI energy consumption (Table-27). Therefore, office space end-uses should be considered the prime target for energy efficiency interventions of the nature modeled in this research project.



	Restaurants	Major Retail	Retail Shops	Library	Hotels	Offices	Residential
Gas	276	14	14	12	49	10	23
Electric	846	398	334	288	235	253	88

Figure 21. Site-A: EE Builder Baseline - TDVI per Space-Use Type

Baseline	Elec. TDVI as % of Total Elec. TDVI	Gas TDVI as % of Total Gas TDVI	Elec. TDVI as % of Total Site TDVI	Gas TDVI as % of Total Site TDVI
Restaurants	3.8%	13.2%	3.5%	1.1%
Retail Shops	15.7%	7.0%	14.3%	0.6%
Major Retail	3.0%	1.1%	2.7%	0.1%
Offices	54.3%	21.5%	49.6%	1.9%
Hotels	6.0%	13.8%	5.5%	1.2%
Library	0.6%	0.3%	0.5%	0.0%
Residential	16.7%	43.2%	15.2%	3.7%

Table 27. Site-A: TDVI per End-Use Area (composite for all buildings types)

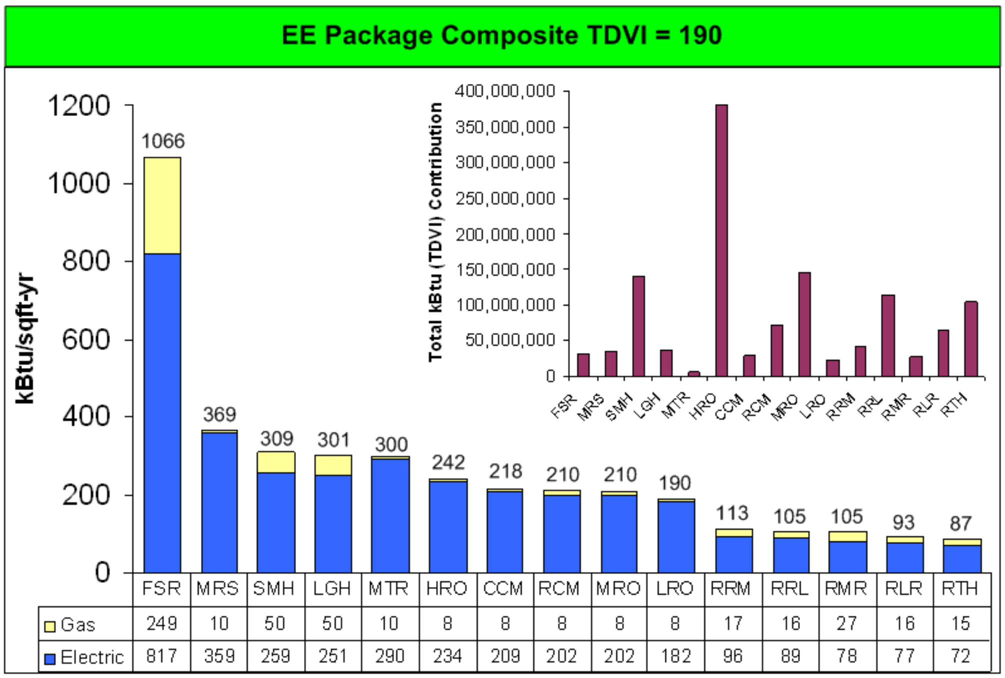
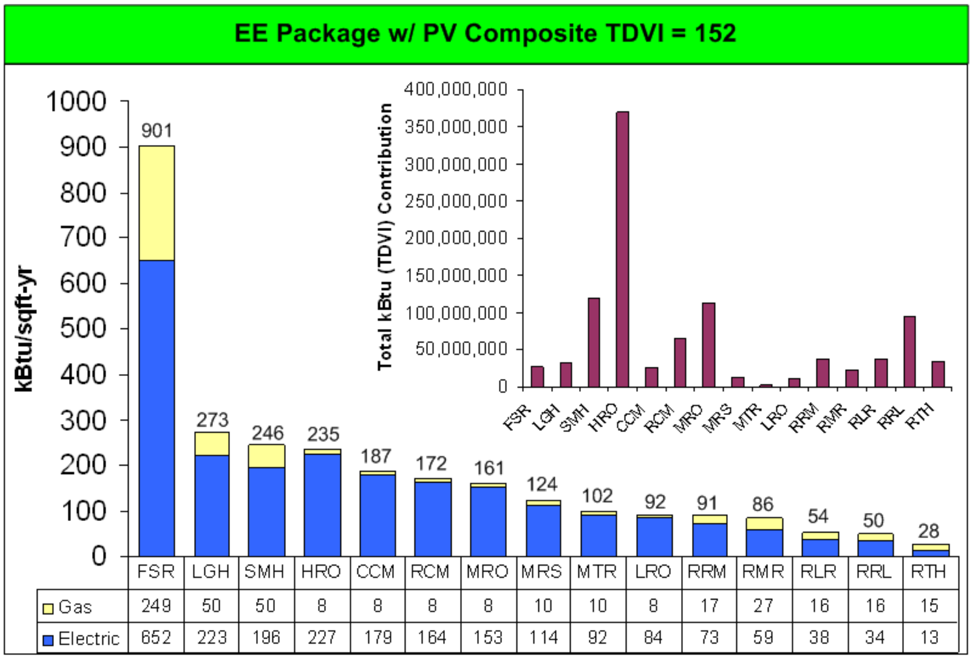
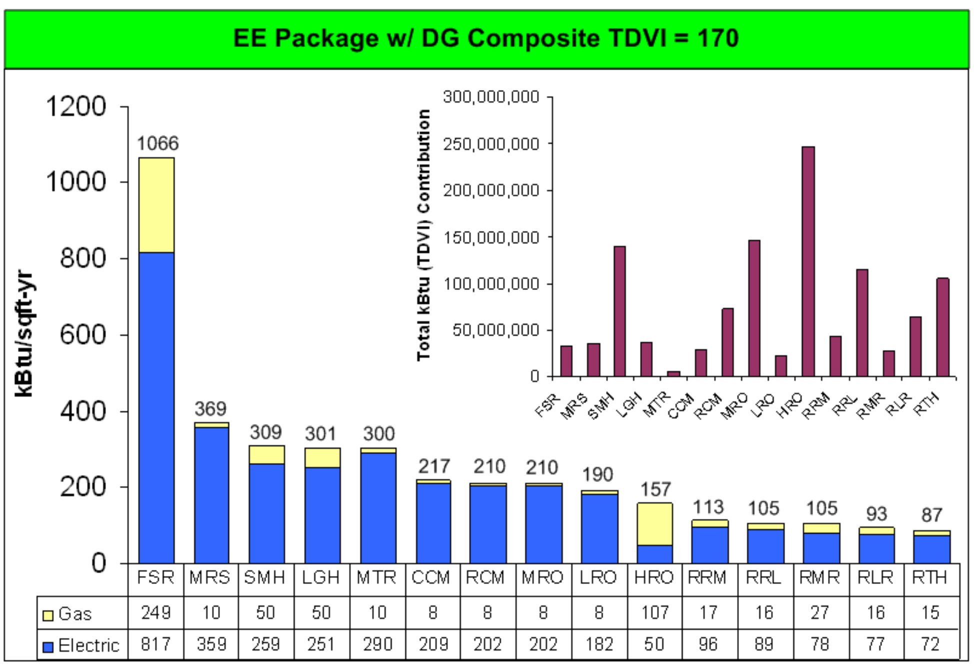


Figure 22. Site-A: EE Package Option - TDVI per Space-Use Type



	FSR	LGH	SMH	HRO	CCM	RCM	MRO	MRS	MTR	LRO	RRM	RMR	RLR	RRL	RTH
Gas	249	50	50	8	8	8	8	10	10	8	17	27	16	16	15
Electric	652	223	196	227	179	164	153	114	92	84	73	59	38	34	13

Figure 23. Site-A: EE Package with PV Option - TDVI per Space-Use Type



	FSR	MRS	SMH	LGH	MTR	CCM	RCM	MRO	LRO	HRO	RRM	RRL	RMR	RLR	RTH
Gas	249	10	50	50	10	8	8	8	8	107	17	16	27	16	15
Electric	817	359	259	251	290	209	202	202	182	50	96	89	78	77	72

Figure 24. Site-A: EE Package with DG Option - TDVI per Space-Use Type

3.1.5 Site-A: Composite Results - Economics and Summary Tables

To assist the reader in making comparisons among the three modeled options and the builder proposed baseline development option, relative to energy consumption, emissions and economics, Tables-28 through -31 are provided below. The first nine of the listed parameters in each table were discussed in the previous sub-sections of this report, therefore only the economic parameters will be discussed in this sub-section.

Parameter	Baseline	EE Package	% Savings
TDVI (kBtu/sqft-yr)	217	190	12.3%
Electricity (kWh/yr)	71,575,322	63,706,917	11.0%
Electric Demand (Max MW)	19.809	16.478	16.8%
Gas (MMBtu/yr)	114,606	95,542	16.6%
Total Energy (MMBtu/yr)	358,821	312,910	12.8%
Emissions - CO2 (tonnes/yr)	30,924	27,174	12.1%
Emissions - SOx (tonnes/yr)	4.55	4.05	11.0%
Emissions - NOx (tonnes/yr)	16.93	14.79	12.6%
Energy Cost ($/yr)	$15,110,206	$13,405,617	11.3%
Simple Payback (years)	n/a	5.9	n/a
ROI (%)	n/a	16.9	n/a

Table 28. Impacts of EE Package vs. Builder Baseline

Table-28 indicates that implementation of the recommended, economically feasible EE options could lower Site-A annual utility costs by $1,704,589 or by 11.3%. The simple payback on the investment necessary to implement the EE options in Site-A would be 5.9 years with a return-on-investment (ROI) of 16.9%.

Parameter	Baseline	EE Package w/ PV	% Savings
TDVI (kBtu/sqft-yr)	217	152	30.0%
Electricity (kWh/yr)	71,575,322	47,003,474	34.3%
Electric Demand (Max kW)	19.809	14.045	29.1%
Gas (MMBtu/yr)	114,606	95,462	16.7%
Total Energy (MMBtu/yr)	358,821	255,838	28.7%
Emissions - CO2 (tonnes/yr)	30,924	21,403	30.8%
Emissions - SOx (tonnes/yr)	4.55	2.99	34.2%
Emissions - NOx (tonnes/yr)	16.93	12	29.3%
Energy Cost ($/yr)	$15,110,206	$10,230,523	32.3%
Simple Payback (years)	n/a	12.4	n/a
ROI (%)	n/a	8.1	n/a

Table 29. Impacts of EE Package + PV vs. Builder Baseline

Table-29 indicates that the enhancement of the EE option with the solar PV feature could reduce Site-A electric and natural gas annual utility costs by $4,879,683 or by 32.3% compared to the builder proposed baseline option. The simple payback of the EE-PV option would be 12.4 years with a ROI of 8.1%[42].

Parameter	Baseline	EE Package w/ DG	% Savings
TDVI (kBtu/sqft-yr)	217	170	21.7%
Electricity (kWh/yr)	71,575,322	49,239,156	31.2%
Electric Demand (Max kW)	19.809	10.851	45.2%
Gas (MMBtu/yr)	114,606	236,634	-106.5%
Total Energy (MMBtu/yr)	358,821	404,638	-12.8%
Emissions - CO2 (tonnes/yr)	30,924	28,865	6.7%
Emissions - SOx (tonnes/yr)	4.55	3.17	30.3%
Emissions - NOx (tonnes/yr)	16.93	10.40	38.5%
Energy Cost ($/yr)	$15,110,206	$12,698,141	16.0%
Simple Payback (years)	n/a	7.0	n/a
ROI (%)	n/a	14.3	n/a

Table 30. Impacts of EE Package + DG vs. Builder Baseline

Table-30 suggests that implementation of the EE-DG option could reduce Site-A combined electric and natural gas annual utility costs by $2,412,065 or by 16% as compared to the builder proposed baseline option. The simple payback of the EE-DG option would be 7 years with a ROI of 14.3%.

However, as previously noted on page 11 of this report, the economic calculations of the DG option were based on the 2007 California Self Generation Incentive Program (SGIP) guidelines which at the beginning of this research project, provided a rebate of $600/kW for internal combustion (IC) engine-based CHP systems and a $800/kW rebate for microturbine-based CHP systems. Subsequently, the 2008 SGIP eliminated all DG rebates except for the wind and fuel cell applications. That makes Site-A DG analysis presented in this report more a "what if" analytical case than a valid energy efficiency option as the DG technology becomes economically infeasible without the rebates. Nevertheless, the analysis of DG energy efficiency impacts on Site-A development remains valid while the economics could potentially become more favorable over time in the advent of lower equipment costs and restored incentives.

Due to a significant energy saving potential for PV technology Table-31 was prepared to illustrate details of the Site-A PV system[43] economics. The evaluated PV installations would total ~1,140 kW (dc) of installed capacity. The installation will reduce Site-A annual electric utility cost by $3,073,567 which includes $336,520 in electricity exported back to the grid.

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[42] Assumes that excess electricity generated PV is sold back to the grid at $0.1141/kWh. PV installation incentive of $2550/kW is applied.

[43] See Appendix-A to review technical details / modeling assumption for PV based on-site power.

The simple payback for PV option alone (with no other EE measures included) would be 14.8 years with an ROI of 6.83%.

Standalone PV Economics		
Excess PV generated electricity exported to the utility grid	Exported Electricity (kWh/yr)	2,949,340
	Electricity Sales ($/yr) @ $0.1141/kWh	$336,520
Economics of PV system (net profit includes excess electricity sales to the grid and direct savings from displaced utility supplied electricity	Net Profit ($/yr)	$3,073,567
	Raw PV installed cost	$73,309,641
	Incentive @ $2.55/watt	$29,136,469
	PV cost after Subsidy	$44,173,172
	PV O&M ($/yr)	$87,972
	Simple Payback	14.8
	ROI	6.8%

Total of ~1,140 kW (dc) of PV systems installed. Roof area available for PV varies from 25% to 60% depending on building prototype. Photovoltaic installed costs as shown include metering and a switchgear.

Table 31. Details of PV* Economic Calculation

3.1.6 Site-B: Energy - Gas and Electric Utility Use Impacts

Figure-25 below presents the results of the four modeled development options for the 866 buildings in Site-B relative to their impact on site-wide annual energy (gas and electric) consumption.

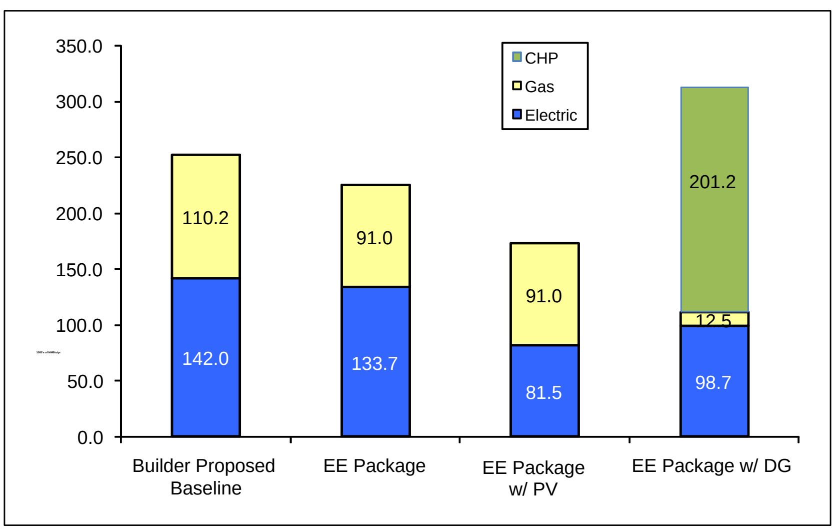


Figure 25. Total Annual Energy Consumption (all buildings)

Analysis of the results indicates that implementation of the all applicable and economically feasible EE options can lower Site-B annual energy consumption from the builder proposed baseline (BPB) of 252,200 MMBtu to 224,700 MMBtu, or by 10.9%. Implementation of the EE-PV option could further reduce electric grid and natural gas utility consumption to 172,500 MMBtu or by 32.6% compared to BPB option. Implementation of the EE-DG option would not be as effective in reducing Site-B consumption of grid-provided electric energy as the EE-PV option, however it can lower that consumption to 98,700 MMBtu from the 133,799 MMBtu expected from the use of the EE option alone. On the other hand, natural gas consumption will increase significantly reaching 237,000 MMBtu as compared with 95,000 MMBtu for the EE option. The increase results in the highest natural gas consumption of any of the modeled development scenarios.

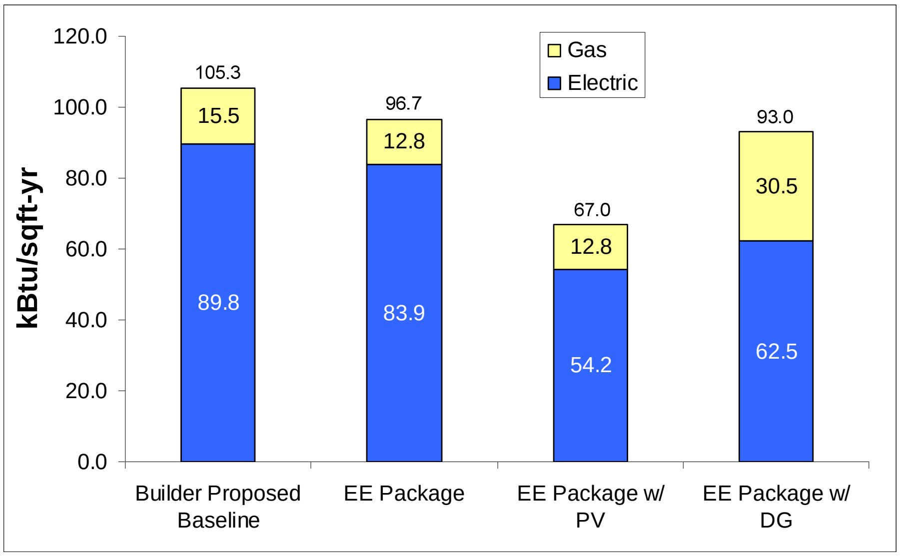


Figure 26. TDVI Energy Consumption (all buildings)

With regard to TDVI energy consumption, Figure-26 indicates that implementation of the EE option can lower Site-B TDVI energy consumption from the BPB baseline option of 105.3 kBtu/sf-year to 96.7 kBtu/sf-year, or by 8.2%. Implementation of the EE-PV option could further reduce TDVI to 67 kBtu/sf-year or by 36.4% compared with the BPB baseline option. Implementation of the EE-DG option would not be as effective in reducing Site-B TDVI energy consumption as the EE-PV option. However in contrast to Figure-25, where the energy is expressed in Btu and the EE-DG option is shown as the highest user, the EE-DG option is 11.7% better than the TDVI consumption of the BPB baseline option. This illustrates the benefit of DG technology which, while increasing consumption of a low TDVI valued fuel like natural gas, can significantly decrease the use of high TDVI valued grid electricity.

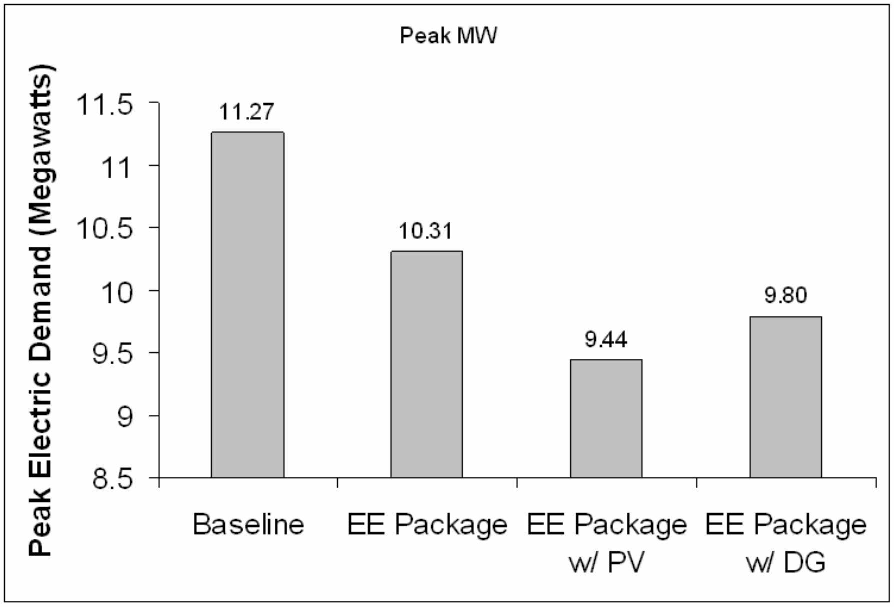


Figure 27. Peak Electric Demand (all buildings contributions)

	Peak MW	Total Cost	$/kW for Reduced Peak Demand
Baseline	11.268	-	-
EE Package	10.308	$7,934,659	$8,265
EE Package w/ PV	9.442	$49,615,206	$27,172
EE Package w/ DG	9.797	$15,843,991	$10,771

Table 32. Specific Cost of Electric Peak Demand Reduction

With regard to peak demand reduction, Figure-27 and Table-32 present the performance and relative costs associated with the modeled development options. They indicate that implementation of the EE option would result in lowering Site-B electric peak demand from the BPB baseline option of 11.27 MW to 10.31 MW, or by 8.8%. Table-32 indicates that this is the least expensive option among those modeled, at $8,265 / kW. Implementation of the EE-PV option could further reduce electric peak demand to 9.44 MW or by total of 16.2% compared with the BPB baseline option. At $8,265 / kW this is the most expensive of the three analyzed options to lower peak demand. Implementation of the EE-DG option could reduce Site-B electric peak demand to 9.8 MW which is slightly less than EE_PV option but still 13% less than the BPB baseline option. The specific cost of implementing the option would be $10,771 / kW reduced[44].

[44] Based on incentives of $800/kW of installed DG. See footnote 4 on page 11 of this report for an additional explanation.

3.1.7 Site-B: Environmental Impacts

Figures-28 to -30 present the annual air emission impacts associated with the consumption of electricity and natural gas for each of the modeled options in Site-B. The calculations assume end-use delivery efficiency of 92% for electricity and 98.4% for natural gas.

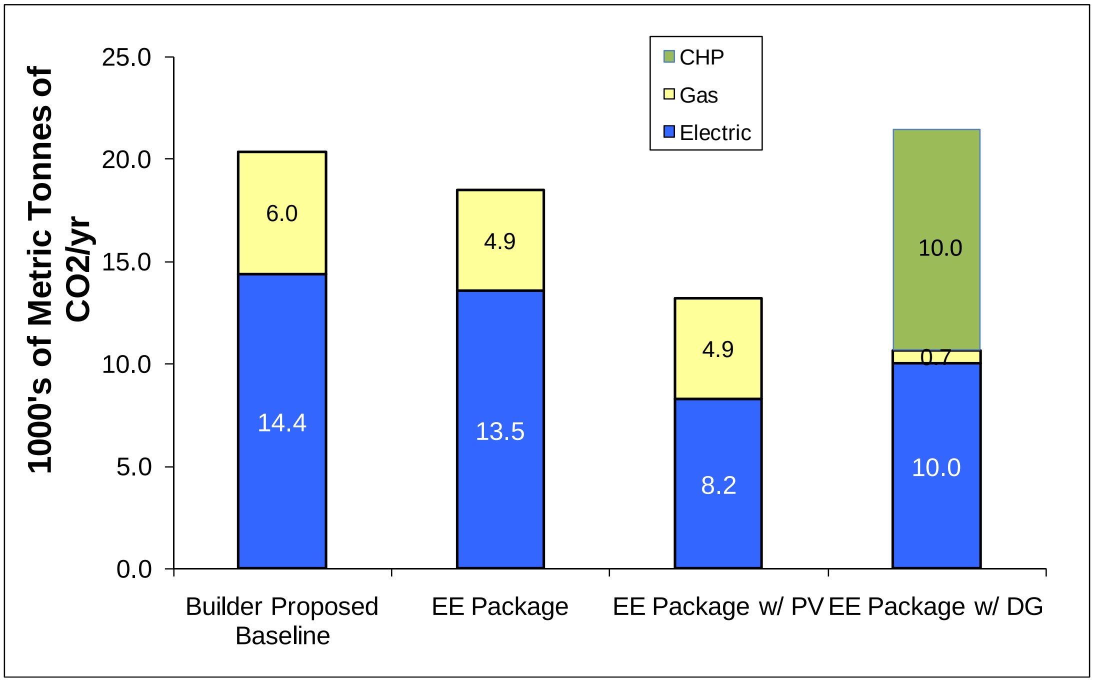
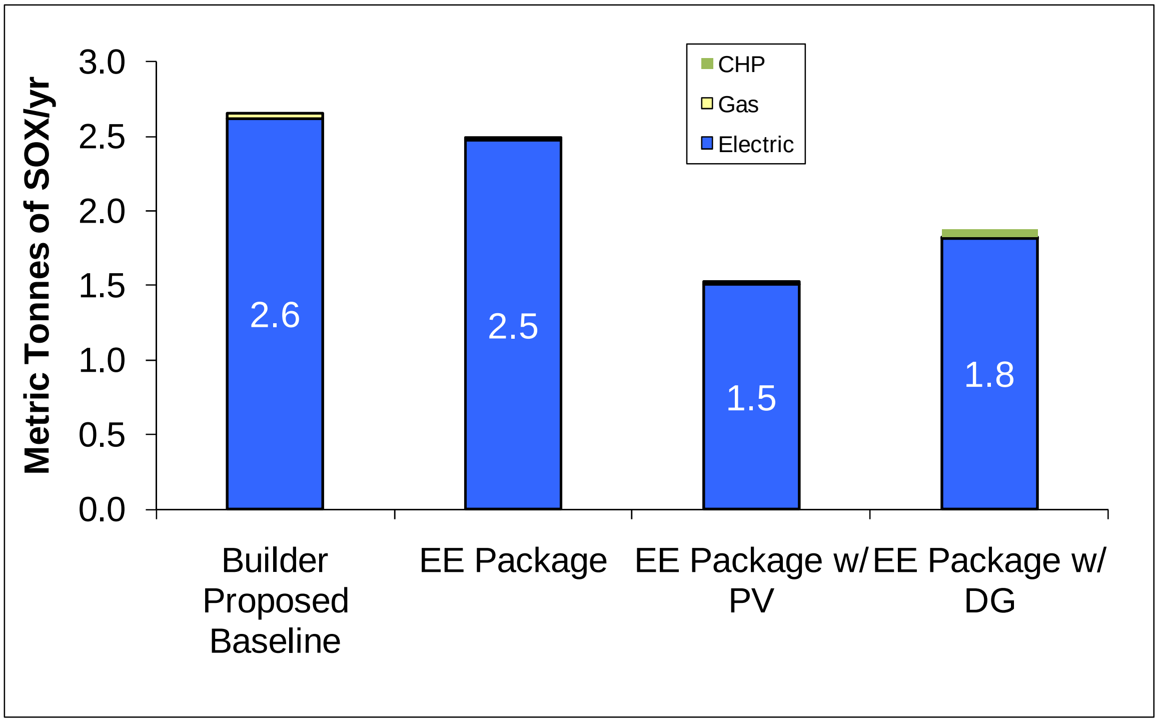


Figure 28. Total Annual CO_2 Emissions (all buildings contributions)

Figure-28 indicates that implementation of the EE option can lower Site-B annual CO_2 emissions from the BPB baseline option of 20,335 metric tons/ year to 18,459 metric tons/ year, or by 9.2%. Implementation of the EE-PV option could further reduce CO_2 emissions to 13,179 metric tons/ year, or by 35.2%. Implementation of the EE-PG option would not be effective in reducing Site-B CO_2 emissions and at 21,393 metric tons/ year it would be 5.2% higher than the BPB baseline emissions.

Figures-29 and -30 show SO_x and NO_x emissions impacts. The EE option can lower Site-A annual SO_x emissions to 2.5 metric tons/year from the BPB baseline of 2.66 metric tons/ year, or by 6.0%. NO_x emissions would be 10.46 metric tons/year with the EE option implemented vs. 11.69 metric tons/year for the BPB baseline, a reduction of 10.5%.



Note; Natural gas and CHP contributions to SOx emissions are too small to clearly show on this chart

Figure 29. Total Annual SO_x Emissions (all buildings contributions)

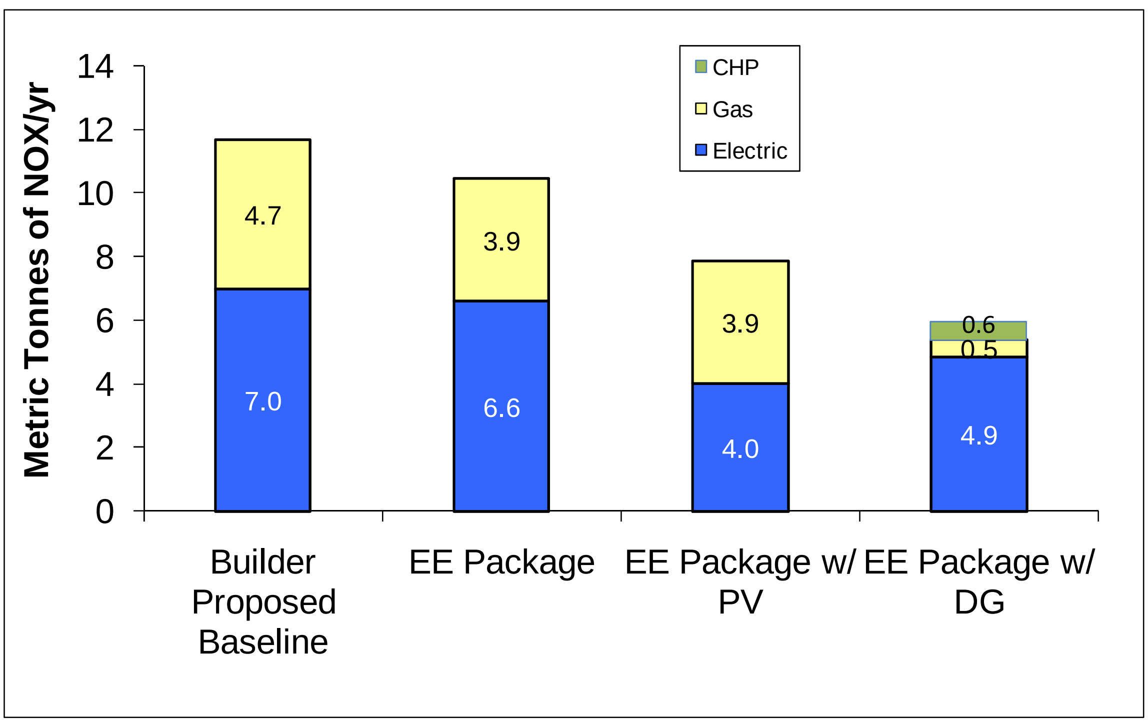


Figure 30. Total Annual NO_x Emissions (all buildings contributions)

Implementation of the EE-PV option could further reduce SO_x emissions to 1.53 metric tons/ year or by 42.3%, and NO_x emissions to 7.88 metric tons/year or by 32.5% as compared to the BPB baseline option. Implementation of the EE-DG option could reduce Site-B SO_x emissions to 1.88 metric tons/ year or by 29.1% and NO_x emissions at 5.97 metric tons/year will be 48.9% lower than the BPB baseline option.

3.1.8 Site-B: TDVI Impacts by Building Prototype

To assist the reader in better understanding which building prototypes are the most energy intensive and the degree to which they contribute to Site-B annual energy consumption, a number of charts and tables are presented below. The charts shown in Figures-31 to -34 provide the TDVI energy density for each of the 5 building prototypes modeled in the research as well as the total annual TDVI – based energy consumption for all the buildings of the same type (shown as a chart insert). Table-33 indicates the relative contribution that each building prototype makes toward the total TDVI energy consumption for Site-B. The results are expressed as a utility-specific percentage (electric and gas) as well as a utility-specific percentage per total site TDVI.

In the Builder Proposed Baseline configuration the *Gateway* mixed-use residential /commercial building prototype has the highest TDVI of 98.9 kBtu/sf-year (Figure-31) and all Gateway buildings contribute to more than 62% of the Site-B: TDVI (Table-33). Considering fact that the Gateway buildings contribute the most to Site-B: TDVI energy consumption, this prototype would be considered the prime target for the deployment of energy efficiency measures at the site.

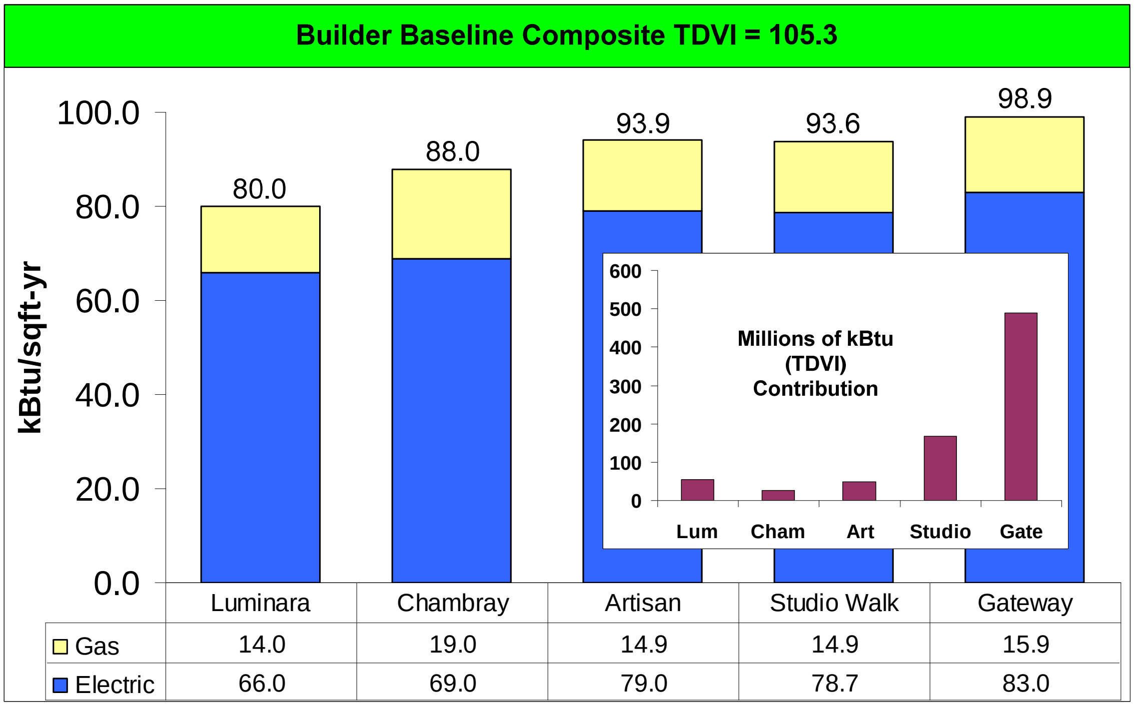


Figure 31. Site-B: Builder Baseline - TDVI per Building Type

	Baseline	Elec. TDVI as % of Total Elec. TDVI	Gas TDVI as % of Total Gas TDVI	Elec. TDVI as % of Total Site TDVI	Gas TDVI as % of Total Site TDVI
1	Luminara	6.6%	8.1%	5.7%	1.2%
2	Chambray	3.0%	4.8%	2.6%	0.7%
3	Artisan	6.3%	6.1%	5.4%	0.9%
4	Studio Walk	21.6%	20.3%	18.4%	3.0%
5	Gateway	62.5%	60.6%	53.3%	8.9%

Table 33. TDVI per Building Type (composite for prototype all end-use areas)

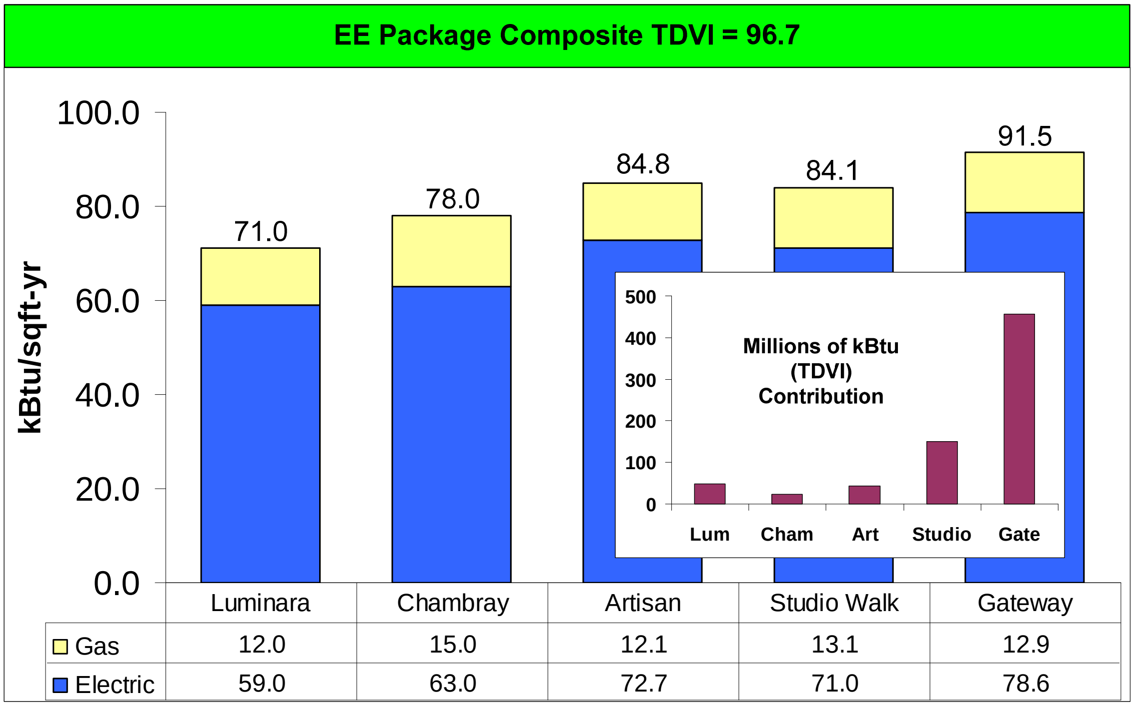


Figure 32. Site-B: EE Packages Only Option - TDVI per Building Type

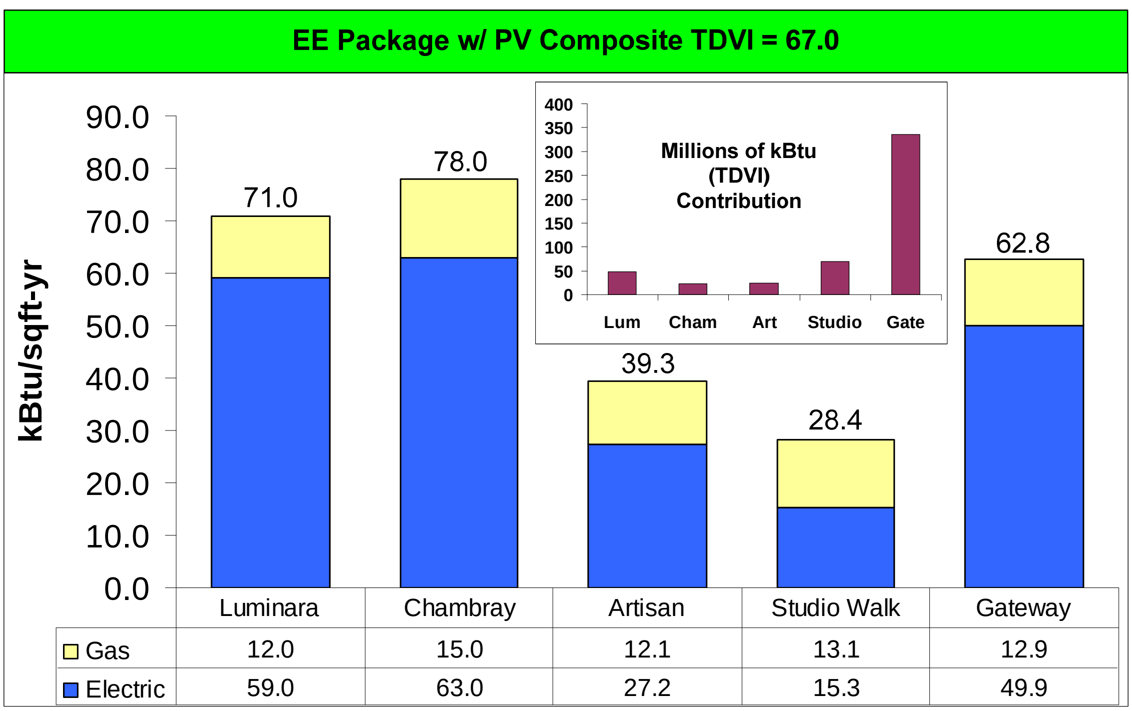


Figure 33. Site-B: EE Package with PV Option - TDVI per Building Type

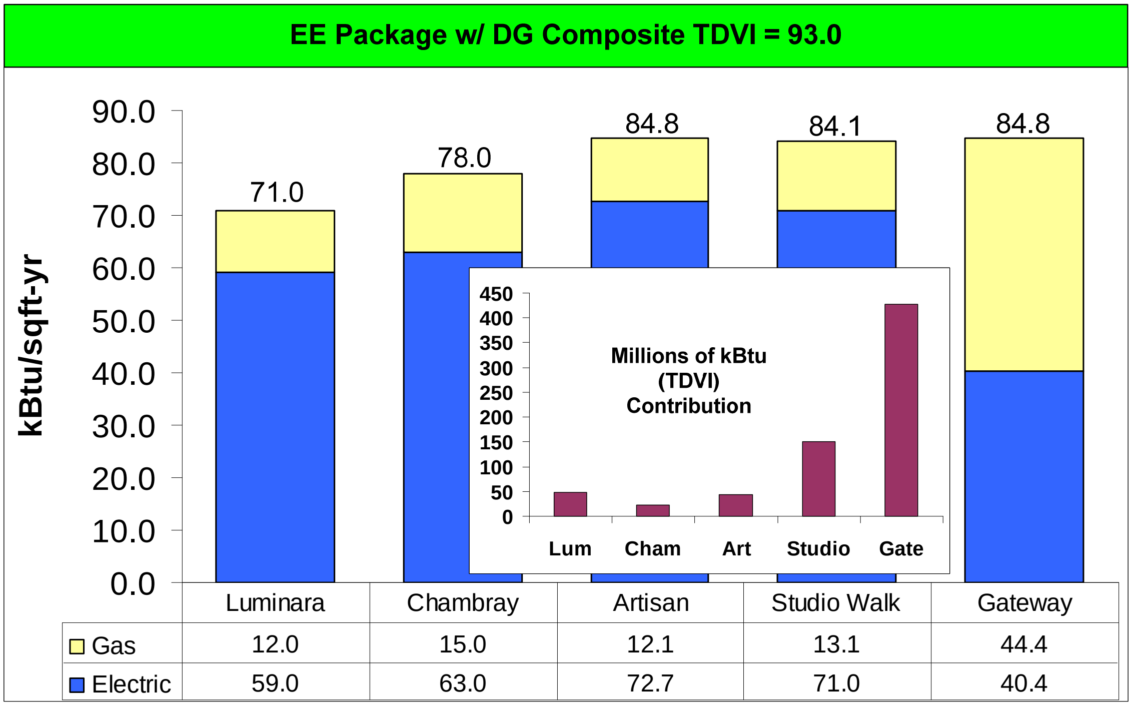


Figure 34. Site-B: EE Package with DG Option - TDVI per Building Type

3.1.9 Site-B: TDVI Impacts by Space-Use Type

Figures-35 to -38 illustrate which of the two building space end-uses, residential and commercial, are the most energy intensive and the degree to which they contribute to Site-B's total annual energy consumption. The charts provide TDVI energy density for residential or commercial end-use spaces/floor plans as well as the total annual TDVI – based energy consumption for all the buildings space end-uses of the same type (shown as a chart insert).As in the previous table, Table-34 indicates the relative contribution that each space end-use makes toward the total TDVI energy consumption for Site-B. The results are expressed as a utility-specific percentage (electric and gas) as well as a utility-specific percentage per total site TDVI.

As illustrated in Figure-35, the commercial end-use floor plans have very high TDVI energy consumption of 300.1 kBtu/sf-year as compared to 87.8 kBtu/sf-year for residential spaces. However because Site-B will consist of 4,270 residential units with total of 6,776,027 s.f. of living space and only 357 retail store/commercial units representing a total of 296,259 s.f. of space, residential spaces contribute to more than 74% of the Site-B TDVI (Table-34). Accordingly, the other three figures in this sub-section portray the same profile.

Therefore despite their lower specific TDVI energy consumption, the residential spaces/floor plans contribute the most to Site-B TDVI energy consumption and would be considered the prime target for the deployment of the selected energy efficiency measures.

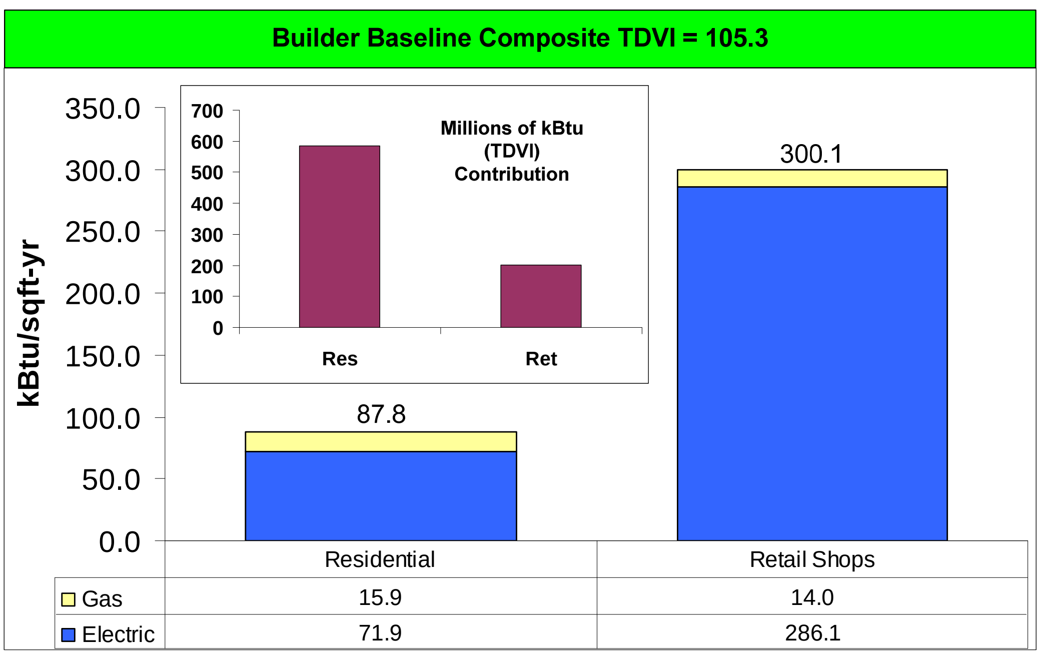


Figure 35. Site-B: EE Builder Baseline - TDVI per Space-Use Type

Baseline	Elec. TDVI as % of Total Elec. TDVI	Gas TDVI as % of Total Gas TDVI	Elec. TDVI as % of Total Site TDVI	Gas TDVI as % of Total Site TDVI
Residential	71.6%	8.1%	61.0%	13.5%
Retail Shops	28.4%	4.8%	24.2%	1.2%

Table 34. Site-B: TDVI per End-Use Area (composite for all buildings types)

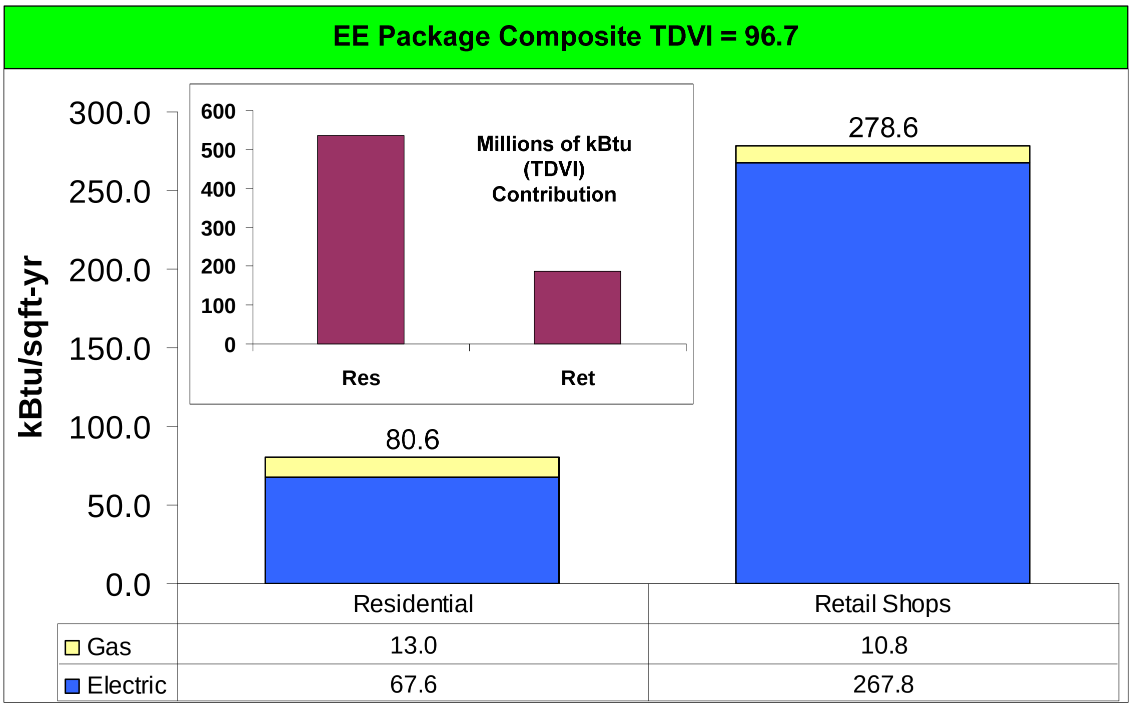
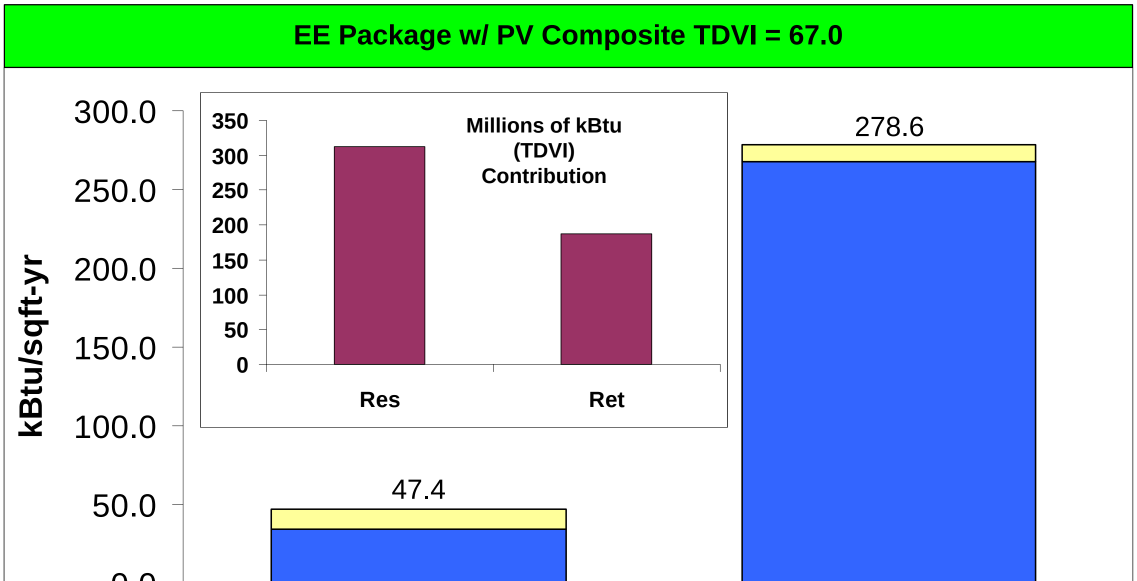
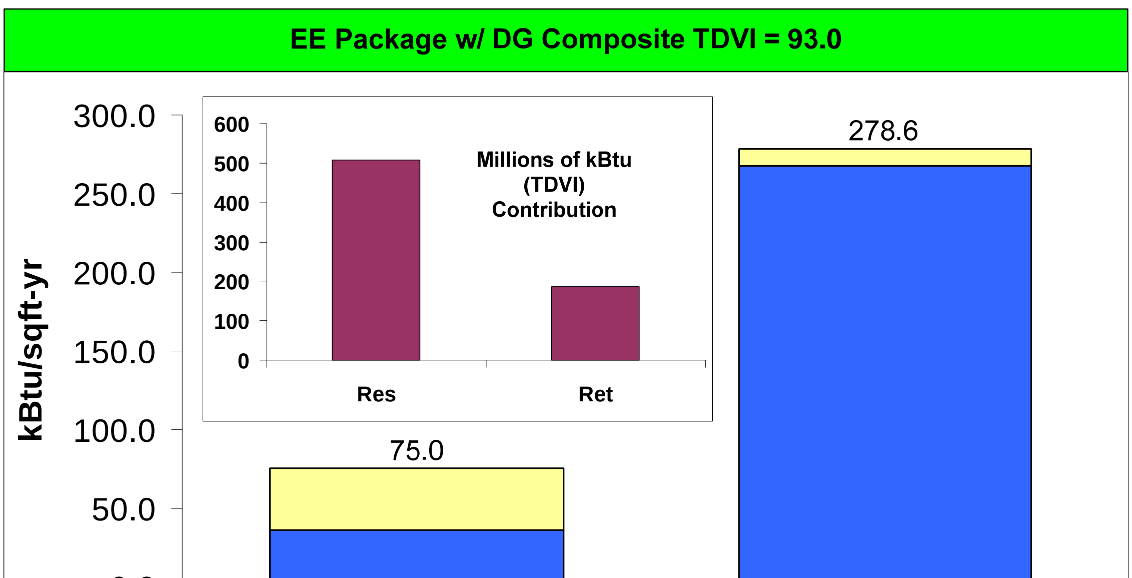


Figure 36. Site-B: EE Package Option - TDVI per Space-Use Type



	Residential	Retail Shops
Gas	13.0	10.8
Electric	34.4	267.8

Figure 37. Site-B: EE Package with PV Option - TDVI per Space-Use Type



	Residential	Retail Shops
Gas	39.1	10.8
Electric	35.9	267.8

Figure 38. Site-B: EE Package with DG Option - TDVI per Space-Use Type

3.1.10 Site-B: Composite Results - Economics and Summary Tables

To assist the reader in making comparisons among the three modeled options and the builder proposed baseline development option, relative to energy consumption, emissions and economics, Tables-35 through -38 are provided below. The first nine of the listed parameters in each table were discussed in the previous sub-sections of this report, therefore only the economic parameters will be discussed in this sub-section.

Parameter	Baseline	EE Package	% Savings
TDVI (kBtu/sqft-yr)	105.29	96.71	8.2%
Electricity (kWh/yr)	41,603,751	39,182,298	5.8%
Electric Demand (Max MW)	11.27	10.31	8.5%
Gas (MMBtu/yr)	110,164	90,968	17.4%
Total Energy (MMBtu/yr)	252,116	224,658	10.9%
Emissions - CO2 (tonnes/yr)	20,335.17	18,458.70	9.2%
Emissions - SOx (tonnes/yr)	2.66	2.50	6.0%
Emissions - NOx (tonnes/yr)	11.69	10.46	10.5%
Energy Cost ($/yr)	$11,983,344	$11,171,189	6.8%
Simple Payback (years)	n/a	9.8	n/a
ROI (%)	n/a	10.2	n/a

Table 35. Impacts of EE Package vs. Builder Baseline

Table-35 indicates that implementation of the recommended, economically feasible EE options could lower Site-B annual utility costs by $812,155 or by 6.8%. The simple payback on the investment necessary to implement EE options would be 9.8 years with a ROI of 10.2%. Supplementing the EE option with PV (Table-36) could reduce Site-B electric and natural gas annual utility costs by $3,346,177 or by 27.9% compared to the BPB option. The simple payback of the EE-PV option would be 14.8 years with a ROI of 6.7%[45].

[45] Assumes that excess electricity generated PV is sold back to the grid at $0.1141/kWh. PV installation incentive of $2550/kW is applied.

Parameter	Baseline	EE Package w/ PV	% Savings
TDVI (kBtu/sqft-yr)	105.29	66.99	36.4%
Electricity (kWh/yr)	41,603,751	23,889,289	42.6%
Electric Demand (Max MW)	11.27	9.44	16.2%
Gas (MMBtu/yr)	110,164	90,968	17.4%
Total Energy (MMBtu/yr)	252,116	180,010	28.6%
Emissions - CO2 (tonnes/yr)	20,335.17	13,178.60	35.2%
Emissions - SOx (tonnes/yr)	2.66	1.53	42.3%
Emissions - NOx (tonnes/yr)	11.69	7.88	32.5%
Energy Cost ($/yr)	$11,983,344	$8,637,167	27.9%
Simple Payback (years)	n/a	14.8	n/a
ROI (%)	n/a	6.7	n/a

Table 36. Impacts of EE Package + PV vs. Builder Baseline

Parameter	Baseline	EE Package w/ DG	% Savings
TDVI (kBtu/sqft-yr)	105.29	92.95	11.7%
Electricity (kWh/yr)	41,603,751	28,920,574	30.5%
Electric Demand (Max MW)	11.27	9.80	13.1%
Gas (MMBtu/yr)	110,164	213,695	-94.0%
Total Energy (MMBtu/yr)	252,116	312,372	-23.9%
Emissions - CO2 (tonnes/yr)	20,335.17	21,393.10	-5.2%
Emissions - SOx (tonnes/yr)	2.66	1.88	29.1%
Emissions - NOx (tonnes/yr)	11.69	5.97	48.9%
Energy Cost ($/yr)	$11,983,344	$9,604,976	19.8%
Simple Payback (years)	n/a	6.7	n/a
ROI (%)	n/a	14.9	n/a

Table 37. Impacts of EE Package + DG vs. Builder Baseline

Table-37 indicates that implementation of the EE-DG option could reduce Site-B combined electric and natural gas annual utility costs by $2,378,368 or by 19.8% as compared to the BPB option. The simple payback of the EE-DG option would be 6.7 years with a ROI of 14.9%. However, as previously noted, the economic calculations of the DG option were based on the 2007 CA SGIP guidelines which provided a rebate of $800/kW for microturbine-based systems with heat recovery. The 2008 SGIP eliminated all DG rebates except for the wind and fuel cell applications. This again makes the Site-B DG analysis presented in this report more a "what if" analytical case than a valid energy efficiency option as the DG technology becomes economically infeasible without the rebates. Nevertheless, the analysis of DG energy efficiency impacts on Site-B development remains valid while the economics could potentially become more favorable over time with the advent of lower equipment cost and the return of incentives.

Due to a significant energy saving potential produced by PV technology, Table-38 was prepared to illustrate economics of Site-B PV system deployment[46]. The evaluated PV installations would total ~10,760 kW (dc) of installed capacity which would require approximately 45% of the available roof areas for all prototype buildings 3, 4, and 5 to be used for PV cells installation. The simple payback for PV option alone (no other EE measures included) would be 13.8 years with a ROI of 7.3%.

Standalone PV Economics		
Excess PV generated electricity exported to the utility grid	Exported Electricity (kWh/yr)	4,979,410
	Electricity Sales ($/yr) @ $0.1141/kWh	$568,151
Economics of PV system (net profit includes excess electricity sales to the grid and direct savings from displaced utility supplied electricity	Net Profit ($/yr)	$3,102,173
	Raw PV installed cost	$69,071,395
	Incentive @ $2.55/watt	$27,452,004
	PV cost after Subsidy	$41,619,391
	PV O&M ($/yr)	$82,886
	Simple Payback	13.8
	ROI	7.3%

* Total of ~10,760 kW (dc) of PV systems installed on 45% of the roof areas of prototypes 3 to 5.

Table 38. Details of PV* Economic Calculation

3.2 Utility Impacts

This section of the results addresses the following research objective:

- Determine the extent to which the application of these technologies, in typical development projects, will reduce peak demand and result in better utilization of existing utility infrastructure;

As in the preceding section, the results of the electric and natural gas utility impacts for each modeled option are presented below for the two development sites in turn, beginning with Site-A.

3.2.1 Site-A: Electric Utility Impacts

The utility impact analysis was conducted by the distribution planners at San Diego Gas and Electric after reviewing all of the load profiles generated by the researchers for each of the modeled development scenarios/options for Site-A.

The results of the analysis indicate that the estimated demand load for the site as planned by the building (BPB development option) is 19.8 MW. The implementation of the EE development option, and specifically energy-efficient lighting, insulation, windows, roof materials and

[46] See page Appendix=B of this report to review technical details / modeling assumption for PV based on-site power

HVAC systems would permanently reduce the distribution system demand load by 3.3MW or a 17.4% reduction in demand.

Implementation of the EE-PV option in Site-A would reduce demand during sunny periods from approximately 9am to 6pm. The demand reduction estimated is approximately 2.4 MW or a 12% reduction from the 19.8 MW load demand for the site. However, it should be noted that PV produces energy intermittently and high residential circuit loads have a peak demand during the weekday between 6pm and 9pm. Therefore, the PV option would not be affect residential peak demand.

Implementation of the DG development option would produce a 5.63 MW or 28% reduction in the Site-A load demand. However, the DG systems would have to be available 100% of the time with N-1[47]redundancy designed into the system in order to eliminate the electric distribution planning to serve the required capacity for the Site.

With regard to circuitry, a estimated demand of close to 20 MW would require three (3) distribution circuits and associated electric facilities. Three (3) circuits will provide for capacity and reliability if an N-1 condition such as a loss of one circuit occurs.

The estimated impact of the EE development option, would still require three circuits in order to provide both capacity and reliability if an N-1 condition occurred. However, average circuit loading would reduce from 6.6MW to 5.5 MW. Additionally, substation loading would reduce by 3.3 MW or 11%, however all substation electric facilities would remain unchanged.

The estimated impact of the EE-PV development option would also still require three circuits to provide both capacity and reliability in the event that an N-1 condition occurred. The planned circuit loading would be the same as the EE development option in the event that the solar energy was not available on cloudy days. However during periods of PV operation, loading would reduce to 4.7 MW. Substation transformer bank loading would reduce by 5.76 MW or 19.2%, however, all substation electric facilities would remain unchanged.

The estimated impact of the EE-DG development option, assuming 100% availability with an N-1 worse case scenario redundancy designed into the system, would reduce the required circuitry from three (3) to two (2) and the associated electrical facilities as well. Given this option, the average load on the two circuits would be 5.4 MW each. Two (2) circuits and associated electrical facilities would provide sufficient capacity and reliability if an N-1 condition resulted in the loss of one of the circuits. Under these same system assumptions, the substation transformer bank loading would reduce by 8.96 MW or 30%. One less circuit would be installed at the substation, however, all other substation electrical facilities would remain unchanged.

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[47] An N+1 redundancy is a system configuration in which multiple components (N) have at least one independent backup component to ensure system functionality continues in the event of a system failure. To be at a level of N+1, the overall system integrity should not be impacted by the failure of any one component, and should continue to function at acceptable performance levels after the loss of any component.

3.2.2 Site-A: Gas Utility Impacts

Similar to the electric utility impact analysis, the SDG&E natural gas distribution planners reviewed all load profiles generated by the researchers to determine the necessary distribution piping, pressures and regulators necessary to serve the Site-A development.

The analysis required the design of alternative piping systems under the different development options and they are contained in Appendices-C through –G. The first design (Appendix-C), shows the existing natural gas utility infrastructure at the development site. The second design (Appendix-D) shows a conventional or "baseline" piping layout (described in the methods chapter) to meet the SDG&E-estimated demand for the Site-A buildings based on the planners best professional judgment and past experience with similar developments. The third design (Appendix-E) shows an optimized piping layout designed to meet the loads of the researcher's modeled EE development option. And the fourth and fifth designs (Appendix-F and –G), show the optimized piping layout designed to meet the modeled EE-DG loads. Given that the EE-PV development option does not impact natural gas usage at the site, a separate gas distribution layout and analysis was not conducted.

Tables-39 through -41 below provide the overall results related to the cost of providing gas mains to serve the SDG&E-estimated demand scenario and the researchers EE and EE-DG development options for Site-A. Necessary piping pressures for the combined sites A and B are contained in Appendix-D, -E and –G.

Site-A: SDG&E-Estimated Baseline Loads w/ Conventional Plan & Pipe Sizing		
Pipe Size	Pipe Footage	Cost $
2-Inch	5148	$200,769
3-Inch	9336	$420,137
4-Inch	8392	$469,927
6-Inch	3811	$255,340
Total	26687	$1,346,172

Table 39. Site-A: Pipe Sizing and Costs – SDG&E Conventional Plan

Site-A: EE Option Loads with an Optimized Plan & Pipe Sizing		
Pipe Size	Pipe Footage	Cost $
2-Inch	22876	$892,157
3-Inch	551	$24,809
4-Inch	3260	$182,545
6-Inch	0	$0
Total	26687	$1,099,512

Table 40. Site-A: Pipe Sizing and Costs – Optimized Plan for the EE Option

Additional Cost Requirement to Accommodate Distributed Generation Loads	
Distribution Regulator Station	$250,000

Table 41. Site-A: Additional EE-DG Costs Requirements

Analysis of the tables and appended plans suggests a significantly lower natural gas demand for the EE development option, and the associated piping system costs given the reduction of the amount of larger pipe sizes, although the total piping length required remains the same as that for the SDG&E-estimated loads. However, the addition of DG to the EE option results in an additional capital requirement of $3, 340 over the SDG&E conventional distribution plan capital requirement.

3.2.3 Site-B: Electric Utility Impacts

The results of the analysis indicate that the estimated demand load for the site as planned by the building (BPB development option) is 11.27 MW. The implementation of the EE development option would reduce the demand load to 10.31 MW. Both of these loads would require two circuits to serve. The utility planners believe that the approximately 1 MW reduction produced by the EE development option over the baseline option could influence future circuit needs if additional/adjacent areas were also targeted with similar high efficiency with measures. However, given the modest scale of the estimated load reductions for the modeled development options at Site-B, and concerns for system capacity and reliability, the utility would not alter its distribution plans for the site.

To provide the reader an additional understanding of the utility's current substation design parameters, most provide 120 MVA (megavolt amperes - one million volt amperes) of capacity through four transformer banks at approximately 30 MVA each. This capacity equates to a maximum of 16 circuits per substation averaging 7.5MW per circuit or 375 Amps at 12 kV. Ties are created between circuits to allow alternative feeds in the event of an outage. Capacity is reserved on the circuits for these contingencies. Due to the heavier loading in denser areas such as the Site-B development site, the utility would typically reduce the number of circuits from the substation to 12 – 14 circuits to provide more flexibility to serve areas from alternative circuits when an outage occurs.

As in the Site-A example due to the utility's inability to rely on the PV or DG technology as a firm resource for peak situations, they would not include these resources for planning purposes. With more redundancy, physical assurance, and confirmed impact on peak under various planning scenarios these resources may be given some credit in the planning process in the future.

3.2.4 Site-B: Gas Utility Impacts

Again, similar to the electric utility impact analysis, the SDG&E natural gas distribution planners reviewed all load profiles generated by the researchers to determine the necessary distribution piping, pressures and regulators necessary to serve the Site-B development.

Tables-42 through -44 below provide the overall results related to the cost of providing gas mains to serve the SDG&E estimated demand scenario and the researchers EE and EE-DG development options for Site-B. Necessary piping pressures for the combined sites A and B are contained in Appendix-D, -E and –G.

Site-B: SDG&E-Estimated Baseline Loads w/ Conventional Plan & Pipe Sizing		
Pipe Size	Pipe Footage	Cost $
2-Inch	12027	$469,058
3-Inch	1115	$50,172
4-Inch	843	$47,199
6-Inch	1465	$98,146
Total	15450	$664,575

Table 42. Site-B: Pipe Sizing and Costs – SDG&E Conventional Plan

Site-B: EE Option Loads with an Optimized Plan & Pipe Sizing		
Pipe Size	Pipe Footage	Cost $
2-Inch	13142	$512,541
3-Inch	2308	$103,846
4-Inch	0	$0
6-Inch	0	$0
Total	15450	$616,387

Table 43. Site-B: Pipe Sizing and Costs – Optimized Plan for the EE Option

Additional Cost Requirement to Accommodate Distributed Generation Loads	
Distribution Regulator Station	$250,000

Table 44. Site-B: Additional EE-DG Costs Requirements

Analysis of the tables and the appended plans suggests a less significant but still lower natural gas demand for the EE development option, and the associated piping system costs, again given the reduction of the amount of larger pipe sizes, although the total piping length required remains the same as that for the SDG&E-estimated loads. However, the addition of DG to the EE option results in an additional capital requirement of $201,812 over the SDG&E conventional distribution plan capital requirement.

3.3 Technology Construction Impacts & Market Feasibility

This section of the results addresses the following research objective:

- Determine the market-feasible combinations of energy technology and design options that will increase building energy efficiency by more than 25% above existing Title-24 2005 standards.

More specifically, the section provides the results of the analyses conducted on the construction and market feasibility of the modeled energy technology options. The market feasibility of the community design options is covered at the end of the next section of the chapter.

As explained in Chapter 2, this assessment included an analysis of construction process impacts of the technologies and an assessment of the potential cost offsets (and concomitant reductions in payback period) associated with utility company incentives. The results from these analyses are presented independently, followed by a discussion of overall assessment of market feasibility.

Building Component	Alternative Type	Process Impacts	Comments
External Walls	Alt 1 & 2: Material substitution	Minimal	Captured by material and/or labor delta
	Alt 3: Additional step (rigid insulation), multiple trades	Interface/ tolerance trade interaction	Interview and modeling required
Roofing (Prototype 6)	Alt 1 & 2: Add'l step (rigid insulation) TBD trade	Trade interaction	Interview and modeling required
	Alt 3: Additional step (rigid insulation), multiple trades, add'l step (elastomeric) same trade	Trade interaction, minimal for elastomeric	Similar to above plus material and labor delta
Roofing (all others)	Alt 1 & 2: Material substitution	Minimal	Captured by material and/or labor delta
	Alt 3 (where present): add'l step (elastomeric) same trade	Minimal	Captured by material and/or labor delta
Windows	Product substitution	Minimal	Captured by material and/or labor delta
HVAC	Product substitution	Minimal	Captured by material and/or labor delta
Space Heating	Product substitution	Minimal	Captured by material and/or labor delta
Appliances	Product substitution	Minimal	Captured by material and/or labor delta
Lighting	Product substitution or arrangement	Minimal	Captured by material and/or labor delta
On-site power generation	Additional system, new trade involved	Minimal to the building package system	Captured by material and/or labor delta

Table 45. Summary of Construction Impacts of Alternative Building Elements

3.3.1 Construction Process Feasibility Assessment

This assessment consisted of four steps as outlined in Chapter 2. The results from each step are presented here.

Evaluation and characterization of process implications
The Site-A: Modeling Assumptions (see Appendix-A) presents a number of alternates for a variety of building systems, including the external walls, roofing, fenestrations, mechanical systems, appliances, and generating systems. The specific changes implied by each alternate were studied to determine the process implications of that alternate. For this initial assessment, the process implications were characterized into one or more of the following types (Table-45), based on an initial assessment of the alternates:

- Product substitution – The alternate requires that a product used in the base case is replaced with a different product. The implications of this kind of alternate are minimal for the process, subject to assumptions of similar product availability and lead time. These assumptions appear to be appropriate for the cases included in this research. An example of a product substitution is the replacement of a standard air conditioning unit with a higher SEER unit – the same trades are involved in essentially the same order, but the specific unit that will be set on the anchor bolts is different. There might be lead-time implications, but those can usually be addressed in the sourcing and buy-out process. Furthermore, alternates considered for this project do not include items with dramatically different supply chain conditions than the “normal” product, so lead-time concerns are not expected.
- Additional step, same trade – Some trade-based subcontractor within the overall production system has to conduct an additional activity, but does not add a handoff to an additional trade. This is a relatively minor disruption, and in effect just means that a given subcontractor will have temporary control of a given area of the project for a longer time. This impact can be estimated effectively from the basic time and material change represented by the new step.
- Additional step, multiple trades – Some trade-based subcontractors have additional steps, and new handoffs exist within the production system. This is a more serious disruption, and requires additional analysis.

Clearly from Table-45, the majority of the building component alternates contemplated for the alternative development scenarios are characterized as substitutions of one material/equipment for another. The process implications of such a change are minimal, and thus expected cost differentials for that alternate can be reasonably described by the difference in cost for the item being replaced over the base case item, and any difference in labor or equipment requirements to install the alternate item. Again, for purposes of this research, lead time or material availability differences, which might have overall process implications, were not studied, because market forces that create these differences are so transitory in nature. The specific replacements contemplated by the set of alternates proposed in this work are not expected to have significant lead time or availability implications, as of this writing.

Selection of potentially disruptive alternates

The exceptions to the general rule of little potential for process disruption are the external wall alternates including rigid insulation, and roofing systems for Prototype 6. These alternates were studied in more detail to evaluate potential cost implications of the resulting process disruptions. For these cases, additional process analysis was conducted to determine whether the potential disruptions actually existed, and if so, what cost implications might ensue.

3.3.2 Process Mapping & Estimation of Cost Impacts

The most important tool in process analysis is the development of process maps. Maps are used in process analysis in a number of ways, including assisting in visualizing the process, communicating the process, and providing material for quantitative analysis of the process, including simulation. The visualization component is particularly cogent in this particular case, as the process maps for two different building alternates can be compared to determine the changed handoffs or additional steps quite readily. Once the map is developed, the appropriate level of analysis to accommodate the proposed objective can be selected.

The information needed for creation of the process maps includes the steps in the process, the entities that conduct those steps, and the process logic. In this context, "process logic" refers to the set of precedence relationships for the steps in the process, or in other words an understanding of the steps that must be completed in order for a given step to begin. The information needed for the creation of process maps can be collected from literature sources and one or a combination of three basic methods (Damelio, 1996): (1) self-generation by the individual creating the process map; (2) interviews with knowledgeable participants in the process contractors, subcontractors, suppliers, etc.; and (3) observation of the process. Although some information for the building alternate construction process mapping effort was obtained from literature, through self-generation, and from observations, one-on-one interviews were the major sources used to verify the information needed for the planned process maps in this research.

The general process consisted of developing an initial map from self-generation and literature review. This map was then used to start the conversation in interviews conducted with project managers and estimators at large commercial construction companies to clarify the processes. A short description of the process map concept was used first, leading to a discussion of the particular map presented for the process of interest. The interviewee was asked to consider the process map and to indicate areas where the map did not match their understanding of the process. The interview resulted in an improved map which was then brought back for clarification and validation a few days later. Finally, observations of the process in action at building sites provided a final opportunity to incorporate additional changes.

Process maps are graphical depictions of the steps that make up a process. However, the nature of the steps composing the process can be variable. Thus, in useful process maps that help recognize process inefficiencies, representative symbols that visually designate activities, buffers, transportation, communication, decisions, and other operations are used. Descriptions added to these symbols can provide further information on the type of activity, inspection, etc. being performed. In the process map, arrows connect each symbol in sequence. For the level of analysis needed for this study, a simplified symbology was used consisting of circles to represent the beginning and end-point of a particular process, rectangles to represent activities conducted during the process, and arrows to outline the process logic. Process logic is further elucidated by the placement of activities into a rough temporal order from left to right.

The type of process map used in the building alternate process mapping effort is the cross-functional process map. Cross-functional process maps depict how the activities within a given process cut across several functions or entities (Damelio, 1996). This type of process map shows the sequence of steps of the process, as well as the functions or entities that are responsible for these steps. It should be noted that the functions or entities can be from within one company–such as different departments of the same company–or, as in the case of processes in the building industry, from several companies–such as the general contractor, trade contractors, inspectors, etc. This type of identification of responsible parties in the case of construction processes is in fact a very useful mechanism that helps identify complexities involved in the construction process, as it is inherent to the identification of handoffs.

In cross-functional process maps, one row, or *swimlane* as it is sometimes referred to, is designated for each department or entity. Everything this department or entity is responsible for will be depicted in one row of the process map. In this particular case, the rows or swimlanes thus provide a means to relate the activities of a given trade contractor, the process logic can be represented by location of activities from left to right and between arrows, and handoffs are clearly identified when process logic arrows cross the boundary (or multiple boundaries) between lanes. The process map for the base case external wall process is presented in Figure-39. The same map would be appropriate for The map for Alternate 3 (rigid exterior insulation) for the prototypes where the exterior veneer is plaster presented in Figure-40.

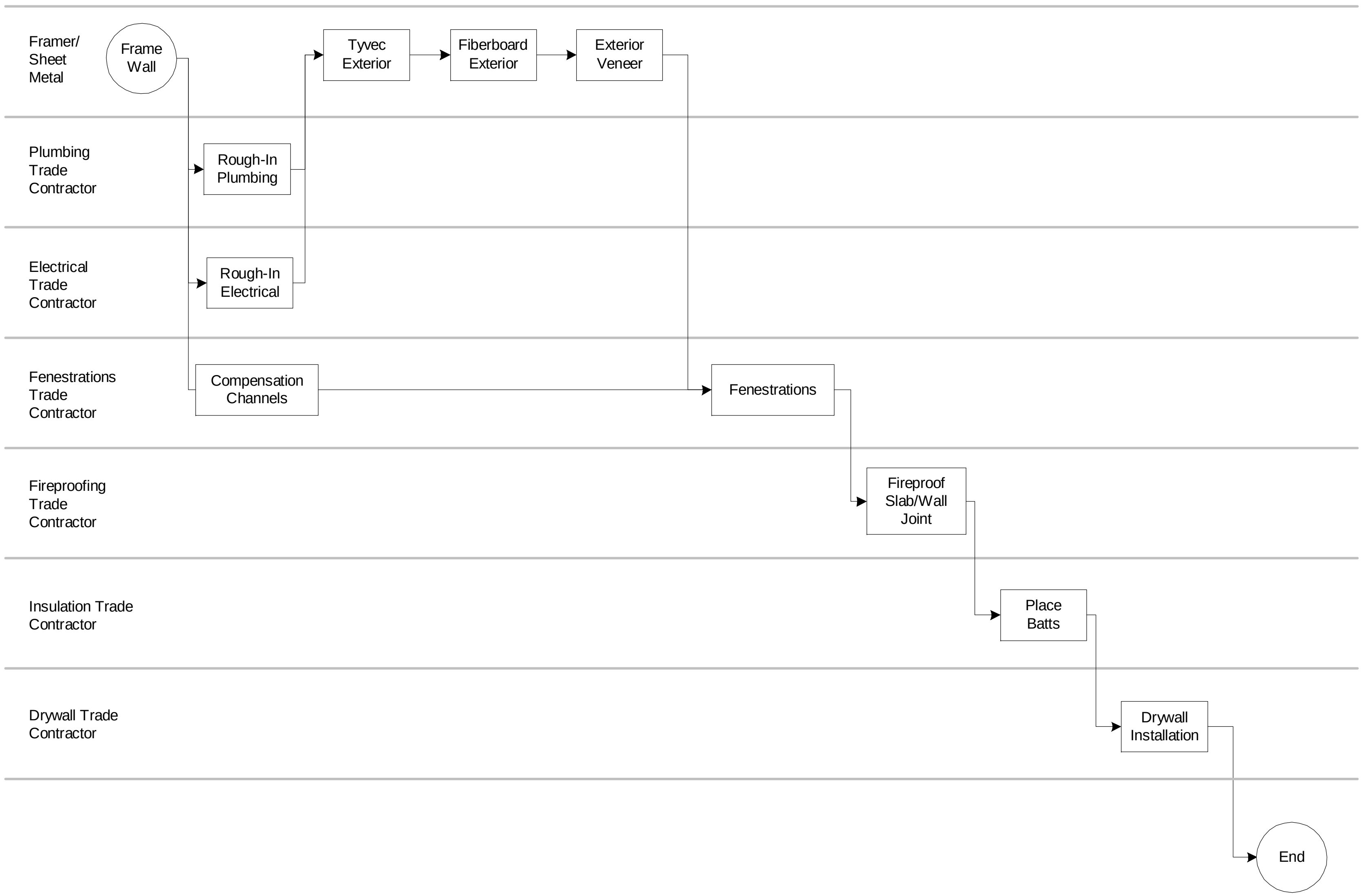

Figure 39. Base Case External Wall Process Map

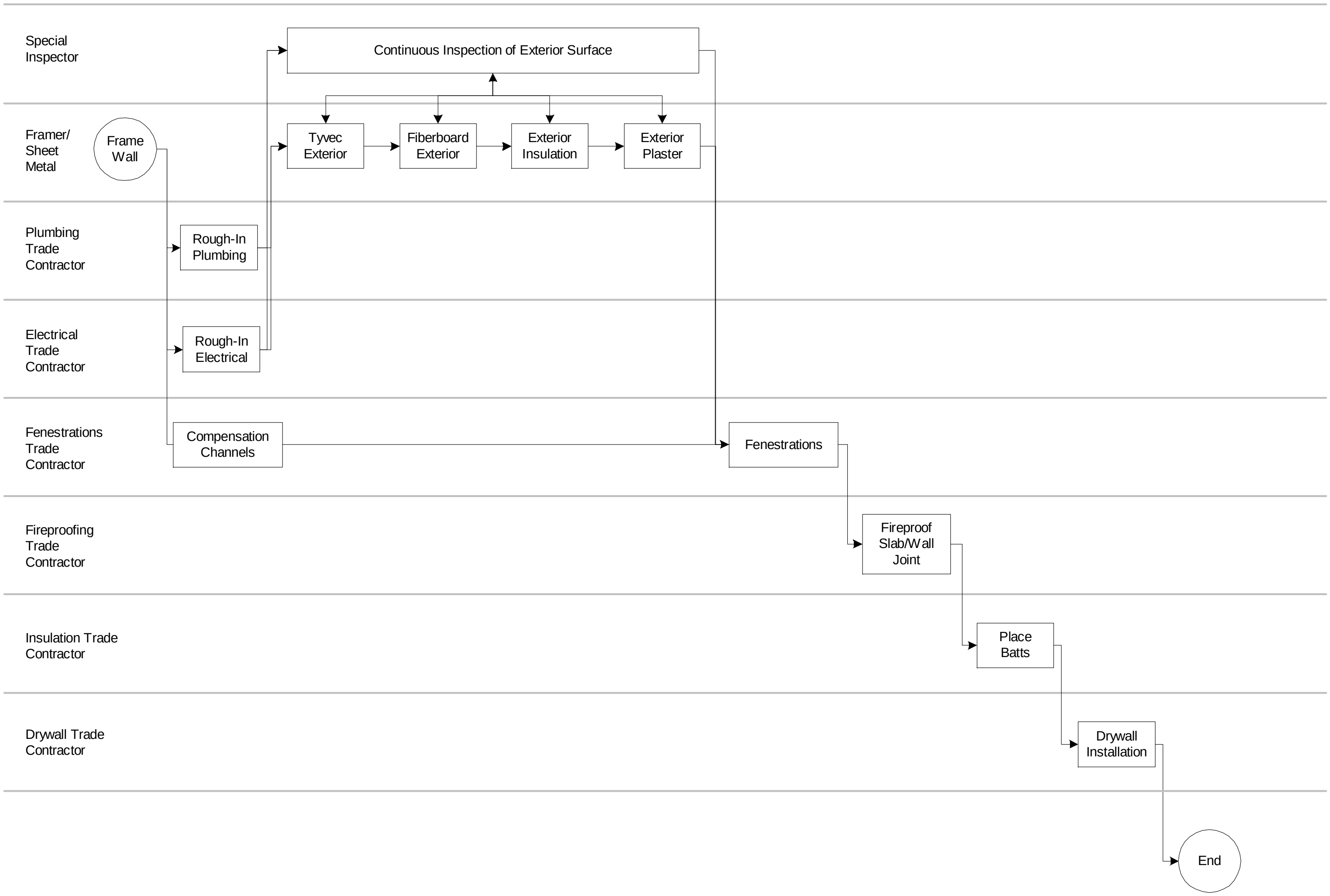

Figure 40. Process Map: Rigid Exterior Insulation - Plaster Veneer

Figure-40 shows a typical construction approach for commercial structures in which the wall is framed, rough-ins are completed, and the exterior veneer is installed. The exterior veneer is usually the responsibility of the framing/sheet metal trade contractor, who is generally assigned the entire exterior wall system as part of their scope of work. Fenestrations are installed around the exterior veneer so that a proper seal can be made for weatherproofing, and then the process continues with fireproofing, insulation, and drywall on the interior surface.

Several of the proposed alternates to the exterior wall system create little or no disruption to this process. Alternates 1 and 2 are thicker insulation in the wall. The change to thicker insulation batts (depending on thickness) would necessitate different framing materials (but by the same trade at the same point in the schedule), and different insulating materials (but by the same trade at the same point in the schedule). These disruptions would be minimal beyond the cost differential of the materials and the labor differential that might be involved in, for example, working with thicker batts. Furthermore, if rigid insulation is used but the exterior veneer is not plaster, the framer/sheet metal contractor would simply be assigned one more activity to install this product. No new inspections or handoffs are created, so only the additional cost for the material and associated labor – by the same trade contractor – would need to be considered.

However, if the exterior veneer is plaster, the system looks very different to the contractor and the community. Because there is a history of problems with exterior insulation finish system (EIFS) performance, any application of plaster over rigid insulation comes under additional scrutiny. Problems that were noted in past EIFS applications include water penetration, mold, and degradation of the underlying sheathing, and a number of very large construction defect liability judgments and settlements have occurred. Thus, even though the product specified in alternate 3 is not technically an EIFS, it shares the broad strokes of EIFS surfaces and creates pressure to view it as such. One impact of this similarity is that contractors in the San Diego region adopt special inspection requirements for such systems (whether required by the particular jurisdiction or not, owing to liability concerns).

The addition of the special inspector results in a new swimlane at the top of Figure-40, which is not present in Figure-39. This represents the addition of a full-time quality control inspector during the exterior sheathing operation. Thus, in addition to the additional cost of labor and material for the insulation itself, there is a need to add the cost for having a contracted inspector on-site during the sheathing process. That cost was estimated for the plaster prototypes based on the total square footage of external wall and a reasonable crewing strategy, and then divided by the exterior square footage to achieve a unit cost impact. The average result for the appropriate prototypes was approximately $0.30 per square foot.

In addition, the exterior rigid insulation products must be sanded and prepped to a smooth surface before plaster can be applied. This process results in a substantial quantity of dust, which is difficult to capture once it is liberated from the insulation product and is generally objectionable to the public, the neighbors, and to the relevant stormwater quality control agencies. To prevent release of this dust, it is common to shroud the scaffolding for these cases, an additional cost. A simplified estimate of this cost was developed by adding five feet to the exterior plan dimensions of the prototypes, and calculating the resulting area of scaffold coverage needed. The result was then divided by the actual exterior wall area to achieve a unit cost impact. The average result for the appropriate prototypes was approximately $0.15/square foot.

Note that aside from the inspections, no new handoffs are associated with the alternate because the addition of the insulation itself is conducted by a trade contractor already conducting work. Thus the cost differential for this alternate over the base case consists of the labor and material cost delta for the exterior insulation, plus the additional impacts of the inspection and shrouding costs. Because no new handoffs are involved, no stochastic analyses such as discrete event simulation experiments were needed. The estimated additional costs for materials and labor for the exterior insulation itself and the thicker bats based on the 2007 R.S. Means Building Cost Data Guide are $0.83/square foot and $0.13/square foot, respectively, for a total cost impact of $1.41/square foot.

Based on the characterization of the potential for disruption in Table-45 for roofing alternates in Prototype 6, a similar effort was begun for the roofing process. The assessment that the alternate created a potential for process disruption was based on the initial determination that the rigid insulation in the middle of the roof membrane system would be installed by a different trade contractor, and thus would represent new handoffs. However, in the interview process it was revealed that this is not the case. In fact, in such systems the rigid insulation is commonly installed by the roofing trade contractor, because they have overall liability for the water-tightness of the whole system. Thus, this simply represents another step and more material for the same subcontractor, and the cost impacts are effectively captured by the material and labor cost differentials.

There are concerns for the potential for damage to the insulation while it is exposed before the membrane covers it, but these are usually handled by scheduling and coordination with roof penetrations and have no significant cost differences. Additional labor is sometimes needed to accommodate changes to the roof drainage with rigid insulation, but this impact is captured in the labor cost differential. Thus, the interview process revealed that the cost impacts are confined to those represented by material and labor deltas without need to proceed to completed process maps.

3.3.3 Assessment of Utility Incentive Impacts on Market Feasibility

Methods and equations used for evaluating the impact of utility-based incentives on the payback period for energy efficiency packages were presented in Chapter 2. Using the methods outlined there, simple paybacks incorporating the incentives were produced, and are summarized in Table-46. Blank fields indicate that a particular package was not considered cost effective and/or practical for addition of photovoltaics, even with incentives. The results with an asterisk (*) indicate that the relevant package and prototype achieve an estimated increase in building energy efficiency of 25% or more above existing the existing Title-24 2005 standard.

Prototype	Optimum EE Package			Combined Optimum EE-PV Package		
	Payback Without Incentive (Years)	Payback Counting SDG&E Incentive High Estimate (Years)	Payback Counting SDG&E Incentive Low Estimate (Years)	Payback Without Incentive (Years)	Payback Counting SDG&E Incentive High Estimate (Years)	Payback Counting SDG&E Incentive Low Estimate (Years)
1 (FSR)	5.5	4.6	4.8	19.0*	16.8*	17.2*
2 (MTR-c)	12.5	11.6	11.7	20.0*	17.9*	18.3*
2 (MTR-i)	11.3	9.7	10.0	19.8*	17.8*	18.1*
3 (MRS)	4.1	2.7	2.9	21.9*	19.8*	20.1*
4 (LRO)	9.7	8.2	8.5	17.2*	15.3*	15.6*
5 (MRO)	3.4*	1.8*	2.1*	11.7*	10.0*	10.3*
6 (HRO)	3.6	2.1	2.3	6.1*	4.4*	4.7*
7 (LGH-hs)	2.9	1.4	1.7	11.0*	9.1*	9.4*
7 (LGH-r)	5.4	4.4	4.6	19.1	17.0	17.3
8 (SMH-hs)	3.8	2.3	2.6	16.2*	14.1*	14.5*
8 (SMH-os)	8.3	6.8	7.1	16.8*	14.9*	15.2*
8 (SMH-r)	6.4	5.5	5.6	19.2*	17.1*	17.4*
8 (SMH-ex)	7.4*	5.8*	6.1*	--	--	--
8 (SMH-in)	7.9*	6.3*	6.5*	--	--	--
9 (RCM-os)	3.6	2.1	2.3	10.8*	9.1*	9.3*
9 (RCM-c)	9.4	8.0	8.3	--	--	--
9 (RCM-in)	8.0	6.5	6.8	--	--	--
10 (RRM-res)	6.9	6.0	6.1	11.1*	9.9*	10.1*
10 (RRM-c)	8.6	7.2	7.4	--	--	--
10 (RRM-in)	7.9	6.3	6.5	--	--	--
11 (RRL-res)	10.7	9.8	9.9	11.8*	10.7*	10.9*
11 (RRL-c)	8.9	7.4	7.7	--	--	--
11 (RRL-in)	9.7	8.2	8.5	--	--	--
12 (CCM-lib)	3.0*	1.4*	1.6*	--	--	--
12 (CCM-os)	3.5*	2.0*	2.2*	10.2*	8.5*	8.8*
13 (RTH)	15.6	12.4	13.0	11.6*	11.3*	11.4*
14 (RLR)	9.0	7.2	7.5	12.0*	11.8*	11.8*
15 (RMR)	6.0	4.5	4.7	10.6*	10.1*	10.2*

Table 46. Site-A: SDG&E Incentive Impacts by Prototype

The prototype numbers and codes and the values reported in the column "Payback Without Incentive" for both packages correspond to the values contained in Appendix-A. The high and low estimates refer to the estimate of the incentive amount. The higher the estimate, the lower the payback, which explains why the column labeled "High Estimate" for each package exhibits a lower payback period. The difference between the high and low estimate is the 20% incentive for sustainable practices.

In addition to the incentive payable to owners, SDG&E also provides incentives to designers to help defray the cost of the additional design work associated with including EE upgrades in the building. These incentives were not explicitly included in the incentives used to develop the payback periods in Table-46, because the design costs are estimated separately in the upgrade costs developed by the researchers. These incentives are presented in Table-47. Designer incentives are not available for Prototypes 13-15.

Prototype	Optimum EE Package	Optimum EE - PV Package
1 (FSR)	$1,086	$6,455
2 (MTR-c)	$63	$1,270
2 (MTR-i)	$209	$1,315
3 (MRS)	$4,816	$32,470
4 (LRO)	$3,896	$16,053
5 (MRO)	$17,515	$35,832
6 (HRO)	$33,828	$42,616
7 (LGH-hs)	$10,718	$21,489
7 (LGH-r)	$1,026	$6,348
8 (SMH-hs)	$7,441	$23,296
8 (SMH-os)	$2,205	$9,152
8 (SMH-r)	$1,100	$6,532
8 (SMH-ex)	$563	--
8 (SMH-in)	$510	--
9 (RCM-os)	$12,141	$22,399
9 (RCM-c)	$230	--
9 (RCM-in)	$214	--
10 (RRM-res)	$4,335	$16,916
10 (RRM-c)	$247	--
10 (RRM-in)	$224	--
11 (RRL-res)	$1,269	$14,794
11 (RRL-c)	$255	--
11 (RRL-in)	$219	--
12 (CCM-lib)	$6,737	--
12 (CCM-os)	$19,524	$34,517

Table 47. SDG&E Designer Incentive: Estimates by Prototype and Package

3.4 Site-A: District Cooling System Evaluation

3.4.1 Annual Electricity Consumption & Cost

As stated in the methods chapter, a special study was conducted under the research project to examine the economic feasibility of a district cooling system in place of conventional stand-alone building air conditioning systems to serve the Site-A cooling loads. The results of the study are presented below.

The district cooling plant electric consumption and costs calculated according to the methods described in Chapter-2 are presented in Table-48 below. More detailed breakdowns of electricity cost calculations for each district cooling alternative are found in Appendix-O.

Utility Rate Period	Builder Proposed Baseline			EE-PV Configuration		
	District Cooling Without TES	District Cooling With TES	Stand-alone (Cooling Production at Individual Buildings)	District Cooling Without TES	District Cooling With TES	Stand-alone (Cooling Production at Individual Buildings)
Summer On-Peak (kWh)	2,665,941	686,010	2,942,222	1,900,159	497,692	1,985,120
Summer Semi-Peak (kWh)	1,590,150	1,668,635	2,176,560	1,148,184	1,157,425	1,515,377
Summer Off-Peak (kWh)	1,285,711	3,004,155	2,033,139	844,981	1,984,139	1,366,911
Winter On-peak (kWh)	338,553	-	704,150	190,954	-	476,573
Winter Semi-Peak (kWh)	2,277,684	78,217	3,572,066	1,362,434	47,378	2,395,329
Winter Off-Peak (kWh)	604,463	3,142,484	1,262,323	341,963	1,847,973	844,801
Total annual electricity use	8,762,503	8,579,501	12,690,461	5,788,675	5,534,605	8,584,112
Total annual electricity cost	$ 1,755,500	$ 1,235,200	$ 2,203,900	$ 1,273,100	$ 857,300	$ 1,529,900

Table 48. Annual Electricity Consumption & Cost

The results of the analysis and content of the table indicate that annual electricity costs are significantly lower for the district cooling alternatives than for the stand-alone alternatives with cooling production at individual buildings. Electricity costs are especially reduced for the district cooling alternatives with thermal energy storage (TES), due to its ability to shift cooling production from high-cost peak times, to lower cost semi-peak and off-peak times.

The factors contributing to the district energy system's cost effectiveness, relative to the stand-alone alternative, are the following:

- The large chillers used in the district system are highly efficient;
- There are a large number of chillers in the district cooling plant, so individual chillers can be more fully loaded at part system loads, and therefore more efficiently;
- Due to the number of chillers, series-counterflow chiller arrangement is practical (as described in the methods chapter);
- The ability to cost-effectively deploy energy cost reducing technologies, such as thermal storage; and
- 24-7 monitoring helps ensure plant is being run at optimal efficiency.

In addition to cost savings, the reduced electricity consumption of the district cooling alternatives will reduce pollution and greenhouse gas emissions generated by central power plants serving power to the Site-A development. Comparing the district cooling with TES alternatives to the stand-alone alternatives, for the Builder Baseline scenario energy consumption is reduced by 4.11 million kWh and for the EE-PV scenario by 3.05 million kWh. Utilization of TES is particularly helpful in reducing environmental emissions, since chilled water production is shifted to off-peak times when electricity is produced by cleaner and more efficient base-load production facilities, versus peaking facilities.

3.4.2 Site-A: Annual Operating Cost Analysis Results

The results of the annual operating cost analysis, comparing the economics of a district cooling system for Site-A against the economics of stand-alone cooling production at individual buildings, is presented in Table-49 below.

Annual Operating Cost Item	Builder Baseline Scenario			EE-PV Configuration Scenario		
	District Cooling Without TES	District Cooling With TES	Stand-alone (Cooling Production at Individual Buildings)	District Cooling Without TES	District Cooling With TES	Stand-alone (Cooling Production at Individual Buildings)
Capital recovery	$ 3,391,200	$ 3,279,500	$ 2,900,700	$ 3,074,000	$ 2,962,700	$ 2,697,400
Electricity	$ 1,755,500	$ 1,235,200	$ 2,203,900	$ 1,273,100	$ 857,300	$ 1,529,900
Water	$ 108,000	$ 108,000	$ 87,100	$ 88,800	$ 88,800	$ 73,900
Water treatment chemicals	$ 67,600	$ 67,600	$ 54,000	$ 55,100	$ 55,100	$ 45,400
Maintenance	$ 398,700	$ 381,500	$ 547,000	$ 359,800	$ 342,700	$ 521,400
Operating labor	$ 390,000	$ 390,000	$ 585,000	$ 390,000	$ 390,000	$ 585,000
Total annual operating costs	$ 6,111,000	$ 5,461,800	$ 6,377,700	$ 5,240,800	$ 4,696,600	$ 5,453,000
Cost diff. from "Stand-alone"	-4.2%	-14.4%		-3.9%	-13.9%	

Table 49. Annual Operating Cost Analysis Results

The results of the economic analysis indicate that the district cooling alternatives without TES have a moderate annual operating cost advantage over stand-alone cooling production at individual buildings. Once TES is introduced to the district cooling configuration, the economic advantage of the district cooling alternatives over the stand-alone alternatives is more significant, due to substantially reduced electricity costs and a minor reduction in plant capital costs.

3.4.3 Site-A: Items Not Evaluated That Could Impact Results

There are a number of items that were not evaluated within the scope of this preliminary analysis that could impact the results of the economic comparison of district cooling versus stand-alone cooling production at buildings. Some of these items are discussed below.

For the scenario with chilled water thermal storage, the researchers have assumed that the thermal storage tank is sited in the vicinity of the district cooling plant. If it is possible to site the thermal storage tank in a more hydraulically beneficial location, such as on the opposite side of the development, then overall distribution piping sizes could be reduced, which may result in a net lifecycle cost benefit to the economics of the thermal storage scenarios.

Another potential scheme for the thermal storage scenarios that was not analyzed within this scope of this analysis, but may provide lifecycle cost savings to the project, is a design that provides lower supply water temperature at peak times (e.g. 36°F versus 40°F). This can be achieved by utilizing a low temperature fluid in lieu of plain water thermal storage, which allows for the benefits of stratified thermal energy storage with chilled water supply temperatures lower than 39.4°F. Although this scheme requires somewhat higher energy consumption at peak times and additional equipment and piping within the chilled water plant, it would reduce the size requirements for both the thermal storage tank and the distribution piping system, offering significant capital cost savings.

If the siting of a chilled water thermal storage tank is not possible due to land constraints or architectural issues, it would be possible to utilize ice storage in lieu of chilled water thermal storage. This solution would have higher plant capital costs and operating costs than chilled water thermal storage, but the space requirements for the thermal storage tank are dramatically reduced. It is unlikely that lifecycle costs will be improved with ice storage versus chilled water storage but, due to the favorable utility rate structure, this option should still provide significant cost savings over a district cooling plant without thermal storage.

As discussed in the methods chapter, if insulation is not required for some or all of the distribution piping then distribution capital cost may be reduced, which would improve the economics of the district cooling alternatives for Site-A.

As discussed in the previous chapter, the new EECC commodity charge rate structure should be beneficial to large customers like district cooling plants, which may improve the economics of the district cooling alternatives for Site-A.

3.5 Community Design Option Performance

This section of the results addresses the following research objective:

- Estimate the degree to which enabling community design options can improve energy technology performance in typical development projects.

In addition to this objective, the analysis was designed to estimate the degree to which these community design options can reduce overall energy consumption and emissions in large-scale development projects.

The design options considered by the researchers included: mixed-use/moderate-density development; stormwater runoff and carbon sequestration measures; urban heat island reduction measures; and passive solar building orientation. The findings presented below are the result of applying the methods described in the previous section to Site-A and Site-X. For both sites, comparisons were made between an optimized scenario featuring these advanced design options and a baseline scenario without these design options. Note: In the case of the district energy system and passive solar design options, the analysis focused on Site-A and Site-X, respectively.

3.5.1 Mixed-Use, Moderate-Density Development

As stated in the methods section, the researchers examined the relationship between mixed-use, moderate-density development and the performance of CCHP and district cooling technologies and the affect this design option has on community energy consumption and emissions reduction relative to transportation and land use efficiency. The research findings support the hypothesis that mixed-use, moderate-density development does enable the economical use of both distributed generation – CCHP technologies and district cooling technologies and results in both a significant reduction of central power plant energy consumption and central emissions. Additionally, the findings indicate that this design option significantly reduced land consumption; vehicle miles traveled (VMT); and associated petroleum consumption and emissions in both case study sites. These research results and supporting evidence for each are presented in turn below.

Result #1: Mixed-use, moderate-density development enabled the economical use of distributed generation-CCHP technologies in Site-A: and resulted in a significant reduction of central power plant energy consumption and emissions. However, these reductions were produced at the expense of significantly increased local emissions.

The modeling results indicated that use of distributed generation-CCHP technologies in Site-A would effectively decrease central power plant electricity consumption by 68%. This decrease translates into significant reductions in central power plant emissions, however use of CCHP also increases local emissions when the technology is driven by a fossil fuel (natural gas)-based prime mover such as an internal combustion reciprocating engine. The results also indicate that although central plant emissions are decreased significantly through the local use of CCHP, the increase in local emissions from use of those technologies more than offsets the beneficial decrease of central power plant emissions.

By contrast, renewably-based CCHP systems could offer the benefit of reduced central power plant energy consumption and emissions and lower or even negligible local emissions, depending on the source of energy used. However, present economic and performance barriers, particularly in regard to the intermittency of solar energy, need to be resolved before renewably-based CCHP systems can cost-effectively deliver those benefits. Similarly, advances in emission controls for fossil fuel-based systems, coupled with the return of utility incentives, may also be able to deliver similar benefits in the near future.

With regard to the numbers underlying the results, central power plant energy reductions resulting from the use of CCHP in Site-A (the optimized scenario) would total 10.3 million kWh annually (approximately 35,263 MMBtu). The associated central power plant emissions (CO2, SO_x, and NO_x) would all decrease by 68% through the use CCHP. However as stated, these central power plant emission reductions would be offset by increases in local emissions associated with the use of CCHP. Specifically, CO2 associated with the use of CCHP would increase by 79%, and NOx would increase by 152% above the emissions expected from a central power plant meeting the same load requirements for the low-density (baseline) development scenario for Site-A. However, use of natural gas-fueled CCHP would result in a 64% reduction in central power plant SOx emissions.

Tables-50 and -51 below provide the detailed numbers from which these summary results have been derived.

	Energy Source	Baseline Scenario Central Plant Elec.	Optimized Scenario CCHP	Delta
	Total Bldgs in Site	53	7	
Per Building Utility-Provided Energy Usage	Electric (MMBtu)	974	2,335	
	Gas (MMBtu)	215	21,807	
Site-wide Utility-Provided Energy Usage	Electric (MMBtu)	51,608	16,355	(35,263)
	Gas (MMBtu)	11,395	152,649	141,254

Table 50. Site-A: Annual Site-Wide Energy Use

Emission	Baseline Emissions by Source			Optimized Emissions by Source				
	Electric	Gas	Total	Electric	Gas	Total	Delta	Change
CO_2 (lbs)	10,590,843	1,340,052	11,930,895	3,354,241	17,951,522	21,305,763	9,374,868	79%
SO_x (lbs)	1,936	7	1,942	613	90	703	(1,239)	-64%
NO_x (lbs)	5,171	1,048	6,220	1,638	14,044	15,682	9,462	152%

Table 51. Site-A: Annual Site-Wide Emissions (electric- and gas-related)

Result #2: Mixed-use, moderate-density development enabled the economical use of advanced district cooling technologies in Site-A and resulted in a significant reduction of central power plant energy consumption and emissions.

The modeling results indicate that the costs associated with a district cooling system designed to serve a moderate-density, mixed-use development are 181% lower than the costs of a system designed to serve the same load in a conventional low-density development. Additionally, the research findings indicate that the cost of a system to serve a low-density development would render such a system economically infeasible.

The primary factor responsible for the elevated costs in the segregated-use, low-density development is the requirement for a greater amount of trench-feet of pipe to distribute district cooling as well as increased costs related to energy transfer station (ETS) connections at the individual subscriber buildings. As Table-52 illustrates below, the low-density (baseline) development scenario is approximately 3.35 times larger than the moderate-density scenario for Site-A. **Error! Reference source not found.**

Table 52. Site-A: Baseline and Optimized Density and Land Area Comparison

To model the cost impacts of a district system in a low-density development scenario for Site-A, the researchers used the same factors for calculating the trench-feet of pipe requirements used for the moderate-density development scenario which was 42,765 trench-feet/sq mile. The total trench feet of piping necessary to serve the low-density development would be approximately 48,751 linear feet. Additionally, matching the same amount of commercial space served in the moderate-density/optimized scenario at lower densities in the baseline scenario results in 110 commercial buildings, 65 more than are served in the optimized scenario. Each additional building represents additional ETS costs to connect subscriber buildings to the system.

Assuming a cost of $650 per -trench-foot of pipe and a length of 48,751 feet, the cost of laying pipe is approximately $31,688,647 in the baseline scenario. In the optimized scenario the cost is $9,451,000 as is illustrated in Table-53. With the addition of ETS costs, the capital costs for a district cooling system to serve the low-density baseline development would be $35.5 million, while the costs for the optimized moderate-density development would be $12.6 million. The total capital cost of conventional stand-alone cooling technologies at individual buildings in the low-density development would be $21,343,000. Those costs would be $23,088,000 in the moderate density development. Given the substantial additional capital investment necessary to build a district system in the low-density development, and the extremely long pay-back on that investment relative to energy cost savings, a project of this nature would not be built.

Capital Costs Comparisons

	Baseline	Optimized	Delta
Piping Costs	$ 31,688,647	$ 9,451,000	$ (22,237,647)
ETS Costs	$ 3,822,000	$ 3,168,000	$ (654,000)
Total Cap Costs	$ 35,510,647	$ 12,619,000	$ (22,891,647)

Table 53. Site-A: Capital Cost Comparisons for District Energy

<u>Result #3</u>: Mixed-use, moderate-density development significantly reduced vehicle miles traveled (VMT) in both Site-A and Site-X and resulted in a significant reduction of petroleum consumption and automobile-related emissions.

Specifically, mixed-use, moderate-density development reduced VMT by 12.5% in Site-A and by 15% in Site-X. This decrease in VMT produced significantly lower petroleum consumption and tailpipe emissions in both sites. The specific findings for each site follow.

Site-A: Results:

Based on the 4D analysis of factors affecting travel behavior, the optimized scenario reduces vehicle miles traveled per-person by 1,182 miles annually. This is a 12.5% reduction in the baseline VMT. Assuming a 63% driving rate, the total annual reduction in VMT for Site-A is 3,683,000 miles, a distance sufficient to circle the Earth at the equator more than 460 times. The annual reduction of 1,182 VMT per-person is equivalent to approximately 153,458 fewer gallons of petroleum per year. This reduction in VMT would lead to reductions of 12.5% in all auto-related emissions. Total emissions for the optimized and baseline scenarios are summarized in Table-54 below.

Emissions (lbs)	Baseline	Optimized	Delta
CO	1,295,035	1,133,625	(161,411)
CO_2	24,014,123	21,021,049	(2,993,074)
Hydrocarbons	88,552	77,515	(11,037)
NO_x	81,191	71,071	(10,119)
PM10	340	297	(42)
PM2.5	321	281	(40)

Table 54. Site-A: Total Annual Emissions by Scenario

Site-X Results:

Application of this set of community design options in Site-X, would result in an annual reduction in VMT per-person of 1,424 miles, a 15% decrease over the baseline. The total annual reduction for this site is over 8,370,000 miles, a distance sufficient to circle the Earth at the equator more than 1,050 times. This would reduce petroleum consumption by approximately 360,600 gallons every year[48]. Related tailpipe emissions reductions are summarized in Table-55.

Emissions (lbs)	Baseline	Optimized	Delta
CO	1,525,631	1,297,012	(228,619)
CO_2	45,357,788	38,560,829	(6,796,960)
Hydrocarbons	167,257	142,193	(25,064)
NOx	116,875	99,361	(17,514)
PM10	641	545	(96)

[48] Based on the EPA and DOT average fleet fuel economy of 24 mpg (2005).

PM2.5	605	515	(91)

Table 55. Site-X: Total Annual Emissions by Scenario

Result #4: Moderate-density development significantly reduced land consumption and dramatically reduced annual household energy consumption for the modeled development sites.

Results indicate that moderate-density development would reduce land consumption by up to 70% in the case of Site-A and nearly 78% in the case of Site-X. Additionally, the diversity in housing in a moderate-density development results in a per-household energy savings of nearly 50% in the case of Site-A and 20% for Site-X. These savings are produced as a result of smaller housing units, shared walls and heating, air conditioning and ventilation systems. Site-specific details are provided below.

Site-A:

As modeled, the optimized and baseline development scenarios show significant differences in per-household energy use. The optimized scenario has 2,401 residential dwelling units. Assuming the same number of units at a density of 3.3 dwelling units per acre, the baseline scenario requires approximately 728 acres of land. This is more than three times the land requirement of the optimized scenario, assuming a moderate gross density of 11.17 dwelling units per-acre. Table-56 provides the data underlying this comparison and Figure-41 expresses the comparison graphically.

	Baseline	Optimized
Dwelling Units	2401	2401
Gross Density	3.3	11.17
Land Area (acres)	728	215
Land Area (sq miles)	1.14	0.34

Table 56. Site-X: Land Use Comparison

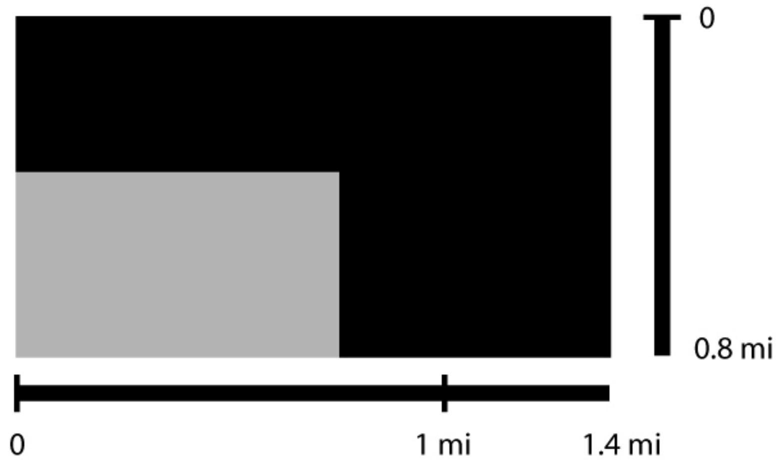

Figure 41. Site-A: Comparison of Land Consumption

Under these land use patterns, the optimized scenario uses approximately 5,493 kWh per-household annually while the baseline alternative uses approximately 11,049 kWh per-household based on average residential energy usage.

Site-X:

The optimized scenario has 4,535 residential dwelling units. Assuming 3.3 dwelling units per gross acre, the baseline residential scenario would require 1,374 acres to accommodate the same number of units as the optimized scenario. In this case the adjusted baseline consumes 4.4 times more land than the optimized scenario.

As in the Site-A analysis, the optimized scenario performs better on a per-household basis. The optimized scenario uses about 8,816 kWh per-household annually, while the baseline again uses 11,049 kWh per-household.[49] Table-57 and Figure-42 below provide the additional details and a graphic expression of the comparison.

	Baseline	Optimized

[49]The prototype single family homes used in this analysis are the same as those used in the Site-A analysis.

Dwelling Units	4535	4535
Gross Density	3.3	14.6
Land Area (acres)	1374	310
Land Area (sq miles)	2.14	0.49

Table 57. Site-X: Land Area Comparison

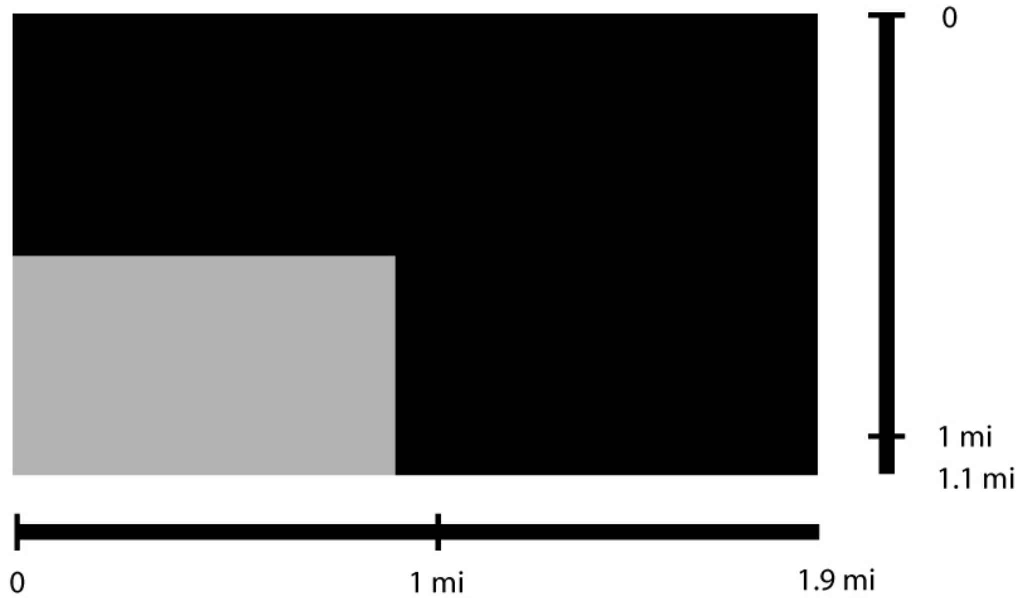

Figure 42. Site-X: Comparison of Land Consumption

Based on an assumption of $22/sf, provided by the City of Chula Vista, the low-density scenario land costs would be nearly $698 million while the moderate-density scenario land costs would be $206 million. Both scenarios maintain the same number of dwelling units, but the moderate-density scenario would save a developer $492 million in land acquisition costs alone. Table-58 summarizes these costs.

	Land Area (acres)	Associated Costs
Baseline	728	$ 697,656,960
Optimized	215	$ 206,038,800
Savings	513	$ 491,618,160

Table 58. Site-A: Comparative Land Acquisition Costs

3.5.2 Urban Runoff Mitigation & Carbon Sequestration Measures

The researchers examined the relationship between urban runoff mitigation measures and energy consumption and related emissions and the relationship between carbon mitigation measures and air quality. Urban runoff mitigation and carbon storage and sequestration measures in this analysis focused primarily on the impact of tree plantings. Because the researchers sought to determine the incremental benefits of trees on a site, the site plan is the same for both scenarios in Site-A and Site-X. This deviates from the other analyses under the research project where the two scenarios fall into different densities and therefore different spatial layouts. This controls for other factors that would differ between a higher density and lower density site such as topography, building layout, and pavement cover. By holding the site layout constant, the research team was able to make conclusions related directly to the impact of planting trees. The findings below include energy and emissions savings due to tree plantings used for runoff mitigation and carbon sequestration at the two development sites.

Result #5: Modest increases in tree canopies and decreases in impervious surfaces produced energy and stormwater facility construction costs savings and emissions reduction for both development sites.

The modeling indicates that a 10% increase in tree canopy results in a 48% increase in stormwater diversion for Site-A and a 64% increase in stormwater diversion for Site-X. Trees provide a number of benefits including stormwater management, air filtration, and carbon sequestration. Diverting stormwater runoff helps to keep pollutants out of the water supply, especially in urban areas. However, it doesn't translate directly into energy savings for communities where stormwater is not combined with sanitary sewer systems. This is the case in Chula Vista, where stormwater is handled by gravity systems and retention or detention ponds. However, to illustrate the value of diverted stormwater from combined stormwater and sanitary sewer systems, the researchers conducted an energy savings calculations for Site-A and Site-X, as if they were located upon a combined sewer system similar to the systems serving Sacramento and San Francisco.

Site-A:
The modeling revealed that a tree canopy placed over approximately 2.4% of the development site (5 acres) would produce a diversion of 65,319 cubic feet (cu ft) of water from stormwater management facilities annually. This 2.4% represents the modest tree cover in the baseline. An additional 10% of tree cover modeled in the optimized scenario, or an additional 20 acres, results in an incremental diversion of 61,149 cu ft. It is important to note that the water diverted is the *additional* amount over the baseline scenario. Taken together, a 12.4% tree canopy contributes to a total diversion of 126,468 cu ft of water (when compared to the same site with no trees).

A reduction in the severity of peak events and overall volume of stormwater runoff due to increased tree cover could conceivably save a developer significant construction costs by reducing the number of retention and detention ponds needed for a development site. With specific regard to Site-A, the addition of a 10% canopy could save the developer approximately $122,300 in costs associated with the construction of these stormwater pond systems.

Table-59 presents the annual energy and energy-related emissions savings as a result of the additional tree coverage on the site if it were served by a combined storm and sanitary sewer system. Although the savings are modest, they would become more significant with the addition of additional tree coverage and the introduction of other stormwater management measures such the deployment of a variety of imperious surfaces across the site.

	Baseline	Optimized	Total
Total Water Diverted (cu ft)	65,319	61,149	126,468
Treatment Energy (kWh/cu ft)[50]	0.0150	0.0150	0.0150
Total Energy (kWh)	977.69	915.27	1892.96
CO2 (lbs)	684.97	641.24	1326.20
SOx (lbs)	0.125	0.117	0.242
NOx (lbs)	0.334	0.313	0.647

Table 59. Site-A: Annual Stormwater Treatment Energy and Emissions Savings

Site-X:

The modeling revealed that a tree canopy placed over approximately 5% of the development site (16.8 acres) would divert 106,806 cu ft of water from stormwater management facilities annually. This is the amount of coverage modeled in the baseline scenario. Increasing this baseline by 10% as modeled in the optimized scenario (an additional 33.7 acres) would divert an additional 193,720 cu ft of water.

In total, a 15% tree cover representing 50.5 acres would divert a total of 300,525 cu ft. The diversion of 193,720 cu ft of water in the optimized scenario is equivalent to a $387,440 construction cost savings for the developer resulting from avoided construction of retention and detention pond systems. Table-60 contains energy and energy-related emissions savings associated with the use of this measure on a similarly sized site served by a combined storm and sanitary sewer system.

[50] Based on an average of 652 kWh/acre-foot (Hoffman 2004)

	Baseline	Optimized	Total
Total Water Diverted (cu ft)	106,806	193,720	300,525
Treatment Energy (kWh/cu ft)	0.0150	0.0150	0.0150
Total Energy (kWh)	1598.66	2899.57	4498.22
CO2	1120.02	2031.44	3151.45
SOx	0.205	0.371	0.576
NOx	0.547	0.992	1.538

Table 60. Site-X: Annual Stormwater Treatment Energy and Emissions Savings

Result #6: Modest increases in tree canopy lead to significant storage and sequestration of carbon and other pollutants in both Site-A and Site-X.

Site-A:

The modeling revealed that a baseline 2.4% tree canopy would store 213 tons of CO_2 in existing trees and would sequester an additional 1.66 tons per year[51]. Additional pollution removal has an estimated value of $1,958 annually based on California's estimates of external costs related to individual pollutants (health care costs, loss of tourism, etc.) as aggregated by CITYgreen™ (American Forests 2004). A 10% increase in canopy cover would result in the storage of 1,099 tons of CO_2 and the sequestration of 8.56 tons annually. The total savings from pollution reductions are estimated at $10,098 annually. Table-61 contains tailpipe pollutant removal data for the baseline and optimized development scenarios for the site.

	Baseline			Optimized		
	Pounds Removed		Value	Pounds Removed		Value
Carbon Monoxide	31	$	13	159	$	68
Ozone	335	$	380	1,731	$	1,959
Nitrogen Dioxide:	124	$	1,031	638	$	5,318
Particulate Matter	247	$	507	1,276	$	2,616
Sulfur Dioxide	35	$	27	182	$	137
Total	772	$	1,958	3986	$	10,098

Table 61. Site-A: Tailpipe Emissions Removed by Trees Annually

[51] Storage refers to the amount of carbon stored in the biomass of trees on planting. Sequestration refers to the additional amount of carbon stored every year the trees grow.

Site-X:

The modeling revealed that a baseline 5% tree canopy stores 725 tons of CO_2 in existing trees and sequesters an additional 5.64 tons per year. The value of removing other air pollutants is estimated at $6,659, based on California's estimates of externalities related to individual pollutants. Increasing the canopy cover to 15% stores 2,174 tons of CO_2 and sequesters an additional 16.93 tons per year. Avoided indirect costs from pollutant removal are estimated at $19,976. Table-62 contains tailpipe pollutant removal data for the baseline and optimized development scenarios for the site.

	Baseline			Optimized		
	Pounds Removed		Value	Pounds Removed		Value
Carbon Monoxide	105	$	45	315	$	135
Ozone	1,141	$	1,292	3,424	$	3,876
Nitrogen Dioxide	421	$	3,507	1,262	$	10,520
Particulate Matter	841	$	1,725	2,523	$	5,175
Sulfur Dioxide	120	$	90	360	$	270
Total	2,628	$	6,659	7884	$	19,976

Table 62. Site-X: Tailpipe Emissions Removed by Trees Annually

<u>Urban Runoff Mitigation and Carbon Sequestration Measure Costs</u> – The principal cost associated with this urban runoff mitigation and carbon sequestration measure is the cost of tree plantings. According to officials at the City of Chula Vista, the average cost of planting a tree, including labor and materials, is approximately $445. Given this unit cost, Tables-63 and -64 provide details on planting costs for the optimized scenarios at Site-A and Site-B, respectively.

Canopy Area (sf)		897,772
Individual Tree Canopy (sf)		1116
Total Trees		804
Unit Cost	$	445.00
Total Cost	$	357,982

Table 63. Site-A: Tree Planting Costs

Canopy Area (sf)		1,467,972
Individual Tree Canopy (sf)		1116
Total Trees		1,315
Unit Cost	$	445.00
Total Cost	$	585,347

Table 64. Site-X: Tree Planting Costs

3.5.3 Urban Heat Island Effect Mitigation Measures

The researchers used MIST to analyze the impact of specific urban heat island mitigation measures. These included cool-roof coatings, cool pavement, and increasing tree canopy. The results of this analysis are presented here for both sites.

Result #7: Modeled application of urban heat island mitigation measures produced 5-14% in kWh energy savings for residential and commercial structures in both development sites

Site-A:

The modeling results indicate that a 10% increase in vegetation and a 0.09 increase in albedo (reflectance of surfaces) results in a temperature decrease ranging from 1.3 degrees F to 2.8 degrees F. This albedo change represents the overall weighted average change for the entire site, as mentioned in the methods chapter. These modeled temperature reductions translate to a 13% savings in residential kWh, a 5% savings in commercial-office kWh, and a 5% savings in commercial-retail kWh. The model results, however, show a small increase in gas consumption due to increased heating demand for residential, retail, and office units. Converting MMbtu's to equivalent kWh, there is a net energy savings of 3,835,803 kWh community-wide, as well as 3,029,248 lbs savings in CO_2 emissions, 635 lbs savings in SO_x emissions, and 1,344 lbs savings in NO_x emissions. Table-63 provides additional details. Table-65 provides additional detail.

			Electricity-Related Emissions Savings			Gas-Related Emissions Savings		
	Electricity Savings (kWh)	Gas Savings (MMbtu)	CO2 (lbs)	SOx (lbs)	NOx (lbs)	CO2 (lbs)	SOx (lbs)	NOx (lbs)
Residen..	7,018,338	(5,000)	4,915,643.77	898.35	2,400.27	(588,045.10)	(2.95)	(460.04)
Office	2,555,640	(844)	1,789,969.92	327.12	874.03	(99,301.13)	(0.50)	(77.68)
Retail	2,206,760	(2,678)	1,545,615.02	282.47	754.71	(314,962.49)	(1.58)	(246.40)
Total		(8,523)	8,251,228.71	1,507.93	4,029.01	(1,002,308.72	(5.03)	(784.12)

Table 65. Site-A: Electric and Gas Energy and Emissions Savings

Site-X:
The modeling indicated that a 10% increase in vegetation and a 0.11 increase in albedo results in a temperature decrease ranging from 1.1 to 2.4 degrees F. MIST's parametric model predicts an average savings of 14% in residential kWh, a 6% savings in commercial-office kWh, and a 6% savings in commercial-retail kWh. The model results, however, show a small increase in gas consumption due to increased heating demand for residential, retail, and office units. Converting MMbtu's to equivalent kWh, there is a net energy savings of 9,283,511 kWh community-wide, as well as 7,248,920 lbs savings in CO_2 emissions, 1,503 lbs savings in SO_x emissions, and 3,245 lbs savings in NO_x emissions. Table-66 contains additional detail.

			Electricity-Related Emissions Savings			**Gas-Related Emissions Savings**		
	Electricity Savings (kWh)	Gas Savings (MMbtu)	CO_2 (lbs)	SO_x (lbs)	NO_x (lbs)	CO_2 (lbs)	SO_x (lbs)	NO_x (lbs)
Residen.	2,351,869	(1,989)	1,647,248.89	301.04	804.34	(233,877.65)	(1.17)	(182.97)
Office	1,840,499	(717)	1,289,085.67	235.58	629.45	(84,353.68)	(0.42)	(65.99)
Retail	789,308	(1,205)	552,831.30	101.03	269.94	(141,686.45)	(0.71)	(110.84)
Total	4,981,676	(3,911)	3,489,165.86	637.65	1,703.73	(459,917.78)	(2.31)	(359.80)

Table 66. Site-X: Electric and Gas Energy and Emissions Savings

Again, it is important to note that MIST tool is primarily a qualitative tool for comparing relative impacts among UHI scenarios. In this regard, these numbers are best used in concert with other analyses to set goals for reducing UHI. Also, this analysis is based on general assumptions about land cover that are not explicitly included in the conceptual land use plans provided to the research team. Recommendations regarding these limitations are presented in the following chapter.

<u>Costs of Urban Heat Island Effect Mitigation Measures</u> - The three UHI interventions modeled for each site included white topping of asphalt, a double coat of white paint on all roofs, and additional tree planting. Tables-67 and -68 contain the incremental costs associated with each intervention for each site.

White topping costs		
Area (SY)		109,059
Thickness (in)		6
Incremental Unit Cost ($/SY/in)[52]	$	4.00
Total Incremental Cost	*$*	*2,617,421*
Roof coating costs		
Area (sf)		2,440,558
Coats		2
Incremental Unit Cost ($/sf)[53]	$	0.20
Total Incremental Cost	$	976,223
Tree planting costs		
Canopy Area (sf)		897,772
Individual Tree Canopy (sf)[54]		1116
Total Trees		804
Unit Cost[55]	$	445.00
Total Cost	*$*	*357,982*
Total Intervention Investment	$	3,951,626

Table 67. Site-A: UHI Intervention Costs

White topping costs		
Area (SY)		287,733
Thickness (in)		6
Incremental Unit Cost ($/SY/in)56	$	4.00
Total Incremental Cost	$	6,905,602
Roof coating costs		

[52] US EPA 2005 *Cool Pavement Report*

[53] PG&E *Cool Roof Design*

[54] Rosenzweig and Solecki 2006

[55] In consultation with City of Chula Vista staff

[56] US EPA 2005 *Cool Pavement Report*

Area (sf)		3,408,049
Coats		2
Incremental Unit Cost ($/sf)[57]	$	0.20
Total Incremental Cost	$	1,363,220
Tree planting costs		
Canopy Area (sf)		1,467,972
Individual Tree Canopy (sf)[58]		1116
Total Trees		1,315
Unit Cost59	$	445.00
Total Cost	$	585,347
Total Intervention Investment	$	8,854,169

Table 68. Site-X: UHI Intervention Costs

Using the results of the MIST modeling, the researchers calculated the energy consumption reduction associated with the application of the UHI mitigation measures for each site. As noted above, although electric energy consumption decreases, natural gas consumption increases marginally to account for additional night-time heating due to the slight decrease in the ambient air temperature. With this slight increase factored into the analysis, the overall annual energy cost savings associated with this set of interventions for Site-A was $903,443. Table-69 below contains the detailed numbers used in this savings calculation.

	Electricity Savings (kWh)	Cost Savings for Electric	Gas Savings (MMbtu)	Cost Savings for Gas	Net Savings
Residential	2,351,869	$ 503,097	(1988.76)	$ (23,705)	$ 479,391.27
Office	1,840,499	$ 315,881	(717.29)	$ (8,550)	$ 307,331.16
Retail	789,308	$ 131,073	(1204.82)	$ (14,361)	$ 116,711.99
Total	4,981,676	$ 950,052	(3910.87)	$ (46,617)	$ 903,434.42

57 PG&E Cool Roof Design

58 Rosenzweig and Solecki 2006. See Also, Attachment-II, Tree Guidelines for Coastal California Communities for coverage by tree species.

59 In consultation with City of Chula Vista staff

Table 69. Site-A: Annual Energy Savings Due to UHI Interventions

The total incremental investment in UHI intervention for Site-A over the baseline scenario is $3,951,626. A simple payback calculation shows a payback from these investments of just 4.4 years. It is important to note that simple payback does not account for full lifecycle costs of the investments such as maintenance. Additionally, the full savings from potential public health benefits are not reflected in these numbers.

The same analysis was conducted on Site-X and it shows a similarly reasonable payback period of 3.9 years, with costs totaling $8,854,169 and annual savings totaling $2,254,377. Table-70 below contains the numbers used in the savings calculation.

	Electricity Savings (kWh)	Cost Savings for Electric	Gas Savings (Mbtu)	Cost Savings for Gas	Net Savings
Residential	7,018,338	$ 1,536,902	(5000)	$ (59,605)	$ 1,477,297
Office	2,555,640	$ 440,969	(844)	$ (10,065)	$ 430,904
Retail	2,206,760	$ 378,101	(2678)	$ (31,925)	$ 346,176
Total	11,780,738	$ 2,355,972	(8523)	$ (101,595)	$ 2,254,377

Table 70. Site-X: Annual Energy Savings Due to UHI Interventions

3.5.4 Passive Solar Building Orientation

As stated in the methods section, the researchers examined the relationship between passive solar building orientation and energy savings. This analysis was tertiary, but the researchers did determine that this design option could produce modest energy savings. These savings result just from orientation and the relationship between glazing and a primary southern exposure. With additional design elements, single-family homes could see even more savings using non-mechanical means.

Result #8: East-west building orientation resulted in modest energy savings from passive solar gains for a prototypical single-family home modeled at Site-X.

Researchers found that east-west building orientation, where the greatest length of a structure is facing south, results in energy usage savings of about 2.8% annually for electricity and 2.2% annually for natural gas. These are modest savings, but result merely from changing the direction of the building without any additional design or mechanical features.

The researchers selected a single-family prototype from the building energy analysis work and modeled the energy efficiency impacts associated with incremental changes in building orientation at Site-X. Prototype 1 for Site-X was modeled in thirty-degree increments.

Figures-43 and -44 below illustrate the electricity (kWh) and natural gas (MMbtu) consumption for the structure plotted against orientation - where 0 is north and 180 is south.

Although it is true that the east-west building orientation - 90 and 270 degrees, resulted in the best energy savings, the percent difference was not substantial from the worst performing orientation. In the case of electricity, the percent difference in energy use was 2.8% with a cost savings of just 4.1% annually. For natural gas, the difference was 2.2% in consumption and 1.8% in cost savings annually. However, similar buildings featuring PV, an east-west orientation, and other passive design features for heating and cooling would result in higher energy savings as mentioned in the methods chapter. Readers are encouraged to investigate NREL's research report on the subject of optimal solar building and subdivision orientation and planning to be published by the California Energy Commission sometime during 2009.

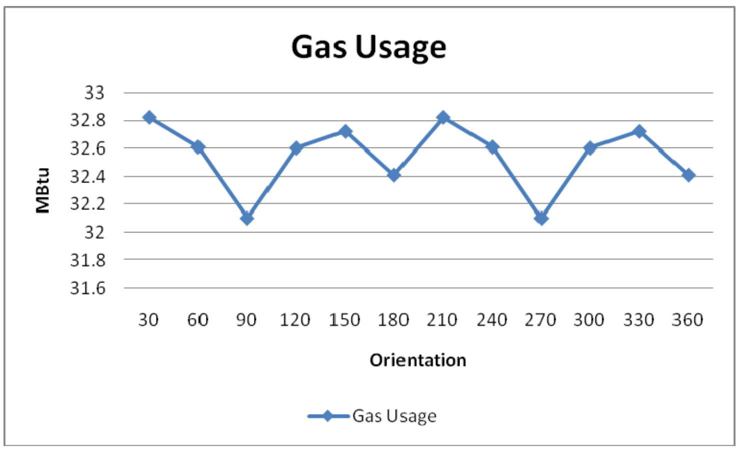

Figure 43. Site-X: Gas Usage for Prototype-1 Plotted Against Orientation

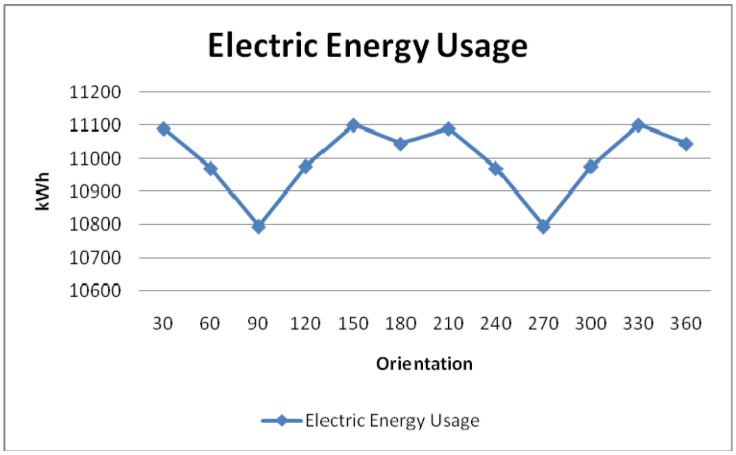

Figure 44. Site-X: Electricity Usage for Prototype-1 Plotted Against Orientation

Cost of Passive Solar Building Orientation - The incremental cost of optimizing building orientation can vary dramatically from no additional costs to rotate buildings or an entire site plan, to high costs associated with changes in topography and infrastructure. Given that these costs are by definition, site-specific, an estimate is not provided in this report.

3.6 Incremental Costs and Needed Models, Policies and Incentives

This section of the results addresses the following two research objectives:

- Determine the maximum incremental cost that the California building industry and consumers will accept for energy-efficient residential, commercial, industrial and institutional structures;
- Determine which financial and business models and associated public policies and incentives will lead to accelerated deployment of EE, DR, RE and DG technologies in typical development projects throughout the State of California.

3.6.1 Maximum Acceptable Incremental Costs

The researchers determined that the maximum incremental cost that the California building industry and their consumers will accept for energy-efficient structures varies by technology enhancement and by developer, builder/industry practitioner. However, the researchers determined that *most* development industry practitioners believe that the incremental costs of the modeled energy efficiency/technology enhancement packages are too high and that presently, there is insufficient market demand for energy-efficient structures[60] of this nature in California. The maximum incremental costs that were deemed acceptable are presented below.

[60] Defined as structures featuring one of the three technology enhancements modeled in the research project.

As stated earlier, the researchers reached these determinations by conducting an online survey of San Diego-area members of NAIOP and CBIA, and through a series of follow-up telephone interviews. Additionally, the researchers reviewed related industry research on the cost of designing and constructing energy-efficient buildings.

Development Industry Survey Results – Twenty two (22) development industry practitioners responded to the survey during late August and early September of 2008. Developers represented 41% of the respondents, followed by property managers (18%) and design professionals (18%). Other participants included real estate brokers, investors and government employees. Figure-45. graphically depicts the distribution of survey respondents by occupational subgroup.

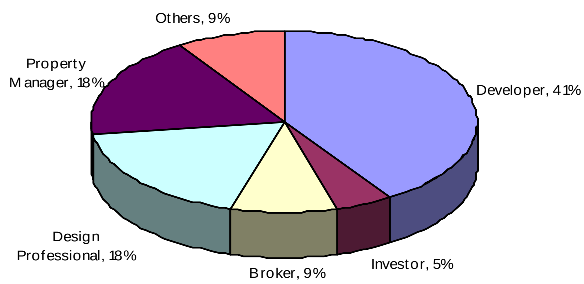

Figure 45. Distribution of Survey Respondents by Occupational Subgroup

For the purpose of this survey, energy-efficient buildings were defined as those that exceed the Title-24, 2005 building energy efficiency standard by 20 to 43%. The survey was structured to solicit industry responses to the specific incremental costs associated with each of the energy-efficient enhancement packages modeled for 40 different commercial and residential building prototypes. These enhancements included:

- Envelope and Equipment Enhancements (EE) – higher efficiency grades of wall and roof insulation, windows, doors, lighting, heating-ventilation-air conditioning equipment, thermal storage technology and energy-efficient appliances;
- Distributed Generation Enhancement (DG) – installation of onsite power utilizing advanced natural gas-fueled electric power generators with heat recovery for heating and/or absorption cooling;
- Solar Photovoltaic Enhancement (PV) – installation of photovoltaic panels on building rooftops.

A combination of these enhancements were examined for each building type and then economically feasible packages of enhancements were determined based on a simple payback threshold – that energy cost savings associated with the use of the package exceeded the useful life of the package components. In general, the various combinations of the EE and EE-DG packages described above have an average simple payback of approximately 7 years, and the EE-PV package has a payback of approximately 14 years (all payback calculations were based on available CA rebates and incentives). The cost of installing the packages were then calculated for each building type and expressed as an additional cost increment / per square foot of construction ("incremental cost"). The incremental costs for these enhancements are as follows:

- EE package = $2 / square foot (with a range of $1 to $5 / square foot depending on building type);
- EE-DG package = $4 / square foot (with a range of $3 to $5 / square foot – assuming incentives);
- EE-PV package = $15 / square foot (with a range of $5 to $30 / square foot).

The first question sought to determine whether, in today's marketplace, developers and builders found the incremental construction costs calculated for the 3 building enhancements to be acceptable or not. Thirty percent either agreed (15%) or strongly agreed (15%) that the incremental costs were acceptable, while 35% either disagreed (25%) or strongly disagreed (10%). One third of the respondents were neutral on the question.

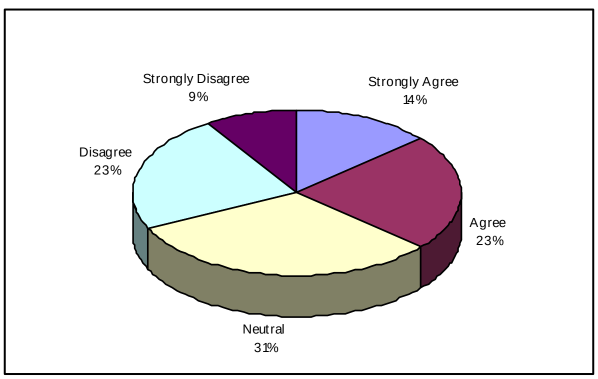

Figure 46. Acceptability of Incremental Costs

The next 3 questions sought to determine what maximum incremental costs the development industry would find acceptable for each of these three enhancement packages. In the case of the EE package, ~18% believed the maximum acceptable cost per square foot (s.f.) of construction would be $3.00, 4.5% believed the cost to be $2.50 per s.f., and ~23% believed that the maximum acceptable cost was $2 per s.f. The balance of the respondents (54.4%) believed the maximum acceptable cost was $1.50 per s.f. or less. The statistical average s.f. cost was $1.84 per s.f.

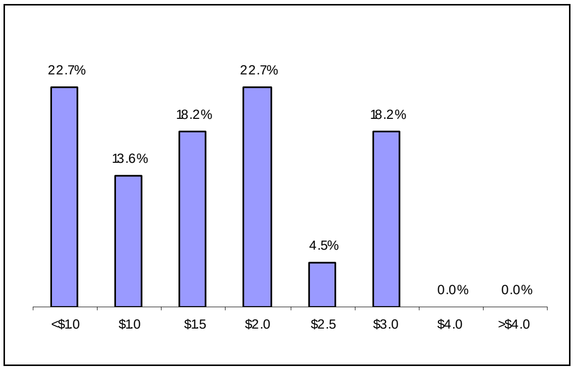

Figure 47. Max. Incremental Costs for EE Technology Enhancements

With regard to the EE-DG package, 31.8% of the respondents found $4 to $5 per s.f. to be the maximum incremental cost that would be acceptable, while the balance of the respondents were fairly evenly divided in their opinions that the maximum acceptable costs lay between $3.50 and less than $2.00 per s.f. Taking into account the range of responses the average per s.f. cost is $2.81.

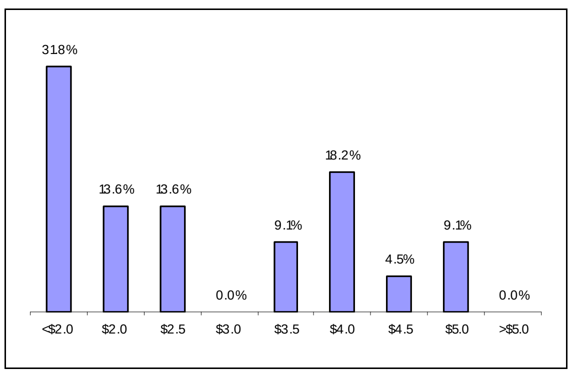

Figure 48. Max. Incr. Costs for EE-DG Technology Enhancements

In the case of the EE-PV package, approximately 19% of the respondents believed that the maximum acceptable cost is between $15 and $20 per s.f. of construction. Approximately 38% believed that the maximum acceptable cost is $10 per s.f. and the balance of the respondents believed the maximum acceptable costs are under $10 per s.f. The average cost across this range is $8.28.

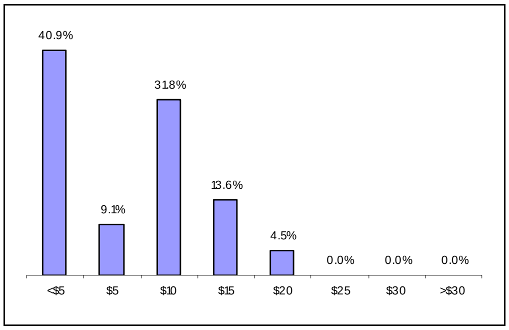

Figure 49. Max. Incr. Costs for EE-PV Technology Enhancements

In summary, the respondent's average maximum acceptable costs were $1.59, $2.64 and $7.41 per square foot for the three types of packages (i.e. EE, EE-DG and EE-PV). In the case of the EE technology option, almost half (45.4%) of the respondents did find the modeled $2.00 cost to be acceptable and some (18.2%) would be willing to pay as much as $3.00 s.f. for that enhancement. However, in the case of both the EE-DG and EE-PV technology enhancements, the majority of the respondents found the $4.00 and $15.00 incremental costs, respectively, to be too high to be acceptable.

To further examine the difference in acceptability among the occupational groups, the researchers evaluated the responses for each major subgroup: developers, property managers, design professionals, and others. Figure-50. below compares their responses for acceptability of the incremental costs for all three enhancements (Question #1). It indicates that both developers and property managers are more pessimistic about the market acceptance of the technology enhancement packages; while design professionals, on the other hand, are much more optimistic.

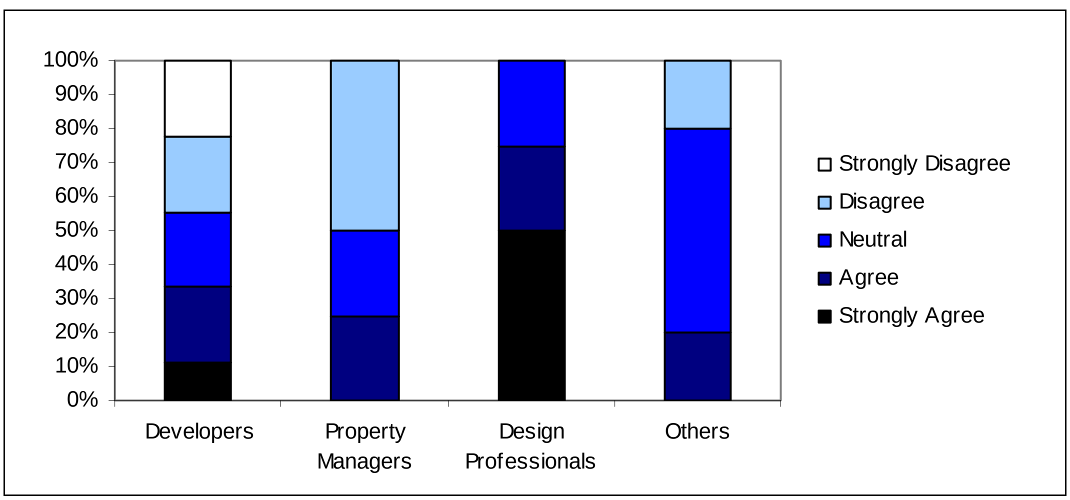

Figure 50. Acceptability of Incr. Costs for the Modeled Technology Enhancements

With regard to the maximum incremental cost per square foot of construction they would accept for each of the packages, the subgroups also had very different opinions. Table-71 and Figure-51 summarize and compare the responses of the four subgroups. They reveal a similar pattern across the subgroups. Design professionals were willing to pay more for the energy-efficient technology enhancements. In contrast, the maximum prices real estate professionals, particularly the developers, are willing to pay was much lower.

Technology Enhancements & Costs / sq.ft.	Overall	Developers	Property Managers	Design Professionals	Others
EE ($2.00)	1.59	1.43	1.45	2.00	1.66
EE & DG ($4.00)	2.64	1.83	2.25	3.63	2.50
EE & PV ($15.00)	7.41	5.22	6.75	11.75	8.40

Table 71. Acceptable Incremental Costs for Technology Packages by Subgroup

These figures are graphically portrayed in the three figures below.

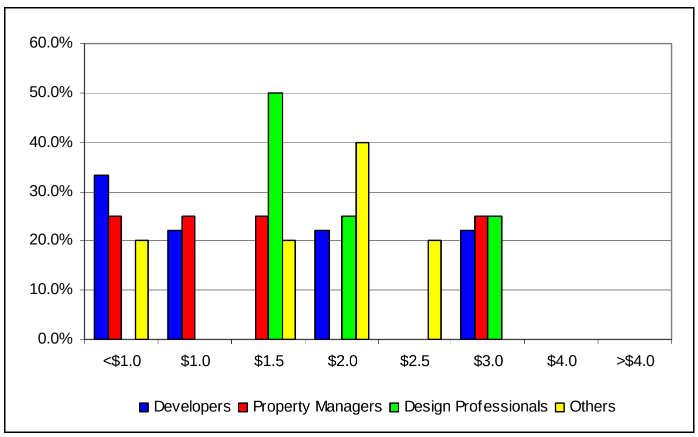

Figure 51. Acceptable Incr. Costs: EE Technologies by Subgroup

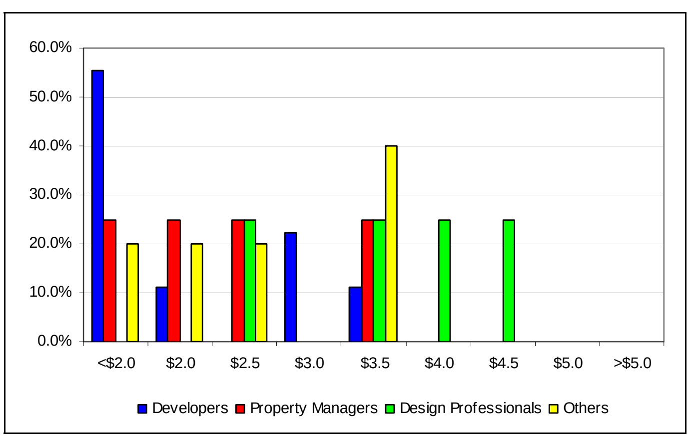

Figure 52. Acceptable Incr. Costs: EE-DG Technology by Subgroup

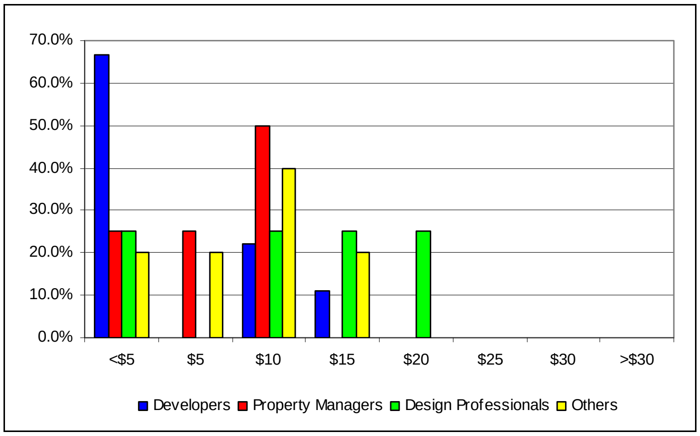

Figure 53. Acceptable Incr. Costs: EE-PV Technology by Subgroup

Follow-Up Interviews - To broaden the analysis to community-scale development projects, the researchers conducted follow-up interviews with select representatives from CBIA-member companies. The interviews were designed to solicit the perceived factors influencing the incremental cost of community-scale energy-efficient development projects, and to assess the current market demand for this form of development.

Interviewed representatives were asked to rank order the most significant factors they believed influence the additional cost of designing and building a community-scale project utilizing advanced renewable and energy-efficient technologies and resource-efficient community design options. The collective responses revealed a remarkable degree of uniformity among the developers in regard to the top-five factors affecting cost. In rank-order they are:

1. Lengthened development cycles due to the novelty of these types of projects and the lack of knowledge among municipal planning officials responsible for approving them;
2. Corresponding increases in planning, design and engineering expenses;
3. Increased material and equipment costs;
4. Increased installation and inspection costs;
5. Interconnection charges for distributed generation technologies, and difficulty negotiating interconnection agreements with the utilities.

With regard to the estimated incremental costs of an energy-efficient community development project, there have been very few projects nationally to evaluate. However, the researchers were able to identify one large-scale sustainable community development project in southern California that the developer was willing to share cost information about, under the condition of remaining anonymous. The 8,200-acre planned community for 120,000 residents will feature energy- and resource-efficient features such as:

- A community solar PV electric system;
- Sustainable site development features;
    - smart growth features
    - mixed-use development
    - passive solar building orientations
    - stormwater runoff mitigation and treatment
    - enhanced trail systems to promote pedestrian mobility
- Building envelope and equipment enhancements;
    - radiant barriers
    - night breeze cooling system
    - ultra efficient HVAC systems
    - indoor air quality features
    - compact Fluorescent Lighting
    - *ENERGY STAR* appliances and windows
    - water-efficient appliances and fixtures
- Construction Site Impact Mitigation
    - Construction waste reduction program
    - Wood conservation program

The developer estimates that the incremental cost of adding these features to the overall project cost to be in the range of 20-35%, depending on available incentives.

Finally, repeating a concern that was heard in each of the earlier workshop discussions, most of the interview respondents indicated that they didn't believe that a sufficient market demand currently exists to warrant the additional cost and risks associated with large-scale, energy-efficient community development projects. Causal factors related to this insufficient demand also mirror the barriers identified in the workshop discussions. These barriers are discussed below.

<u>Related Research</u> - While two-thirds of the survey respondents did not find the incremental costs of the modeled building technology enhancements to be acceptable, there is collateral evidence that some developers are willing to assume the additional cost and inherent risks if there is a perception of achieving a competitive advantage within certain real estate markets.

A recent study entitled *The Economics of Green* examined the incremental construction costs associated with the design and construction of buildings built to meet the standards of the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) certification. The study suggested that some developers are willing to pay between 3.7% and 10.3% more for buildings that carry the LEED-certification and perceive that additional investment to be capable of producing a competitive market advantage. The findings were derived from an examination of 1,788 LEED-certified buildings in 5 commercial markets around the country and the costs associated with more resource-efficient building materials, operating equipment and design features. The average cost increases associated with receiving a specific LEED designation changes based on the (1) designation and the (2) jurisdiction, as evidenced by Table-72[61].

Markets	Platinum	Gold	Silver
San Francisco	7.8 %	2.7 %	1.0 %
Merced	10.3 %	5.3 %	3.7 %
Denver	7.6 %	2.8 %	1.2 %
Boston	8.8 %	4.2 %	2.6 %
Houston	9.1 %	6.3 %	1.7 %

Table 72. Incr. Costs for LEED-Certified Buildings by Markets

3.6.2 Financial and Business Models and Public Policies and Incentives

The researchers determined that the financial and business models and public policies and incentives that will accelerate deployment of energy-efficient technologies in projects across California will be those that resolve the economic, informational and procedural barriers that prevent this form of development. Specifically models, policies and incentives that address the:

1. Need for direct and indirect financial support for developers and builders;
2. *Split Incentive Dilemma* - the misalignment between investment costs and benefits;
3. Lack of knowledge among municipal officials inhibiting approval of EECD projects;
4. Lack of uniform municipal procedures and related incentives for EECD projects;
5. Lack of municipal investments in enabling green infrastructure;
6. Lack of consumer willingness to pay for the value of energy-efficient features;
7. Investment risks that inhibit capital market entities from financing EECD projects.

These seven barriers, in rank-order of importance, emerged as the top barriers generated by stakeholders attending the workshops, by the capital market and development industry surveys and by the follow-up interviews with industry practitioners and leaders.[62] This subsection

61 The table is contained in"*The Economics of Green"* by Norm Miller, (USD Burnham Moores Center for Real Estate), Jay Spivey, and Andy Florance (with CoStar), 2008.

62 Notes from the second stakeholder workshop addressing the five market and policy research questions and the related barriers and solutions is contained in Append-V.

describes these seven barriers and presents stakeholder input with regard to the needed financial and business models and public policy incentives to address them.

<u>Addressing the Need for Direct and Indirect Financial Support for Developers and Builders</u>

This unmet need is considered the single greatest barrier to the adoption of energy-efficient building technologies and EECD projects by the California development and building industries. Although the barrier emerged among others during the stakeholder workshops, it became the top barrier during October of 2008 after an extensive set of telephone and in-person interviews conducted with senior officials of the CBIA, and executives from some of the top production homebuilding companies in the State. Specifically, interviews were conducted with the President and CEO of the CBIA, current and past CBIA officers and statewide opinion leaders, including both the current CBIA Chairman and the CFO/Secretary. The researchers also spoke with senior executives with Lennar Homes, Pardee Homes and Brookfield Homes, three of the most aggressive and sustainability-minded builders in the country in 2008.

When asked what the most important message their industry could send to State and local government officials relative to the prospects for energy-efficient community development in the California, there was a unanimous and clear response – substantial financial support. One senior company executive captured the consensus of all those interviewed when he stated:

"For the foreseeable future, our emphasis is on least cost construction.
We have had the worst numbers since records have been kept.
If we invest in clean technologies on a community-scale, we will need
offsets and incentives to help us make those investments."

Due to the slowdown in new residential construction, builders are cutting prices and offering never-before-seen bargains on new homes. For example, a Brookfield Vice President told the research team that a new, 3,200 square foot home in Ontario that was originally listed for $600,000.00 in early 2008, recently sold for $419,000.00. The Vice President went on to say that Brookfield paid $71,500.00 in school and city fees on the $419,000,00 home. "We need help on deferring these development impact fees" said the Vice President. CBIA's current President added:

"We see no near-term relief in sight.
Land has a negative value in many areas across the state,
and improved lots are selling for far less than their value.
Once we get home values stabilized we can begin working earnestly on
more sustainable construction techniques.
We want to do it, but it will not happen in the near future
without financial incentives."

<u>A Recent Shift in Industry Priorities</u> - From the initiation of the research project in April of 2007 until late summer of 2008, their appeared to be a uniform consensus among the developer/ builder stakeholders regarding the type of incentives they believed were necessary to stimulate investment in energy-efficient development projects. Specifically, the consensus that emerged

from stakeholder workshops was that their industry was most in need of any municipal procedural incentive that would accelerate the entitlement process. Expedited plan review/check had been considered the most valuable incentive a developer could seek in exchange for agreeing to pursue a "green" development project. However, with the advancing sub-prime mortgage crisis, the industry leaders interviewed, without exception, now believe that both direct and indirect financial incentives are now what their industry seeks most and must secure to move forward with this new form of development.

The reason for this shift appears clear - builders will be struggling to sell their existing inventory over the next year or two, and they are no longer concerned with faster plan review/check as local government planners and building officials now have plenty of time on their hands to review the few plans that do go through City Hall (or to their external plans reviewers). Reinforcing this notion, one CBIA Officer stated: "There is no problem getting plans out of any City in California. Everyone is slow."

As the priority interest of the industry has now shifted to financial, rather than procedural incentives, the leaders believe that fee deferrals, fee waivers and other financial incentives are the top benefits that need to be incorporated into future discussions about energy-efficient community-scale development projects. They cited the rising cost of development impact fees (DIFs), and the fact that these fees are averaging close to $100,000 *per home* now, where a decade ago they explained these fees averaged closer to $25,000 per home in California. One officer pointed out that the new DIF in Dublin, California is $156,000 per home.

These leaders also generally agreed that high local government fees for multifamily homes were, for the first time, keeping potential builders out of the apartment building business. "High fees are legitimately keeping builders out of the apartment business," said Bob Rivinius, CEO of the CBIA. One other builder commented, "The economy is going down and people are struggling, yet commercial fees are going up. It can't be sustained. We need relief."

Industry leaders also suggest that attention needs to be given to carefully structuring new State and local government and utility financial incentives for this type of construction. "What is there now is not enough," said one CBIA leader. Developers are trying to bridge the gap between higher construction costs for greener construction and what it costs to simply meet code—and regardless of the state of the economy, incentives are needed to help bridge this gap.

Industry leaders also suggested that State and local government agencies and utilities need to work together to centralize information about available financial incentives and technical assistance for the development industry and seek to establish a uniform set of rules governing how they are to be sought and administered.

An example illustrating the need for such an information source and a uniform set of rules was provided by a senior Vice-President of Brookfield Homes. Together with the assistance of an energy efficiency consultant, he sought to assemble an exhaustive list of available local, state, federal, utility and research funding sources to approach for what he had hoped would be the most energy-efficient, sustainable community in California - the Avenue, in Ontario.

This effort identified many potential funding sources, including the U.S. Department of Energy *Building America* funds, U.S. Environmental Protection Agency *Energy Star* funds, Southern California Edison (utility) energy efficiency funds, Inland Empire Utility Agency (IEUA) water efficiency funds, City of Ontario incentives, State of California energy efficiency and solar incentives and federal tax credits for energy efficiency and solar new residential construction. This effort took the Vice President and his consultant several weeks of work to assemble the list and to meet with representatives from each entity identified. In exasperation, he stated - "There has to be a better, more cost-effective way to arrange benefits. This is a terribly time-consuming and expensive process."

<u>The Industry's Top-6 Requested Financial Incentives</u>

With these perspectives establishing the industry outlook for the near-term development market in California, the leaders interviewed were asked to identify the most important public and private sector incentives they believe will stimulate industry investment in energy-efficient community development projects. Collectively, six financial incentives were offered and then rank-ordered by the researchers relative to the frequency with which the industry leaders referenced them, independently of one another. The incentives are presented below in rank-order of importance.

<u>Development Impact Fees Deferral Programs</u> **-** The City Council of Ontario, California has pioneered a program to permit the deferral of the payment of Development Impact Fees (DIFs) from the time a building permit is issued to the final building inspection. This easy to implement and track incentive is the type of low-cost option many California communities could emulate. A DIF does impact the potential earnings a community would have received during the period of deferral (up to one year), however, this loss of earnings does not impact General Fund revenues as interest earnings on Development Impact Fees must be segregated from other City revenues and remain in the Development Impact Fee program account. The City of Ontario requires an administrative fee of $5,500.00 for those that participate in the Development Impact Fee Deferral Program to help offset the City's costs for initiating and administering the fee deferral agreements.

Through this innovative, temporary fee deferral, a residential developer of multiple units may elect to defer the payment of all DIF fees (except the Inland Empire Utility Agency Sewer Capacity Fee and the City's Species, Habitat Conservation, and Open Space Mitigation fee) on a construction phase of residential units up to a maximum fee amount of $1.8 million. If a developer wishes to defer fees in excess of $1.8 million, then an irrevocable Letter of Credit or other acceptable form of security must be provided to ensure payment of the deferred fee amount. The deferred DIF amounts become due when final inspection is requested on the first completed unit of the construction phase, or after 12 months, whichever comes first.

In order to qualify for the DIF deferral program, a developer of multiple residential units must enter into an agreement with the City acknowledging that the fees are being deferred until the developer requests a final inspection of the first completed unit. The agreement will also provide standard terms to indemnify the City and other provisions that define the specific terms of the DIF deferral for the specific development entity. The resolution authorized the City Manager to execute such agreement without further action by the City Council.

The Ontario Development Impact Fee Deferral Program was designed and approved for an interim time period (initially 8 months) and will automatically end (December 31, 2008), unless extended by an action of the City Council. After the interim period ends, no more deferral agreements will be offered. Any existing deferral agreements will continue until the fees are due under the agreement. The California Building Industry Association would like to see permanent DIF deferral programs established for industry participants in energy-efficient community development projects in communities across California.

Sustainable Buildings Tax Credit - The State of New Mexico enacted a Sustainable Buildings Tax Credit in 2007, which one CBIA Board member suggested could be passed in California in the future. SB 463, enacted in April 2007, established both a personal and a corporate tax credit for sustainable buildings in New Mexico, known as the Sustainable Buildings Tax Credit (SBTC). Commercial buildings which have been registered and certified by the US Green Building Council at LEED* Silver or higher for new construction (NC), existing buildings (EB), core and shell (CS), or commercial interiors (CI) are eligible for a tax credit. The amount of the credit varies according to the square footage of the building and the level of certification achieved. Residential buildings certified as sustainable homes can also qualify for the tax credit. Eligible residential buildings include single-family homes and multi-family homes which are certified as either Build Green NM Gold, or LEED-H Silver or higher, and *Energy Star* certified manufactured homes. The amount of the credit also varies according to the square footage of the building and the level of certification achieved.

To receive the tax credit the building owner must obtain a certificate of eligibility from the Energy, Minerals and Natural Resources Department after the building has been completed. The Department will only grant certificates in any given calendar year until the equivalent of $5,000,000 worth of certificates for commercial buildings and $5,000,000 worth of certificates for residential buildings have been awarded in that calendar year. Further, no more than $1,250,000 of the annual amount for residential buildings can be applied to manufactured housing.

The taxpayer must then present their certificate of eligibility to the Taxation and Revenue Department to receive a document granting the Sustainable Building Tax Credit. If the total amount of a Sustainable Building Tax Credit is less than $25,000, the entire amount of the credit can be applied to the taxpayer's income tax in that year. If the credit is more than $25,000 the credit will be applied in increments of 25% over the next 4 years. If a taxpayer's tax liability is less than the amount of credit due, the excess credit may be carried forward for up to seven years. A solar thermal system or a photovoltaic system may not be used as a component of qualification for this tax credit if a tax credit has already been claimed for it under New Mexico's separate Solar Market Development Tax Credit.[63]

[63] For more information about the tax credit, interested parties can contact Susie Marbury, New Mexico Energy, Minerals and Natural Resources Department, Energy Conservation and Management Division, 1220 S. St. Francis Drive, Santa Fe, NM 87505. Phone: (505) 476-3254.

Higher Density Allowance – Relaxed Park Fee Incentive - Another innovation currently in use in the City of Ontario in an area designated as a green development is one in which developers are allowed higher densities through the use of the City's relaxed park fee incentive. In the targeted green development, the density is approved at an overall 4.6 units per gross acre (including parks). However, the City of Ontario collects park fees for only ~three units per thousand population instead of the allowed five units per thousand population, which frees up additional funds for developers and allows greater net densities (since the park acreage granted by the City of Ontario is not included in the units allowed per the gross acre calculation). Essentially, developers in Ontario are allowed the higher number of units (closer to a net of 6.0 units per acre according to the City of Ontario Planning Department) while paying less to the City in park-related fees.

Utility and State Financial Incentives for Energy-Efficient Community Design - One building industry leader thought that utilities and the State of California were "…missing the boat by not providing design assistance funding to developers up-front in the development process for community-scale projects." He thought that utilities should provide design assistance funding to builders through their traditional energy efficiency programs, or come up with some new programs. In his words, "If the utilities were allowed to give us $5K or $10K…or more…to help us design more sustainable neighborhoods, this would go a long way toward getting us the energy and environmental savings the Governor wants. It takes money to design things right." Some California utilities are evidently considering providing money to builders for LEED design through their energy efficiency program offerings. This may be an effective way to spur more community-scale green construction.

Utility Financial Incentives for Green Build Program Participation - There was general consensus from the building industry experts that there are two primary green builder programs in California at the present time - the California Green Builder Program (CGBP) and the Build It Green (BIG) program. Some of the industry leaders suggested that builders who participate in these programs should be provided special financial incentives, especially in the existing (depressed) California housing market. The majority of the industry experts thought that the financial incentives for building to these standards should be significantly higher than the $250.00 to $500.00 per home offered by utilities for building to *Energy Star* standards. "The data shows that we spend $2K-$3K on energy efficiency upgrades for most of our homes. Utilities need to help us here," commented one CBIA leader.

Municipal Bond Funds for Developer Loans - Due to the state of California's current financial/budget crisis, several of the interviewed building industry experts thought that local government bond funds would be more important to energy-efficient development projects in the near future. Through this mechanism, the city or county collects the funds through a bond, and then disperses the funds to developers involved in more sustainable construction techniques and practices. The City of Phoenix, Arizona currently uses such a bond instrument, and offers low interest loans to developers to assist them with community-scale, sustainability-related development. Said one CBIA leader, "It is about going where the money is...if the state doesn't have it, we need to go the local governments for help."

Addressing the *Split Incentive Dilemma* – A Misalignment Between Investment Cost and Benefits

The so-called "Split Incentive Dilemma" exists when the party investing in energy-efficient building features (energy-efficient building materials, technologies and systems) does not directly benefit from the investment. The dilemma is well known in the commercial and residential real estate markets where building owners have little incentive to invest in energy-efficient features that produce benefits/savings for tenants who are unwilling to pay premiums to receive them. On the other side of the dilemma, tenants have little incentive to improve a leased space unless they intend to occupy the space for a period of time sufficient to obtain a return on the investment through energy savings. To do otherwise would only produce a benefit for the building owner or future tenant.

The corollary dilemma for the large-scale community developer is a reluctance to invest in energy-efficient building features when the benefits of those features are realized by the eventual homeowner over a long period of time, well beyond the timeframe of the developer's involvement with the project. The dilemma is further complicated by the fact that development industry sees insufficient demand for these features in the market at the present time, and believes that builders are forced to eliminate conventional amenities - such as upgraded kitchen features and granite countertops, to accommodate these features.

To address this barrier the stakeholders attending the research workshops took a comprehensive look at the related factors that contribute to it and proposed a strategy that over time, would transform the present real estate marketplace into one in which:

- "True Cost" pricing of real estate products (homes, commercial structures and planned communities) reflect the externalities associated with their direct and embedded energy consumption;
- Real estate appraisers, brokers and buyers are aware of and are willing to pay for the "Total Value" of energy-efficient and environmentally compatible real estate commodities;
- Developers/builders integrate energy-efficient and renewable technologies into their projects and are recognized and monetarily rewarded for the energy and emissions savings that they produce;
- Residential, commercial, institutional and municipal consumers are aware of and responsible for the energy and water consumption and air emissions associated with their structures and communities.

The stakeholders believe that a series of public-private partnership initiatives between the real estate development and finance industries and State and local agencies must be mounted to transform the market but that the overall leadership for this effort must sit with the government. Further, stakeholder input suggested the following to address each strategic component listed above.

To produce "True Cost" pricing, we must advance our understanding of the externalities related to both the direct and embedded energy consumption and emissions impacts associated with conventional and alternative building designs, materials, internal building operating equipment (illumination, space conditioning and control systems), and appliance uses. This will entail additional research that also advances our understanding of the potential energy and emissions benefits of alternative land use, infrastructure, transportation and urban design features at the community-scale and the incremental design, development and municipal planning process and entitlement costs to the developer for including them. The rationale for this strategic component is that "True Costs" cannot be known without a comprehensive assessment of the energy and emissions impacts and subordinate costs of both conventional and alternative energy-efficient development projects.

To produce consumer willingness to pay for the "Total Value" of energy-efficient and environmentally compatible real estate commodities, consumers must have some sense of what total value means in relation to their buying decisions. Presently, consumers receive little information related to the energy-efficiency of a new home or commercial structure. Outside of efficiency ratings on HVAC and refrigeration equipment, the consumer doesn't have an opportunity to judge the overall efficiency, much less the emission impacts of a structure for sale, making comparisons to other real estate products on the market impossible. This is further aggravated by the fact that, outside of the voluntary LEED certification, industry-wide adoption of uniform product labeling for energy-efficient structures is not in place to aid consumers in making informed decisions.

Whether through a voluntary industry initiative or mandatory State and/or local government regulations, uniform adoption of energy-efficiency and emissions performance for all structures and communities must be put into place if consumers are expected to understand and be willing to pay for the "True Value" of an energy-efficient and environmentally compatible real estate commodity.

To produce a willingness among developers and builders to integrate energy-efficient and renewable technologies into their projects, the stakeholders suggested that there must be a new model or paradigm for project accounting and/or appropriate financial mechanisms put into place to produce a direct return on investment. The new model or paradigm would be one in which a return on investment equals both an internal and an external rate of return, taking into account all related externalities.

With regard to financial mechanisms, this could include incentives, rebates, tax credits or mortgage arrangements that would result in the consumer's willingness to pay premiums for the energy-efficient features at the point of purchase. Alternately or in addition, this could include 3rd party economic incentives for developers that offset the incremental cost of including these features in their products prior to marketing. In addition to these mechanisms, the stakeholders also suggested that development and construction practitioners will need to have information resources that outline related best practices and guidance on the assessment and use of these technologies in large-sale development projects. This might entail development of an industry and municipal online information clearinghouse. They also suggested that municipal officials must address outdated and conflicting development and building ordinances and train personnel to be able to assess energy-efficient development proposals submitted by developers.

To produce consumer awareness and responsibility for energy and resource consumption, there must be advances in research, development and demonstration of whole home/structure resource monitoring so that occupants can observe resource consumption in real-time and modify that consumption in response to the information. This will entail advances in building systems metering devices, whole-house/building electrical and water monitoring systems and display technologies that convert resource use into household/building economic and emissions impacts.

With regard to leadership and resources to support this initiative, the stakeholders suggested that such a fundamental transformation of the marketplace will require centralized government leadership and suggested that a California Executive Order would be necessary to realize the full strategy. Additionally, they suggested that some portion of the public goods funds should be used to plan and execute contributing initiatives and that the investor-owned utilities (IOUs), join with the California Public Utilities Commission (CPUC), the Energy Commission, the Department of Finance and the Treasurers office to further develop this strategy in the future.

Finally during the industry interviews, one of the most aggressive green production homebuilders in the State of California independently agreed with the workshop participants that the dilemma will only be resolved when State and Local governments and the IOUs offer incentives that transform the marketplace to the point where private lenders and investors are willing to step in to bridge the gap over the long-term. The builder echoed the call for some of the incentives listed above and added others he believes State and local government agencies and the utilities need to consider in order to accelerate the needed market transformation. These include the following:

<u>State and Local Government and Utility Incentives</u>

- Incentives for designing, constructing and performance verifying energy-efficient community demonstration projects;
- Incentives for passive solar heating and cooling design and construction;
- Incentives for the installation of in-home displays that will allow the consumer to monitor and more wisely manage household energy use.

<u>Local Government Incentives</u>

- Code flexibility to allow grey water to be recycled back to the toilet. Corresponding wastewater reduction credited back to the builder in the form of a sewer fee reduction;
- Credit to the builder for installation of water saving fixtures and corresponding reduction in water fees;
- Incentives for builders to recycle graywater for use in the landscape;
- An incentive for building homes smaller than 2,000 square feet
- Municipal offers to lock-in incentives for a period of 4-5 years to allow developers to plan and entitle energy-efficient communities.

Investor-Owned Utility Incentives

- Higher per kW rebate incentives to help bridge the gap between cost and revenue;
- Higher incentives offered for peak kW reduction than for total kW reduction;
- With the new energy code update, to get the highest incentive do not requite T-24 plus 35%. In actuality, it will be T-24 plus 50%. So the standard with the new Title-24 should be plus 20% for the highest incentive
- Incentives to builders for the use of CFL's, radiant barriers and other non-Title-24 design features that provide clear energy reduction;
- Increased incentives for solar water heaters to off-set their cost
- An incentive for developer/builders providing Neighborhood Electric Vehicles (NEVs) and plug-in technology for hybrid and electric vehicles in development projects.

Addressing Lack of Knowledge Among Municipal Officials Inhibiting EECD Projects

One consistent finding from the stakeholder's workshops was the commonly held perception that most municipal government elected and appointed officials and planning and building department personnel are neither familiar with, nor capable of evaluating energy-efficient community development projects. This is fully understandable as the subject area is just now evolving with studies like the present one and new funding for related research now being provided by the Energy Commission.

Additionally, with the exception of municipally owned utilities, energy supply, transmission and local distribution has long been the exclusive province of the investor-owned utilities and not a resource local planning officials have had much experience with at any significant level of detail. A key dimension of this barrier is that few municipalities have funding available to develop in-house expertise in this area or to contract out for consulting assistance. And again, as a result of the sub-prime mortgage crisis and the slowing economy, a precipitous fall-off in building permits and diminishing growth of local property tax revenues now make funding for training of this nature particularly scarce. Yet another dimension of the problem is that there are few external training resources that municipalities can draw upon to build the in-house capabilities needed.

To address this barrier and these related factors, the stakeholders proposed a strategy that entails development and pilot demonstration of a model municipal program on energy-efficient community development specifically designed for California municipalities. The program would include components that: make the local government "business case" for pursuing EECD; provide case studies of successful and transferrable municipal program elements found elsewhere; provide a set of model EECD site design guidelines and standards (including a set of EECD carbon metrics that enable municipalities to quantify the carbon reduction potential of different design features); provide a model municipal sustainable community development policy that aligns economic and community development priorities with specific energy efficiency and emissions reduction goals; provide guidance on translating the development policy into specific codes and standards modifications; and provide a list competent academic or private training consultants capable of crafting and delivering onsite training for municipal personnel. In addition to these components, the stakeholders suggested the development of a Peer-to-Peer network of municipal officials that can facilitate the transfer of EECD best practices and a clearinghouse of information similar in nature to the one described above.

With regard to the leadership and resources necessary to implement this strategy, the stakeholders suggested that the utilities might be best suited to take the lead and to seek CPUC approval to make the related program elements eligible for funding under their innovation and energy efficiency portfolio programs. Organizations such as the Local Government Commission, California universities and subject matter experts were mentioned as appropriate partners that the Utilities might consider collaborating with to develop an implementation plan for this strategy.

<u>Addressing the Lack of Uniform Municipal Procedures and Incentives for EECD Projects</u>

The lack of uniform municipal procedures and related procedural incentives surfaced during the workshop discussions and industry interviews as a major impediment for developers considering energy-efficient community development projects in California. Most large-scale developers and builders pursue projects in several municipalities across the state and often simultaneously. Consequently, they face the challenge of determining for each project, what design features will or will not be permissible and incentivized in each jurisdiction. Meeting this challenge, and the challenge of finding available financial incentives outside of the municipality for an energy-efficient project, represents a substantial additional expense to the developer/builder. The aforementioned experience of the Brookfield Homes executive seeking funding for the Avenue project in Ontario, California provides evidence that the challenge is both frustrating and expensive.

Input obtained through stakeholder discussions and industry interviews suggests that again, some form of a voluntary energy-efficient site development standard is needed along with a set of uniform incentives tied to the standard, that municipalities could offer developers and builders. The U.S. Green Building Council's LEED standard for Neighborhood Development (LEED-ND) is one such voluntary standard that's currently being pilot-tested nationally and in several California communities. However, several developers interviewed specifically stated that a new standard, specific to California and aligned with the States climate change goals and objectives, should be pursued by State agencies working in consort with the utilities, municipal and county advocacy organizations and the relevant industry trade associations.

Should such a standard be developed, the interviewed development industry participants suggest that the following be considered as key components of a companion incentives program.

<u>More Flexibility in Zoning Code Requirements</u> - This incentive, now common in many communities across the nation, allows the greener developer/builder more zoning flexibility in return for greener, energy-efficient construction. Allowing decreased setbacks and bonuses, and relaxed parking requirements and street standards in return for greener construction is the now

generally the rule, rather than the exception, and will only become more important in community-scale projects into the future. The CBIA builder interviewees were especially supportive of relaxed parking requirements.

Cross-Departmental Expedited Plan Review - After years of experience with expedited plan check review benefits in California, builders have learned that unless all of the municipal departments are involved in expediting plans, the plans can and will get stuck in departments uninvolved in the formal faster plan check loop. This requires oversight by a senior City official who shepherds the paperwork through the city process. At least two of the CBIA officials interviewed pointed out that all departments needed to be involved in expedited permitting.

"Gold Star Treatment" - Pioneered by the City of Chula Vista Building Official, this easy to implement benefit entails ensuring that a green builder's plans are affixed with a "Gold Star" when they are received at the City, and conducting weekly status reviews to ensure that the plans are moving expeditiously through the review process. This administrative solution carries a surprising amount of weight with builders when the market is busy. This incentive is considered less valuable during down markets.

Priority Field Inspections - Like the "Gold Star Treatment" mentioned above this benefit is not as important during a downturn in the economy, since delays are at a minimum due to the lack of construction underway. However, ensuring that greener builders get inspections when they need them is usually a very easy benefit for most communities to provide. It is a very low cost benefit, and provided by many jurisdictions at the present time.

"One-Stop-Shopping", Aggregating Benefits and Sustainability Coordinators - Some of the building industry experts interviewed disagreed on the importance of a single point of contact when negotiating and/or implementing benefits for greener, energy-efficient construction. Some thought it was very important while others believed that they could negotiate issues directly through the City Manager and/or Council as needed. In some jurisdictions, an experienced Building Official can offer financial and recognition incentives without Council involvement. One industry leader suggested that a new area for builder benefits will involve City-hired "Sustainability Coordinators." He said, "Cities may want to appoint a sustainability coordinator whose job it is to aggregate benefits for green developers like me".

Sustainability coordinators may be in a position to help spur greener, energy-efficient development in the future. Sustainability coordinators are now being hired by some cities to help coordinate all green building functions, so this may be an important trend when it comes to arranging more benefits for green developers and builders.

Accelerated Processing of Entitlement and Permit Applications - Despite the fact that this important (general) incentive is not as important now as providing direct financial incentives to most builders, it is still a very important policy. Shaving time off of the review processes will always be important to builders, especially after the market picks up again and city staffs once again become stretched thin. Some cities are able to reduce the entitlement turnaround process by as much as 25- to 50-percent if a builder's homes perform 50-percent above minimum energy code compliance. For an energy-efficient community-scale development project, this benefit will be critical, particularly to reverse the generally held perception that greener projects take longer to move through the entitlement process.

Residential Development Allowances in Commercial Zones - This increasingly popular policy was referenced by three CBIA officials as important to industry members during the research interviews. It simply entails allowing a builder to construct residential structures in a commercial area in exchange that builder's commitment to design and build an energy-efficient community-scale project. This is an easy-to-implement incentive for most cities and counties to provide.

Tiered Utility "Energy Star-Plus" Category Is Needed – During the industry interviews, only one CBIA leader mentioned the *Energy Star* label. He also mentioned that the *Energy Star* label is important to some of his colleagues, but said that it has become less important for many others over the past year. He believed that utilities should consider structuring their financial incentives more toward an "*Energy Star*-Plus" category, where, "…we are rewarded with more funding for building well beyond *Energy Star* levels." The researchers believe that this two-tiered policy is likely to become commonplace in the near future. Many utilities are already offering this two-tier incentive at this time, such as the Public Service Company of New Mexico.

Addressing the Lack of Municipal Investments in Enabling Green Infrastructure

The stakeholders identified municipal investment in enabling green infrastructure as a necessary pre-requisite to engage the development industries in the effort to design and build energy and resource-efficient community development projects. Specifically, they cited the need for government leadership that results in partnership initiatives with local utilities that capitalize green infrastructure projects and enable the development industry to take advantage of proven distributed energy and renewable energy technologies, alternative vehicles and transit, water reclamation systems and stormwater runoff and urban heat island reduction measures. The stakeholder discussion suggested that the related factors supporting this barrier include regulatory and utility rules that discourage municipal investment in energy systems, lack of capital for these investments and lack of constituent awareness and apparent interest in the subject.

To address the barrier and these supporting factors, the stakeholders proposed a strategy that entails collaboration between local government advocacy organizations (i.e. Local Government Commission, California League of Cities, etc.), the three major IOUs, Energy Commission, CARB and the CPUC to:

- Examine and modify the existing regulatory and utility rules that impede municipalities and developers from taking advantage of available energy-efficient and renewable energy technologies and systems. Chief among these are those affecting distributed generation interconnection, sub-metering, standby charges, and inter-lot transfers of energy;
- Provide local governments guidance on the formation of financial mechanisms that can generate the necessary capital for these investments. This could include formation of energy-efficient and renewable technology districts (e.g. Berkeley's solar district), utility

surcharges to create municipal green technology investment funds whose dividends support revolving loan programs for projects;

- Formulate mechanisms to inform and involve consumers in the responsible use of energy, water and material resources. These will include: public information elements that educate consumers about the direct and indirect environmental impacts and costs associated with individual consumption practices; clear utility price signals and in-home displays that communicate the cost of their consumption in real-time; and economic incentives and disincentives such as a utility or local tax rebate for consumer conservation performance at the end of a calendar year or a carbon-tax/surcharge on excessive consumption.

Again, the development industry stakeholders believe that government and utility leadership on these initiatives will be necessary to lead to private investment. Other entities to enlist in such an effort should include regional transit planning organizations, infrastructure industry trade organizations and financing entities.

<u>Addressing the Lack of Consumer Willingness to Pay for the Value of Energy Efficient Features</u>

As stated above and repeatedly reiterated during all of the stakeholder breakout discussions, *most c*onsumers are uniformed about the value of, and are unwilling to pay premiums for energy-efficient and sustainable design features in their homes, businesses and communities. At this early stage in the evolution of this movement, this is not a surprising finding. However, it is clear that action needs to be taken as soon as possible to address this barrier, as it underpins the majority of the barriers identified in this research initiative.

The stakeholders focusing on this barrier envision a strategic future where energy-efficiency and responsible resources management is the norm among consumers, rather than the exception, and where enabling technologies are incorporated into the construction of all homes, offices and institutional buildings to aid consumers in this practice.

Further, they believe that if their vision is to become a reality, a series of incremental steps will need to be taken that will lead to a market transformation similar in nature to the one described by the first break-out group for the Split Incentive barrier. Specifically, there must be steps taken to: increase the market volume for energy-efficient features to the point where their inclusion in new construction represents only a negligible incremental cost to the developer and builders; to ensure that at the point-of-sale, all real estate products convey standard industry information about the structure's energy efficiency, emissions impact and the embedded energy costs of materials; and to ensure that all buildings feature real-time information displays on energy, water and material consumption and both their environmental impact and economic costs to the consumer.

Considered together, the stakeholder input suggests a strategy that entails additional research to quantify the energy and emissions profiles of different structural building materials and internal operating equipment and systems; a public information campaign and a targeted information dissemination effort to ensure these findings reach consumers and industry trade organizations; State regulation that mandates minimum building and community development site performance levels for carbon emissions reduction, similar to the Title-24 standard for energy efficiency; and economic disincentives and utility price signals similar to those mentioned above in response to the previous barrier.

With regard to leadership and collaborators best suited to mount this effort, the stakeholders believe that State and local government agencies must lead it, but that all other sectors and in particular the real estate finance and development entities must be active collaborators. In addition, given that the stakeholder's strategy is founded on additional research and consumer education, the California universities should play a significant role in the collaboration.

Addressing Investment Risks that Inhibit Capital Market Entities from Financing EECD Projects

To determine the investment risks and barriers that inhibit capital market entities from financing energy-efficient development projects, the researchers conducted an online survey of those entities. In early June 2008, 175-email survey invitations were sent to randomly selected members of the National Association of Industrial and Office Properties (NAIOP) and the Pension Real Estate Association (PREA).

In total, 120 questionnaires were completed and collected between June 15 and June 30, 2008. Respondents of the survey represented three occupational subgroups - lenders (34%), equity investors (49%) and developers (17%). The majority of respondents (20%) were located in California, followed by those located in Colorado, Illinois, Texas, New York and Florida. Over 65% of the participants had been involved with LEED-certified projects or *Energy Star* designated buildings. The high percentage of participants with experience in energy-efficient projects may suggest a sampling bias, i.e. those with experience are more interested in being part of this research project and thus more willing to complete the survey.

The survey contained questions relating to perceived costs, value, risk, barriers and participant engagement in energy-efficient building and community development projects. The following text, tables and figures summarize the survey results.

Incremental Costs Vs. Value

The first survey question was designed to extend the researcher's examination of incremental costs to capital market survey participants by asking them if they believed that an energy-efficient building cost more than an otherwise comparable conventional building. The vast majority of the respondents (94%) indicated that they did believe that an energy-efficient building would cost more than a conventional building. More specifically, about one third of the sample (38%) estimated the incremental cost to be 1-5% higher, and another one third (35%) estimated the cost to be 5-10% higher. The balance of the respondents (21%), thought that the incremental cost would be over 10%. Figure-53 graphically portrays these survey responses for the entire sample population.

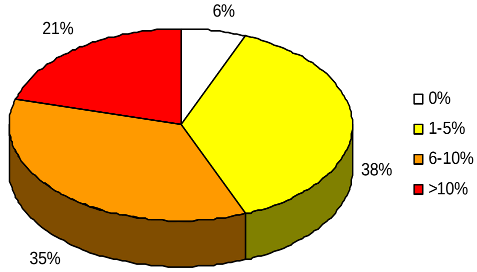

Figure 54. Perceived Incremental Costs of an Energy-Efficient Building Project

With regard to *value*, more than 90% of the sample believed that an energy-efficient building has a higher value than an otherwise comparable conventional building. An overwhelming majority of the respondents considered lower operating costs as the primary factor contributing to that higher value. Other contributing factors include higher rent, lower vacancy rate, and lower tenant turnover.

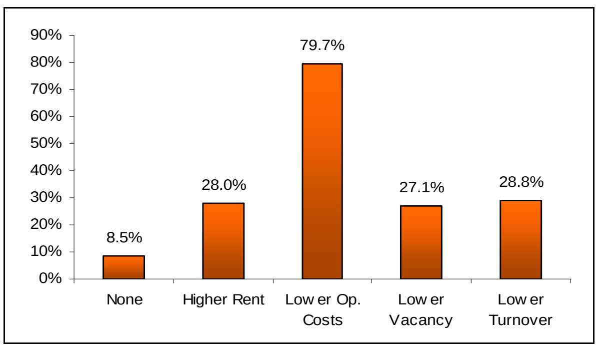

Figure 55. Perceived Factors Associated With Added Value

Given that an energy-efficient building is considered more costly to construct but more valuable to own, the respondents were asked if the additional value was sufficient to offset the higher costs. Nearly 60% believed that the value is sufficient to offset the cost, while 22% disagreed. About 20% of the participants were not sure about the cost-value tradeoff.

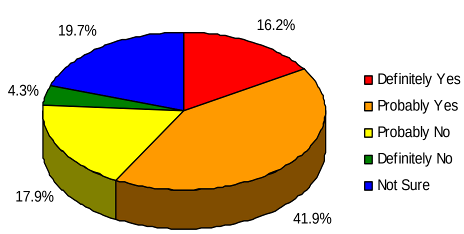

Figure 56. Perception that Added Value is Sufficient to Offset Higher Costs

<u>Investment Barriers</u>

Drawing from the input received during the stakeholder workshops, the research team identified five barriers believed to influence finance/investment decision-making relative to energy-efficient building and development projects. These barriers are presented below in Table-73. along with a set of impact factor scores the survey sample assigned to each.
The table indicates that the surveyed lenders, investors and developers believe that the most significant barrier is that consumers aren't aware of the benefits of energy-efficient buildings or development projects, and are presumably would be unwilling to pay premiums to occupy them (Barrier #2). The next two most important barriers were the lack of public (State and local government) and private (utility and financial institution) incentives (Barrier's #3 and #4). There are no statistically significant differences among the top three barriers in terms of their ratings by the survey respondents. The last two barriers - out-dated building codes and scarcity of experienced design teams (Barriers #1 and #5) on the other hand, were significantly less important.

Barrier	Description	Impact Factor*
Barrier 1	Local building codes are out-dated, so energy-efficient buildings and development projects may violate existing codes	2.21
Barrier 2	Consumers/space users are not aware of the benefits of energy-efficient buildings and development projects	2.67
Barrier 3	State/local governments don't provide sufficient financial incentives	2.65
Barrier 4	Private sector entities such as lenders and utilities don't provide sufficient financial incentives	2.58
Barrier 5	Experienced design teams are difficult to find	2.25

* Each respondent rates the barriers using the following scale: great impact (4), moderate impact (3), little impact (2), no impact (1), and not sure (NA). The impact factor is the weighted average of the ratings, excluding those who were not sure about the impact.

Table 73. Barriers Preventing Investment in Energy-Efficient Development

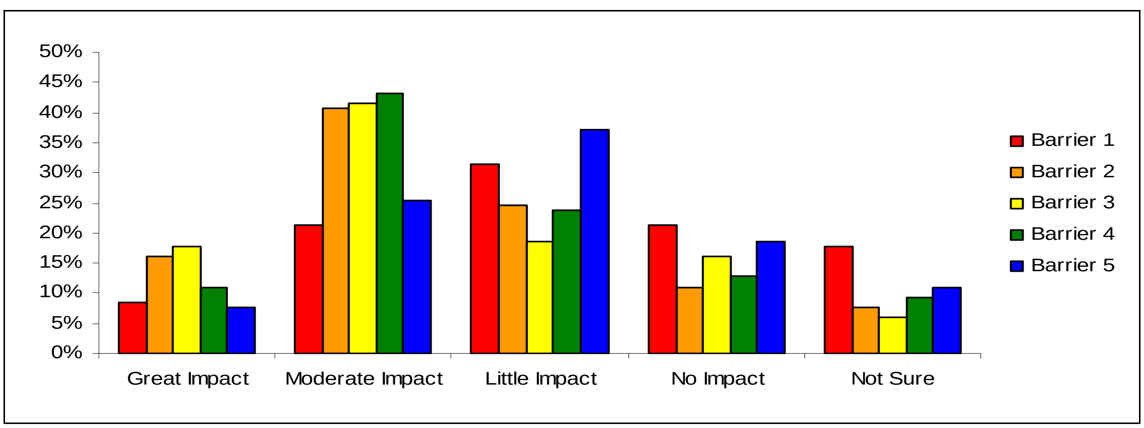

Figure 57. Perceived Impact of Barriers

Investment Risks

Next, the survey respondents were asked to rate the importance of seven risk factors the stakeholders had identified as having potential influence on return on investment (Table-74).
The survey responses indicate that the two risks of greatest concern are that tenants will not be willing to pay higher rents to occupy energy-efficient buildings and that the added value of energy-

efficient features will not be recognized nor credited by other lenders or appraisers. After these risks, the next two of greatest concern were that building owner's would be unable to capture the added value when they sell their energy-efficient buildings, and the possibility of incurring additional fees associated with the design, installation and inspection of energy-efficient building features. It is somewhat surprising that on average, the survey participants were not very concerned about the possibility that the approval and/or entitlement process for an energy-efficient building project might take longer than a conventional project.

Risk	Description	Concern Factor*
Risk 1	Tenants might be unwilling to pay higher rent for an energy-efficient building or development project	2.75
Risk 2	The benefits of an energy-efficient building might not be reflected in value (by lenders, appraisers, etc.)	2.62
Risk 3	The owner might be unable to benefit from the higher value when selling the building	2.28
Risk 4	The design process might take longer due to the lack experienced teams	1.93
Risk 5	The approval/entitlement process might take longer	1.63
Risk 6	There might be additional requirements and/or fees involved (design, installation, inspection, etc.)	2.26
Risk 7	As technology continues to change, the building might become functionally obsolete soon	1.97

* Each respondent rates the risks using the following scale: extremely concerned (4), moderately concerned (3), mildly concerned (2), not concerned (1), and not sure (NA). The concern factor is the weighted average of the ratings, excluding those who were not sure about the impact.

Table 74. Risks Preventing Investment in Energy-Efficient Development

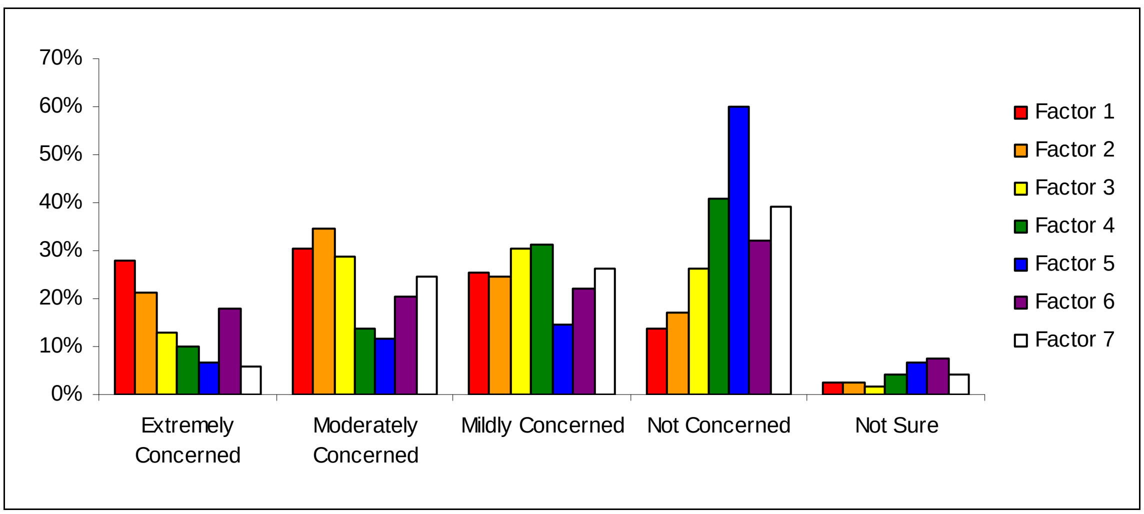

Figure 58. Perceived Importance of Risks

<u>Survey Results by Occupational Subgroup</u>

To further examine how the real estate capital markets perceive barriers and risks, the survey results were stratified and analyzed by occupational subgroup. Again, the subgroups were comprised of lenders, equity investors and developers. Table-75 presents the average rating of each barrier, as well as its ranking among all barriers (in parentheses), by the entire survey sample and each of these three subgroups. Equity investors consider the lack of consumer awareness of the benefits of energy-efficient buildings as the most significant barrier; lenders and developers, in contrast, perceive the lack of government incentives as the top barrier. The top three barriers also include the lack of incentives from the private sector, such as utilities and financial institutions. All three subgroups agree that neither outdated local building codes nor the scarcity of experienced design teams are significant barriers.

Barrier	Entire Sample	Lenders	Equity Investors	Developers
Barrier 1	2.21 (5)	2.31 (4)	2.14 (5)	2.18 (4)
Barrier 2	2.67 (1)	2.68 (2)	2.70 (1)	2.53 (2)
Barrier 3	2.65 (2)	2.71 (1)	2.53 (3)	2.88 (1)
Barrier 4	2.58 (3)	2.58 (3)	2.63 (2)	2.38 (3)
Barrier 5	2.25 (4)	2.31 (4)	2.26 (4)	2.06 (5)

Table 75. Comparative Impact of Barriers by Occupational Subgroup

Table-76 below compares the perception of risk factors by occupational subgroups. The table indicates that all three groups are most concerned about the possibility that tenants might not be willing to pay higher rent for energy-efficient space. Other important risk factors include the possibility that the benefits of an energy-efficient building might not be reflected in the appraised property value (by lenders, appraisers, etc.) and that there might be additional requirements and/or fees involved. On the other hand, the approval/entitlement process is the least concern by all three groups.

Risk	Entire Sample	Lenders	Equity Investors	Developers
Risk 1	2.75 (1)	2.87 (1)	2.66 (1)	2.72 (1)
Risk 2	2.62 (2)	2.72 (2)	2.63 (2)	2.33 (3)
Risk 3	2.28 (3)	2.18 (4)	2.41 (3)	2.17 (4)
Risk 4	1.93 (6)	1.95 (5)	1.91 (6)	1.94 (5)
Risk 5	1.63 (7)	1.70 (7)	1.54 (7)	1.78 (6)
Risk 6	2.26 (4)	2.29 (3)	2.15 (5)	2.53 (2)
Risk 7	1.97 (5)	1.74 (6)	2.22 (4)	1.78 (6)

Table 76. Perceived Importance of Risks by Occupational Subgroup

Survey Results by Respondent Experience

The researchers also examined the survey results in terms of the respondent's past experience with the design and construction of energy-efficient buildings projects. Sixty-five percent of the survey respondents have financed, developed or invested in LEED/Energy Star buildings. These respondents consider the lack of government incentives (Barrier #3) as the most significant barrier to energy-efficient development projects, followed by the lack of consumer awareness of the benefits of owning energy-efficient space.

In contrast, respondents who have not been involved in LEED or Energy Star projects believe that the lack of consumer awareness has the greatest impact; the lack of incentives offered by the private sector and the public sector are ranked second and third. Regardless of their experience, the respondents agree that outdated local building codes and the scarcity of experienced design teams have much less impact than the other barriers. An interesting pattern is that the impact factors for respondents without experience are significantly higher than those with experience across all barriers. This difference in perception might explain why some firms have not engaged in LEED or Energy Star building projects. Table-77 below provides the numbers upon which these findings are based.

Barrier	Entire Sample	With Experience	Without Experience
Barrier 1	2.21 (5)	2.10 (5)	2.42 (5)
Barrier 2	2.67 (1)	2.51 (2)	2.95 (1)
Barrier 3	2.65 (2)	2.60 (1)	2.74 (3)
Barrier 4	2.58 (3)	2.49 (3)	2.75 (2)
Barrier 5	2.25 (4)	2.14 (4)	2.43 (4)

Table 77. Impact of Barriers by Practitioner Experience

With regard to risks, both groups identify the possibility that tenants might not be willing to pay higher rent for energy-efficient space and that the benefits of an energy-efficient building might not be recognized by third parties as the top risk factors. On the other hand, the approval/entitlement process is the least concern. Similar to the impact factor of barriers, the concern factors for respondents without experience are much higher than those who have financed/ developed/invested in energy-efficient projects. Table-78 below provides the numbers upon which these findings are based.

Risk	Entire Sample	With Experience	Without Experience
Risk 1	2.75 (1)	2.53 (1)	3.13 (1)
Risk 2	2.62 (2)	2.36 (2)	3.08 (2)
Risk 3	2.28 (3)	2.12 (3)	2.63 (4)
Risk 4	1.93 (6)	1.77 (6)	2.24 (5)
Risk 5	1.63 (7)	1.40 (7)	2.08 (7)
Risk 6	2.26 (4)	1.99 (4)	2.78 (3)
Risk 7	1.97 (5)	1.88 (5)	2.18 (6)

Table 78. Perceived Importance of Risks by Practitioner Experience

Summary

In summary, the capital market survey indicates the following:

- The vast majority of lenders, investors and developers believe that energy-efficient building projects are more expensive to build (5-10% or more), but are also more valuable to own than comparable conventional buildings. The latter perception is due primarily to the assumption of lower owner operating costs. However a minority also believe that there may be lower rates of tenant turn-over and the possibility of higher rents. Additionally, most respondents believe these benefits offset the additional costs.
- With regard to the most significant barriers to investment, equity investors believe that the lack of consumer awareness of the benefits of energy-efficient buildings is the top barrier followed by the lack of private (utility and financial institution) incentives. Lenders, and particularly developers on the other hand, believe the top two barriers are

the lack of public (government) financial incentives and again lack of consumer awareness.

- With regard to the most significant risks, all three occupational subgroups believe that the top risk is that tenants will not be willing to pay higher rents for energy-efficient space, followed by concern that the value of this space may not be recognized by lenders and appraisers.

With regard to needed models, policies and incentives to overcome these barriers and risks, the workshop and industry interviews generated a number that could be considered appropriate. Specifically, these include the following economic incentives and informational mechanisms:

Economic Incentives

- State and local carbon credits for EECD development projects;
- Cash rebates for consumers buying properties in energy-efficient developments;
- Discounted insurance rates for energy-efficient construction;
- Utility and/or municipal subsidies to developers for EECD design consultant costs;
- Delay the collection of increased property tax until close of escrow;
- Defer payment of special assessments until close of escrow;
- Low-interest financing for energy and/or sustainable construction projects;
- Tax credits for homeowners in energy-efficient developments;
- Federal and state income tax reductions for developers and builders of EECD projects;
- Research to generate means of aligning EECD investments costs with long-term benefits;
- Energy-efficient mortgage instruments.

Information Mechanisms

- Demonstration projects to document the value of EECD for the development industry;
- Development industry case studies and examples of successful EECD projects;
- Consumer, lender and appraisal industry education and training initiatives;
- Best Practices information for public, private and utility planning practitioners;
- Centralized source of information on EECD (information clearinghouse on incentives);
- Professional training resources for public, private and utility development practitioners;
- Model design and development guidelines and standards for EECD.

Chapter 4. Conclusions and Recommendations

This chapter describes the conclusions and recommendations for the six research objectives. The conclusions are drawn directly from the research results for each objective presented in the preceding chapter. There is also a set of additional conclusions that are broader than the individual research objectives that are presented below the conclusions for the numbered objectives. Similarly, recommendations are presented in the subsequent sub-section for each numbered objective and followed by a set of additional recommendations for the Commission's consideration.

4.1 Conclusions

Research Objective #1 - Estimate the relative energy efficiency and emissions reduction performance of individual energy efficiency (EE), demand response (DR), renewable energy (RE) and distributed generation (DG) technologies (advanced energy technologies) in typical development projects (residential, commercial, industrial, institutional).

The researchers have concluded that there are no *typical development projects* and given that they are all site-specific, energy efficiency and emissions reduction performance of individual advanced energy technologies will vary by site. Specifically, the mix of building types, their end-uses, their proximity to one another and the climate all determine the appropriate combinations of technologies to reach optimum performance. Further, as was apparent with the analysis of distributed generation, the availability of incentives will impact the economic feasibility of deploying these technologies in development projects.

Having stated this, the researchers conclude that significant energy savings and emissions reductions could be achieved for Site-A and Site-B through the use of different energy efficiency and advanced energy technology applications. The specific modeling results upon which this conclusion has been drawn are summarized below for each site in turn.

Site-A

- The results of the modeling indicate that use of the *EE Package* could reduce Site-A community annual TDVI based energy consumption (kBtu/sf-year) by 12.3% below what would be expected if the buildings were built per the developer/builder's specifications. Supplementing the EE option with solar PV-based on-site power generation systems could further reduce the site TDVI to 30.0% below the builder's baseline approach. Substituting solar PV power generation technology with natural gas-fired DG would result in a 21.7% reduction in TDVI energy consumption.
- Relative to natural gas, use of the EE option would achieve a 16.6% reduction in annual consumption (MMBtu/year). Adding PV technology to the EE option for obvious reasons would not alter the natural gas consumption at the site. However, using DG technology instead of PV could result in a significant increase in the consumption of natural gas at the site, and specifically by 106.5% as compared with the builder's proposed baseline approach.

- With regard to electric energy consumption (kWh) and peak demand (kW), implementation of the EE option could reduce site annual kWh by 11% and demand by 16.8% below the builder's baseline approach. Supplementing EE package with PV technology would result in a cumulative reduction of kWh by 34.3% and kW by 29.1%. Alternatively, using the DG technology with the EE option would reduce annual kWh by 31.2% which is close to the impact of the PV option. However, DG would be more effective in controlling electric peak demand and could reduce it by 45.2%.
- Given the reduction in energy consumption resulting from the use of the energy-efficient option, energy-related air emissions would be also be significantly reduced. Specifically, Carbon Dioxide (CO_2) emissions would be reduced by 12.1%, Sulfur Dioxide (SO_x) emissions by 11%, and Nitrogen Oxide (NO_x) emissions by 12.6% as compared to the emissions expected from the builder's baseline approach. Similar numbers for the EE-PV option show reductions of 30.8% in CO_2, 34.2% in SO_x, and 29.3% in NO_x. The EE - DG option is not as effective in reducing emissions as the EE – PV option, however with the reductions of 6.7% in CO_2, 30.3% in SO_x, and 38.5% in NO_x it is still better than the builder's baseline approach.
- Annual utility costs savings associated with the use of the energy-efficient option are estimated at 11.3% when compared with the builder's baseline approach. Simple payback for the EE package is estimated to be 5.9 years with a ROI of 16.9%. The EE-PV option utility cost savings are 32.3% with simple payback of 12.4 years and a ROI of 8.1%. Implementing EE-DG option would result in annual utility cost savings of 16%, a simple payback of 7 years, and a ROI of 14.3%[64]

Site-B

- The results of the modeling indicate that the use of the EE option could reduce Site-B annual TDVI based energy consumption (kBtu/sf-year) by 8.2% below what would be expected if the buildings were built according to the builder's specifications. Supplementing EE with the solar PV-based on-site power generation could further reduce the site TDVI to 36.4% below the builder's baseline. Substituting PV power generation technology with the microturbine-based DG/CHP generation systems would result in an 11.7% reduction which is smaller than the EE-PV option but still better than the EE option alone.
- Relative to natural gas, use of the EE option would achieve a 17.4% reduction in annual gas consumption (MMBtu/year). Adding PV technology to the EE option, would not, for obvious reasons, change the natural gas consumption at the site. However, implementing gas-fired microturbine-based DG technology in place of PV could increase Site-B natural gas consumption by 94%.

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[64] Assumes SGIP rebates of 600/kW.

- With regard to electric energy consumption (kWh) and peak demand (kW), implementation of the EE option would reduce site annual kWh by 5.8% and demand by 8.5% below the builder's baseline approach. Supplementing EE option with the PV technology would result in a cumulative reduction of kWh by 42.6% and kW by 16.2%. Using DG technology with EE option could reduce annual kWh by 30.5% and demand by 13.1%.
- Given the reduction in energy consumption resulting from the use of the energy-efficient EE option, energy-related air emissions are also significantly reduced. Specifically, Carbon Dioxide (CO_2) emissions would be reduced by 9.2%, Sulfur Dioxide (SO_x) emissions would be reduced by 6.0%, and Nitrogen Oxide (NO_x) emissions would be reduced by 10.5% as compared to the emissions expected from the builder's baseline approach. Similar numbers for the EE-PV option show a reduction of 35.2% in CO_2, 42.3% in SO_x, and 32.5% in NO_x. The EE-DG option is not as effective in reducing emissions as the EE-PV option, though it still provides SO_x and NO_x reductions of 29.1% and 48.9% respectively over the builder's baseline approach. However, the CO_2 emission of the EE-DG option is 5.2% higher than the builder's baseline approach. This is because the CO_2 emissions of the DG deployed at Site-B entails a mix of microturbine-based power generation and heat recovery technologies that release more CO2 than is released during production of an equivalent amount of electricity at a central power plant in California.
- Annual utility costs savings associated with the use of the energy-efficient option are estimated to be 6.8% when compared with the builder's baseline approach. Simple payback for the EE option is estimated to be 9.8 years with a ROI of 10.2%. The EE-PV option utility costs savings are 27.9%, the simple payback is estimated to be 14.8 years, and a ROI is estimated to be 6.7%. Implementing EE-DG option would result in annual utility cost savings of 19.8%, a simple payback of 6.7 years, and a ROI of 14.9%[65].

The energy efficiency measures recommended for implementation in various Site-A and Site-B building envelopes include more efficient building materials, higher efficiency HVAC equipment and selective deployment of DG and PV technologies. However, as expected, each building and each space-use type will demand a different combination of these measures to produce optimum energy efficiency and emissions reduction.

The descriptions and specific details of the recommended combinations for each building prototype are provided in Appendix-A for Site-A, and Appendix-B for Site-B. These 2 appendices provide tables listing recommended measures and showing energy savings and environmental and economic impacts for each of the analyzed prototypical buildings. The results provide a wealth of information that can be used by developers/builders when considering appropriate building energy technology packages for their large-scale development

[65] Assumes SGIP rebates of 800/kW. See footnote 2 and 5 of this report for additional explanation.

projects. Of equal utility are the analysis found in these tables that indicate that certain energy efficiency measures, commonly considered valuable for inclusion in building projects, in fact proved to have limited benefit and are not recommended for implementation by the researchers.

With regard to the special feasibility evaluation of a district cooling system to serve Site-A, the researchers conclude that incorporation of the system compares favorably to stand-alone cooling production at individual buildings. District cooling for the site is most attractive when TES is incorporated into the district cooling system, allowing for substantial energy cost reductions due to the time-of-day rate structure of the utility tariff. The *Optimum Configuration* district cooling with TES alternative has the lowest annual operating costs of the six alternatives evaluated. This district cooling alternative optimizes system efficiency through incorporation of a series-counterflow chiller arrangement, VFDs driving chillers, and chilled water TES.

The reduction in electricity consumption by over 3 million kWh for the Optimum Configuration district cooling plant with TES alternative will also provide substantial reduction in emission of pollutants and greenhouse gasses. Furthermore, the ability to peak shave with the TES alterative significantly reduces peak power requirements, thereby reducing the amount of electrical infrastructure required to meet peak cooling loads for the development site. In addition to the benefits of incorporating district cooling into the site discussed above, other less tangible advantages of district cooling over cooling production at individual buildings are discussed in the section below.

Research Objective #2 – Determine the extent to which the application of these technologies, in typical development projects, will reduce peak demand and result in better utilization of existing utility infrastructure.

As stated above, the researchers conclude that typical development projects don't exist, rather that each site is considered unique to a certain extent. This is particularly true with regard to utility distribution planning. Both the electric and gas distribution planners were quite explicit in stating that each site requires careful examination of individual and aggregate building loads and adjacent near- and mid-term development plans to design utility systems to meet both existing and future capacity and to do so with reliability. And although the gas distribution planners were able to calculate the capital cost impacts of the alternative development scenarios for both Sites-A and –B, the electric distribution planners were reluctant to do so for either site.

With regard to the impact of the modeled development options on the electric utility, neither the EE nor the EE-PV development options would result in an alteration in the electric utility plans for either site or for the EE-DG option in Site-B. Only the EE-DG development option in Site-A was considered a candidate that could reduce the need for one of three circuits and the associated substation facilities. The primary reason the other options were not deemed to have a significant utility impact was not one of insufficient load reduction, but rather a concern for ensuring system capacity and reliability. This was particularly the case with the EE-PV option given the intermittency of solar energy given variable cloud coverage. And in the case of the

EE-DG option, both emissions performance and the lack of an available utility incentive now make its use both economically infeasible and undesirable from an environmental standpoint.

With regard to the impact of the modeled development options on the natural gas utility, the researchers concluded that given the conventional approach to distribution pipe planning, and specifically plans to meet the worst case climate conditions for a given area, the optimized natural gas loads for Sites-A and –B would not result in the alteration of the utility's infrastructure plans. Indeed, given the increased natural gas loads associated with the EE-DG option, additional pipe pressures and a regulator station would be necessary to meet demand.

Given the forgoing, the researchers conclude that unless sufficient energy system redundancy and non-intermittent sources of renewable energy (or improved solar storage technologies) are included in site development plan to ensure system capacity and reliability, they can't expect substantial utility savings from reduced utility infrastructure costs. Additionally, the researchers conclude that until the emissions performance of fossil-fueled distributed generation technologies are improved and utility incentives are restored, the substantial benefit they provide in peak demand reduction will not be realized in the State.

<u>**Research Objective #3** - Determine the market-feasible combinations of energy technology and design options that will increase building energy efficiency by more than 25% above existing Title-24 2005 standards.</u>

In addition to the combinations of building envelope measures and technologies exceeding Title-24 that are contained in Appendix-A (page-22) and –B (page-24), the researchers also determined that disruptions in the construction process associated with their installation must also be considered in determining market-feasibility. With regards to the modeled measures and technologies for these two specific sites, the construction process implications entail primarily product substitutions. Product substitutions have relatively minor impact on the construction process, which can be adequately described by differential costs for labor and material associated with the substitutions.

One of the roofing alternates however, would add an additional step to the process, but this step is completed by the same trade contractor. Since this case does not introduce additional handoffs, no cost implications beyond the labor, equipment and material differentials should be expected. Of greater concern though, was that one of the exterior wall alternates (stucco over rigid insulation) exhibited a significant potential to disrupt "normal" processes by the addition of inspection and scaffolding activities. This suggests that an analysis of construction process impacts, and their associated costs, must accompany the developer/builder's evaluation of first costs of alternative energy-efficient building measures for large or even smaller-scale projects.

With regard to the means of offsetting additional costs associated with the modeled development options, the researchers conclude that available utility incentives do make a significant contribution. These incentive programs were found to reduce the simple payback period for the EE option in the Site-A prototypes by an average of approximately 1.3 years, from an average of about 7.3 years to an average of about 6 years. For the optimal energy efficiency packages augmented with photovoltaic generation, the average simple payback periods are reduced by about 1.5 years (from about 14.5 to about 13 years) by available utility incentive programs. For the optimal energy efficiency package, four of the 15 prototypes experience energy performance at least 25% better than existing Title-24 2005 standards. When photovoltaic generation is included, all of the prototypes (less one sub-prototype) experience energy performance at least 25% better than the existing Title-24 2005 standards.

Research Objective #4 - Estimate the degree to which enabling community design options (i.e., mixed-use/moderate density/transit-oriented development; stormwater runoff and carbon sequestration measures; urban heat island reduction measures; and passive solar building orientation) can improve energy technology performance in typical development projects.

Based on the modeling results, the researchers conclude that the community design options examined will improve the economics and performance of both CCHP and district energy technologies in large-scale development projects. Additionally, their use and the use of other modeled community design options/measures will produce significant reductions in land, energy and petroleum consumption and energy-related emissions in California communities. These conclusions are drawn directly from the following summary of results.

- Mixed-Use, Moderate-Density Development Increases Energy and Land Use Efficiency and Significantly Reduces Transportation-Related Air Emissions

As expected, compact development does lower per-capita energy use as compared to conventional low-density development typical in most California communities. With residential energy use reduced by more than 25%, compact development contributes significantly to the State's zero net energy goals. These energy savings are the result of the use of multi-family, mixed-use structures that share walls (and envelope efficiencies), highly efficient heating-ventilation-air-and-conditioning systems, and a reduction in transmission line losses, estimated to be approximately 9% of the central power plant electricity delivered on average (Energy Information Administration).

The efficient use of land is the key to growth management for all California's communities. Over the past 20 years, California's population has grown by almost 32%. This population growth is a primary factor in the increase of congestion and related emissions throughout California, and requires efficient use of land to be manageable. More efficient use of land through the mixing of uses and increased density can enable California communities to pursue more effective multi-modal transportation options (highway, rail, bus, bike, and air) and offer more efficient community- and building-scale technologies like CCHP and district cooling.

Through thoughtful, responsive planning, California communities can increase the number of choices for residents in housing and transportation options and build "up" instead of "out" at moderate levels. Also, California communities should pursue context sensitive density options that would allow for a range of development options depending on factors such as transit, proximity to an existing employment or downtown center, and projected population and employment growth.

The average US citizen uses more energy for transportation than citizens from any other industrialized nation, in part due to the greater distances traveled (Gilbert 2002). As of 2006, the percentage of trips to work in a private vehicle in California, excluding carpooling, is not significantly different from nation-wide rates. Seventy-three percent (73%) of California drivers use private vehicles while the national average is 76%. However, according to a study by Ferrel and Deaken (2001), California has led the nation in automobile use since the end of World War-II with the rest of the nation catching up only in the early 90's. Trends toward automobile usage have historically been much steeper in California. On average, transportation accounts for about one-third of energy consumption in the United States (Energy Information Administration). This is similar for California. Significant savings in energy and reductions of greenhouse gas (GHG) emissions result from reducing community vehicle-miles-traveled (VMT).

From this research, and earlier work on this subject, it is clear that compact, mixed-use development promotes energy and GHG savings by reducing VMT. The mix of employment and housing, a strong network of pedestrian walkways and streets, access to alternative means of mobility, and close proximity to retail stores promotes more walking and less driving. This has less to do with a large number of people living in a neighborhood and more to do with the practical efficiency of living close to places in which one works, shops and recreates.

- Modest increases in Tree Canopies and Decreases in Impervious Surfaces Produce Energy and Stormwater Facility Construction Costs Savings and Emissions Reduction in Large-Scale Development Projects

The researchers conclude that in addition to providing shade, trees also increase albedo and provide pervious surfaces that significantly reduce the velocity of stormwater flows. The diversion of stormwater provides significant savings to communities by reducing the size of stormwater management facilities need to accommodate flows from large-scale developments. In addition, increased tree canopy and decreased impervious surfaces recharge ground water supplies, and can reduce the need for irrigation of lawns and landscaping. This, in turn, reduces both water and energy use. According to analysis on both sites, total savings in Site-A were as low as 977 kWh annually in the baseline and 1,893 kWh with a 12.4% canopy. Site-X ranged from a savings of 1,599 kWh annually to 4,498 kWh annually.

- Modest Increases in Tree Canopies Produce Significant Storage and Sequestration of Carbon Dioxide and Other Pollutants in Large-Scale Development Projects

Although the carbon emission reductions proposed by various strategies throughout this project are significant, the ability of trees and other vegetation to store and sequester carbon dioxide should not be overlooked. The average adult tree sequesters 26 pounds of carbon dioxide a year, and produces enough oxygen for a family of four. Additional air quality improvements can also be significant given that trees trap or absorb many pollutants and reduce air temperatures thereby reducing the volatility of other pollutants. These associated benefits reduce overall community health care costs and improve quality of life for residents.

- Use of Urban Heat Island Effect Mitigation Strategies Produce Community-Wide Energy Savings

The research has shown that a 10% increase in vegetation and albedo can reduce ambient air temperatures in a typical southern California community development project between 1.3-2.8 degrees Fahrenheit. The researchers conclude that this change results in a significant energy savings. Additionally, a number of recent studies concur with this conclusion and show that urban heat island intervention measures such as cool white roof paints can have large impacts on the heat island effect and can reduce cooling energy use substantially.

As an example, a forthcoming study by the Lawrence Berkeley National Laboratory Heat Island Group will show that similar decreases in the warmest climates of California may reduce cooling energy use by as much as 20% (LBNL Heat Island Group 2008). This is especially true in dry, sunny climates such as Chula Vista where solar gain tend to increase temperature dramatically, and where the evaporative cooling provided by trees is particularly effective. Additional reductions in temperature and energy use for building cooling can be achieved through further application of high reflective materials to urban surfaces and additional tree plantings.

- Passive Solar Building Orientation on an East-West Axis Alone Can Produce Some Improvements in Energy Efficiency

The results of the limited analysis conducted here led the researchers to conclude that building orientation alone, without the aid of additional passive solar building design features, will produce improvements in energy efficiency and cost savings, although modest. Specifically, reductions in natural gas and electric consumption range between 2% and 3%.

Research Objective #5 – Determine the maximum incremental cost that the California building industry and consumers will accept for energy-efficient residential, commercial, industrial and institutional structures.

The researchers conclude that the average maximum incremental cost the California building industry and consumers will accept for energy-efficient structures is between $1.59 and 7.41 per square foot of construction, depending on the technology enhancement. Additionally, given that this range is below the range calculated for the enhancements ($2.00 to $15.00 per square foot), the researchers conclude that significant economic incentives will be necessary to encourage their adoption in today's market.

With regard to the energy-efficiency technology enhancement described in this report, close to half of the building industry practitioners (45.4%) believe that an incremental cost of $2.00 per square foot of construction is acceptable and some (18.2%) would be willing to pay as much as $3.00 per square foot. However, the balance of the responses from the surveyed industry practitioners brought the average acceptable incremental cost to $1.59 per s.f. of construction, leading the researchers to conclude that additional economic incentives are necessary to offset costs and achieve widespread adoption of this enhancement package by the industry.

With regard to the energy-efficiency and distributed generation technology enhancement, building industry practitioners believe that the maximum acceptable incremental cost is between $1.83 and $3.63 per square foot of construction (statistical average of $2.64 per s.f.). This average and even the range is considerably below the $4.00 per square foot cost that was calculated for this technology enhancement (including the benefit of a now retired utility incentive). Given this gap, the researchers conclude that utility economic incentives must be reinstated and adjusted upward to enable the building industry to cost-effectively maximize the potential of the distributed generation technologies modeled in this research.

With regard to the energy-efficiency and photovoltaic technology enhancement, the average acceptable incremental cost is $ 7.41 per s.f. of construction. The calculated cost for this enhancement, including all available solar incentives, is more than twice the average acceptable incremental cost. This once again leads the researchers to conclude that at least for the members of the California building industry surveyed (including developers, property managers, design professionals, real estate brokers, investors and government employees) additional economic incentives must be offered the industry to achieve significant adoption of this building technology enhancement.

Additionally, the researchers conclude that developers are the most price-sensitive occupational subgroup in the industry and the most conservative in their estimation of what constitutes acceptable incremental costs. By marked contrast, design professionals were the least price-sensitive among all surveyed subgroups. Specifically, the survey responses suggest that design professionals are more than twice as liberal in their estimation of what constitutes acceptable incremental costs as developers. This finding leads the researchers to conclude that specific economic incentives need to be targeted to developers in order to accelerate adoption of energy-efficient technologies by the building industry.

Research Objective #6 - Determine which financial and business models and associated public policies and incentives will lead to accelerated deployment of EE, DR, RE and DG technologies in typical development projects throughout the State of California.

The researchers conclude that widespread adoption of these advanced energy technologies and community design features by the development industry will not be realized without a fundamental transformation of the real estate development marketplace. Additionally, this transformation will not take place until at least seven principal economic, informational and procedural barriers to energy-efficient community development are adequately addressed. These barriers include the:

1. Need for direct and indirect financial support for developers and builders;
2. *Split Incentive Dilemma* - a misalignment between investment costs and benefits;
3. Lack of knowledge among municipal officials inhibiting approval of EECD[66] projects;
4. Lack of uniform municipal procedures and related incentives for EECD projects;

[66] EECD – Energy Efficient Community Development projects

5. Lack of municipal investments in enabling green infrastructure;
6. Lack of consumer willingness to pay for the value of energy efficient features;
7. Investment risks that inhibit capital market entities from financing EECD projects.

In reaching this conclusion, the researchers adopted the California Public Utilities Commission's definition of market transformation. Specifically:

Long-lasting sustainable changes in the structure or functioning of a market achieved by reducing barriers to the adoption of energy efficiency measures to the point where further publicly-funded intervention is no longer appropriate in that specific market.[67]

The researchers conclude that the two essential changes necessary to achieve this transformation are that:

- The value of energy-efficient building technologies and community design options is recognized by all entities in the real estate development transaction chain (lenders, investors, developers, builders, design professionals, appraisers and brokers); and that
- This recognition results in market transactions that enable developers to capture capital investments in energy-efficient design features through real estate sale prices that are acceptable to consumers.

The researchers further conclude that State and local government- and utility-funded intervention will be necessary to produce these changes over the near-term (5-10 years). Given the results of the research, this intervention should include at least the following seven components:

- Additional research to further estimate the economic and environmental costs and benefits of alternative energy technologies and community design features in large-scale development projects (discussed in greater detail in the Recommendations sub-section below). This research should advance our understanding of the dynamics of community-scale energy consumption and improve the tools and methodologies for assessing different technology and design options.

  Additionally, this research should entail performance verification to quantify actual energy-efficiency and emission reduction gains of these options in built projects that later can be communicated to the development/building industry through case studies;
- A set of California-specific, *mandatory* site development standards for energy-efficiency and carbon emissions reduction. These should be performance-based standards to allow developers and builders flexibility in achieving compliance and they should be based on verified performance of the alternative technologies and design options determined by the aforementioned research;

[67] California Public Utilities Commission Decision 98-04-063, Appendix A.

- A uniform set of direct and indirect economic and procedural incentives for developers and builders that recognize and reward, on a graduated scale, performance above minimum compliance. These should include as many of the incentives described in the previous chapter as possible and information about these incentives should be centralized in one database accessible to all development practitioners;
- Uniform product labeling of all residential, commercial, industrial and institutional structures and planned communities that communicates the estimated energy, water and resource efficiency of each to consumers at the point-of-sale;
- An education effort mounted to inform the lending, investment, and real estate appraisal and brokerage industries about the value of energy- and resource-efficient structures and community development projects. This should be conducted along with a companion initiative to revise real estate appraisal practices and to generate new financial instruments and mortgage products that reflect that value;
- Further development of real-time resource (electricity, gas and water) monitoring technologies that inform consumers about their resource consumption;
- A workforce training initiative for municipal authorities on the use of tools and methods to evaluate energy-efficient development projects and an awareness-building initiative to communicate the value of these projects/properties to the consumer.

In conclusion, the researchers believe that it will take this combination of *market push* and *market pull* mechanisms, in roughly this sequence, to transform the market to the point where public and utility intervention will no longer be necessary to sustain energy-efficient community development in California.

4.2 Additional Conclusions

The researchers conclude that current policy, planning and regulatory initiatives in California concerning climate change, energy and the built environment68, will significantly advance energy-efficient community development in the near future, in particular California's Global Warming Solutions Act of 2006 (Assembly Bill-32/AB-32). This prospect is further enhanced by recent Federal initiatives that are advancing research in Zero-Net Energy (ZNE) buildings, communities and smart grids69, and linking Federal energy technology R&D with the economy, environment and the effort to rebuild national infrastructure.70 These initiatives will bring new resources to this field of research and could potentially provide support to resolve many of the barriers identified in this project.

While the AB-32 Scoping Plan does eventually contemplate the formulation of strategies for local government use of planning, development, and code compliance to advance its energy efficiency targets71, the most immediate State policy initiative that will advance energy-efficient community development is Senate Bill-375. The bill ties AB-32 greenhouse gas emission (GHG) reduction goals for cars and light trucks to the regional transportation planning process and to land use and transportation policy (Steinberg 2008).

The bill exempts developers of residential or mixed-use projects from the requirement to complete GHG and growth impact assessments on those projects if they include transit elements or are consistent with the metropolitan planning organization's sustainable communities strategy or the alternative planning strategy. Relief from these CEQA requirements represents a significant indirect economic incentive for developers in both time saved in the entitlement process and in consultant fees. The bill also provides streamlining of Transit Priority Projects (TTP) - defined as having 50% or more residential use, at a minimum density of 20 dwelling units per-acre, and located with half a mile of a transit stop or corridor. Streamlining incentives for projects that entail energy-efficient buildings, water conservation measures and those that meet minimum open space and low income housing requirements may be eligible for a partial or total CEQA exemption for a portion of a TTP.

Although the incentive relates primarily to the objective of reducing GHG emissions associated with VMT, researchers believe that it will help to stimulate development industry interest in seeking additional means of reducing the carbon footprint of their projects in the future. This may include use of the building energy technologies and enabling community design options modeled in this research initiative. This interest will be further stimulated should local

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[68] These initiatives include: CEC's 2007 Integrated Energy Policy Report; California's Global Warming Solutions Act of 2006 (Assembly Bill-32) and the California Air Resources Board AB-32 Draft Scoping Plan; the Energy Action Plan II; SB-375 (green house gas reduction, land use and transportation policy); AB2021 (statewide energy efficiency goals); the Governors Green Building Executive Order; the California Public Utilities Commission's California Long Term Energy Efficiency Strategic Plan.

[69] Federal Research and Development Agenda for Net-Zero Energy, High-Performance Green Buildings, National Science and Technology Council – Committee on Technology, Oct 2008 and the Energy Independence and Security Act of 2007

[70] President-Elect Obama's proposed Economic Stimulus Measure announced November 25, 2008

[71] Page 42, Climate Change Proposed Scoping Plan: A Framework for Change, California Air Resources Board October 2008

governments and private development projects become considered eligible sources of carbon offsets under a statewide Cap-and-Trade program.

The Draft AB-32 Scoping Plan does include a recommendation for a statewide Cap-and-Trade program that will be tied to a western regional program under the Western Climate Initiative.72 While preliminary CARB recommendations do not contemplate the participation of local governments in direct carbon trading, a policy will be developed with regard to their eligibility as a source of offsets. In conjunction with Cap-and-Trade program, a California Carbon Trust is contemplated as an active manager of the carbon market, playing a similar to that of the Federal Reserve. Revenues generated by the Trust through the auction of emission allowances or through the assessment of carbon fees are intended to invested in further GHG reductions and research, development and demonstration project funding.

Two such investments currently being considered are local government incentives and RD&D funding for local government climate change plans. The researchers conclude that in the advent such incentives and funding materialize; they could both be used to help resolve the essential economic barriers preventing both the development and the capital market industries from adopting energy-efficient community development projects.

The next policy/planning initiative that will have significant influence in moving energy-efficient community development forward in the State is the Public Utilities Commission's California Long Term Energy Efficient Strategic Plan. The plan, created in consort with the three major IOU's, also targets market transformation as the necessary end-game the State must reach in order to meet a set of ambitious Zero-Net-Energy goals for residential and commercial building construction by 2020 and 2030 respectively. Together with optimal HVAC performance and consumer access to low-income energy efficiency benefits, these constitute the four goals of the Commission's "Big Bold Energy Efficiency Strategies". The plan contains a set of specific strategies for the four vertical market sectors and seven cross-cutting areas and provides as set of near-term (2009-2011), mid-term (2012-2015), and long-term (2015-2020) actions designed to implement each strategy.

The most promising aspect of the plan is that it contains many of the very same needed resources called for by the stakeholders, developers and capital market professionals solicited in this research project. Specifically needed: customer incentives; codes and standards; education and information; technical assistance; and additional research, development and demonstration. However, with regard to the built environment, the plan's resources are focused almost exclusively on building-scale, rather than the community-scale energy efficiency. Additionally, the plan does not consider transportation, water efficiency conservation or energy efficiency performance measurement, evaluation and verification. Fortunately, during the next planning cycle, the Commission does plan seek an alignment between their plan and other long-term water, land use and greenhouse gas mitigation plans, and will likely consider community-scale energy-efficiency to a larger degree at that time as well. The researchers conclude that this plan and the resources it can make available to local governments and the development industry is

[72] See: http://www.westernclimateinitiative.org/

perhaps the best single vehicle for the State to use in advancing the movement toward community-scale energy efficient development.

With regard to the opportunity to leverage California's leadership and resources in this field of inquiry through collaboration with other entities, there are currently 16 Federal agencies pursuing research, development and demonstration initiatives on various aspects the subject. Specific topic areas for potential collaboration are contained in the National Science and Technology Council's October 2008 document entitled: Research and Development Agenda for Net-Zero Energy, High-Performance Green Buildings. The broad outline of a specific proposal in this regard is presented below under recommendations.

Finally, the researchers believe that a significant opportunity exists for potential collaboration with the U.S. Green Building Council to enhance their evolving LEED standard for Neighborhood Development (LEED-ND) and to develop the California-specific standard proposed in this report.73 Both the Energy Commission and USGBC would benefit from such collaboration. The Commission would benefit from the use of the LEED-ND standard as an excellent foundation for its own standard and from lesson's learned in its formulation. The USGBC would benefit from the use of Commission-funded research that could be used to revise its LEED-ND standard to better reflect the actual energy-efficiency and emissions reduction performance and value of alternative energy technologies and development options.

[73] LEED for Neighborhood Development Rating System – Pilot Version, U.S. Green Building Council, February 2007

4.3 Recommendations

Research on the Potential of District Cooling in Chula Vista and the State of California

Chula Vista - As discussed in the Conclusions chapter, the results of the preliminary study indicate that implementing a district cooling system for the Site-A development is an economically attractive alternative to distributed cooling production at individual buildings for much of the development. Additionally, incorporation of district cooling into the Site-A development would bring benefits of convenience, reliability, reduced emissions and, potentially, lower electrical infrastructure requirements. Given the results of this preliminary evaluation, the recommended next step is a more detailed study that addresses:

1. Siting constraints relative to incorporation of TES and CHP;
2. Evaluation of the economic, energy and environmental benefits of:
    - Ice storage (if siting of chilled water TES may be problematic)
    - Low temperature supply water
    - Combined heat and power (CHP);
3. Assess the economic benefits of district cooling implementation to electric infrastructure requirements;
4. Assess the energy, environmental and economic benefits of district cooling relative to offset grid electricity based on the heat rate, emissions footprint and costs of power grid generation, transmission and distribution;
5. Full conceptual design for optimal district cooling configuration(s), including preliminary layout drawings and technical recommendations;
6. Pro-forma level financial analysis of optimal district cooling configuration(s).

State of California - Building on the Chula Vista study, the researchers recommend that a study be undertaken to assess the potential energy, environmental and economic benefits of district cooling in California. This state-wide study would assess the potential for district cooling to reduce:

- Energy consumption;
- Greenhouse gas emissions and other pollutants;
- Electric infrastructure requirements; and
- Economic costs of meeting future energy requirements.

The study would examine this potential in light of recent changes in energy facility capital costs and fuel costs, and in the context of GHG reduction and the associated market value of reductions. Future capital and fuel cost trajectories will be assessed for a variety of technologies including:

- Low-temperature electric centrifugal water chillers;
- Ice generation and storage;

- Chilled water storage;
- Natural-gas-fired combined heat and power (CHP);
- Natural-gas-fired chillers with absorption chillers driven with waste heat;
- Solar thermal energy driving absorption chillers; and
- Ocean-source and lake-source cooling.

Economic analysis would be addressed through a robust life-cycle cost (LCC) approach including capital, operating and maintenance costs as well as flexibility for variable energy costs of different fuels and GHG pricing. The economic analysis would be sensitive to different risks and uncertainties over the long term to weigh decisions on possible outcomes beyond that of a simple present value economic analysis. The GHG pricing would be included in the economic analysis to account for possible carbon compliance costs, offset market pricing (voluntary and pre-compliance markets) and the projected long term implications of proposed regulatory frameworks.

Sensitivity analyses will then be performed to evaluate the impacts on total LCC with variations in macro level cost factors: fossil fuel prices and carbon dioxide market value.

The researchers estimate the cost of such a study to be in the range of $850,000 to $1.25 million. The study would require approximately 24-months to complete.

<u>Research on Improved Modeling Tools for the Design of Low Carbon Communities</u>

Research is needed to better integrate site planning and urban design tools with building energy analysis tools so that public and private planners can more readily assess the energy and emissions impacts of alternative development scenarios for community-scale projects.

In the CVRP, researchers were able to create a data sharing protocol through which individual building energy consumption files were co-registered with site planning elements in a GIS-based planning tool to assess aggregate, site-wide energy and emissions impacts of alternative development scenarios. Although the effort was successful, it required a considerable amount of effort and required modeling individual buildings on a prototype basis. This approach had significant limitations and did not facilitate the rapid assessment of alternatives as any change to the building assumptions had to be reloaded into the GIS tool in order to conduct site-wide impact analysis of the alternatives under the new assumptions.

The researchers believe that the integration could and should be much tighter and enable applications to "talk" to each other dynamically. NREL's BEopt – Building Energy Optimizer and their Subdivision Energy Analysis Tool (SEAT) do move in this direction and should continue to be supported as these tools will be of great value to the development community.

Further, the researchers believe that it is in the best interest of California to create a suite of *open*, accessible, and interoperable tools capable of sharing data easily rather than to focus on the development of a single tool for community-scale energy analysis. With open data sharing standards such as eXtensible Markup Language (XML) it has become easier to pass data between applications. The researchers believe that a two- to three-year timeline would be necessary to examine all relevant standards and to develop a set of California guidelines, standards and tools that could be integrated to assist municipal planners and private development practitioners analyze the full range of energy and GHG impacts associated with alternative land use, infrastructure and building development options. This recommended research initiative would cost somewhere between $140,000 and $250,000 to complete.

With respect to VMT, 4D analysis provided all of the VMT reduction estimates and related GHG estimates in the CVRP. In the absence of specific data, the researchers had to make reasonable assumptions. With CommunityViz™, however, these assumptions were adjusted on the fly allowing the researchers test a range of assumptions based on real and hypothetical data. Nonetheless, the process of estimating VMT on a development-scale needs significant improvement.

Rising obesity, increasing congestion, and global climate change stem partly from dependence on the automobile, which in turn is linked to the way we envision and build communities. There is a significant need for tools to help transportation and land use planners understand and demonstrate, to both the public and policy makers, how design alternatives affect global climate change objectives as well as community livability. There are a number of factors that contribute to walkability, bikability, and transit ridership that the 4D analysis only begins to approximate:

- Public transit - Good public transit is important for walkable neighborhoods.
- Street width and block length - Narrow streets slow down traffic. Short blocks provide more routes to the same destination and make it easier to take a direct route.
- Street design - Sidewalks and safe crossings are essential to walkability. Appropriate automobile speeds, trees, and other features also help.
- Pedestrian-friendly community design - Are buildings close to the sidewalk with parking in the back? Are destinations clustered together?
- Freeways and bodies of water - Freeways can divide neighborhoods. While streams, lakes, and other bodies of water can make a walking environment much more enjoyable, they also can make it much more difficult to get to near-by “as the crow flies” destinations.

A follow-up study is recommended with SANDAG and municipalities such as Chula Vista that would help develop more indicators of VMT reductions and tighten assumptions behind the 4D analysis. A one- to two-year project with SANDAG, Chula Vista, and other transportation authorities in the region would allow the team to look closely at design and behavioral impacts on VMT at a site planning scale. These types of analyses would complement the much larger regional analyses and projections conducted by SANDAG. Implementing this recommendation would cost approximately $60,000 to $180,000 and require approximately 12-months.

Research on Use of Urban Heat Island (UHI) Effect Mitigation Strategies

UHI is a complicated phenomenon affected by multiple variables such as climate, wind patterns, density, impervious cover, and tree canopy. Most UHI modeling tools run through complex micro- and meso-climate simulations that have not yet scaled down to desktop applications. The process of predicting UHI in an un-built environment presents many more complications. In place of direct simulation of UHI, the team used the EPA's MIST tool to estimate relative changes in ambient temperature. The MIST tool is based on a parametric model derived from observed data. It is a good general guide, but does not pretend to be highly accurate.

In order to advance UHI analysis in California, the researchers believe there should be a focus on a diagnostic tool that identifies areas in a site plan that will contribute most to UHI. This tool would guide developer and planner decisions on tree plantings, high albedo coatings and pavements, and other interventions to promote cooling. Using expertise at the LBNL, the researchers believe that a one- to two-year project would suffice to develop and implement this type of diagnostic and decision support tool. Additionally, the researchers believe that follow on research on intervention methods and their relative effects on UHI could be used to develop baselines for more accurate estimates on impacts. All of this is in support of helping planners and developers make better decisions, even if the information is not perfect. As part of an increased study on UHI decision support tools, the team recommends a full look at the lifecycle costs of UHI interventions. This would include:

- The full production, maintenance, and replacement costs of concrete cement weighed against asphalt;
- A full assessment of maintenance and installation costs for cool roof technologies above minimum requirements;
- A full assessment energy savings of trees accounting for growth, maturation, and death of trees;
- Analysis of the effects of wear on surfaces

Implementing this recommendation would cost approximately $60,000 to $180,000.

Research on the Impact of EECD on State and Local Development Policies and CEQA

As the market and policy analysis sections of this report have suggested, significant research is necessary to address the priority barriers that currently prevent energy-efficient community development (EECD) in California. Additionally, research is necessary to translate solutions to these barriers into viable public policies, guidelines and development standards at the State, regional and local levels of government. Appendix-V of this report provides the specific areas of focus for the proposed market and public policy research that should be coordinated among academic and independent research organizations across the State of California. Individual budgets and timelines for completion will naturally vary among research focus areas covered and by research entity.

4.4 Benefits to California

The results of this research project, and those expected from the proposed research will produce benefits for California's electricity and natural gas rate payers by enabling public and private development practitioners to significantly contribute toward the improvement of community-scale energy efficiency, affordability and reliability. These contributions will also significantly decrease both local and global environmental impacts associated with end-use energy and resource consumption.

This report has provided specific quantification of the energy and emission reduction gains that can be achieved by even the most sophisticated/smart growth-oriented development projects. The proposed research would move beyond this work and chart a feasible pathway to even more substantial gains, potentially reducing aggregate energy consumption of large-scale, mixed-use, residential, commercial and institutional development sites (500-2,000+ acre) by as much as 50% and CO_2 emissions by 50% or more.

The advanced energy-efficient technologies and community design options modeled in this research can be viewed as key tools to assist California as it struggles with significant energy, environmental and economic challenges, including:

- Rising fuel and electricity prices;
- Inadequate generation, transmission and distribution capacity to meet increasing electricity demand;
- The imperative to reduce greenhouse gas (GHG) emissions; and
- The need to reduce other air pollution associated with meeting energy requirements.

With specific regard to CCHP and district cooling technologies and distribution systems, their use is growing significantly in other parts of the USA, and in Europe, Asia and the Middle East due to the significant benefits they provide community residents and utility rate payers. These same benefits are available to California rate payers and include their ability to reduce peak demand, improve environmental quality, increase building occupant comfort and to provide building owners and mangers increased convenience, flexibility and reliability at lower costs. Using district cooling as a specific example, these benefits are described further below.

<u>Reducing Peak Power Demand</u> - The benefits of district cooling relative to power demand and annual energy are especially important. District cooling reduces power demand by efficiently producing and delivering ready-to-use cooling to buildings, and by shifting power demand to night-time off-peak periods. The economies of scale achieved through district cooling allow Thermal Energy Storage (TES) to be deployed cost-effectively and efficiently. The ability to *peak shave* with TES can significantly reduce peak power requirements, thereby reducing the amount of electrical generation, transmission and distribution infrastructure required to meet peak cooling loads.

The ability of district cooling to facilitate TES is especially relevant in view of the California building energy standard, Title 24-2005. By incorporating consideration of time dependent valuation (TDV) into performance evaluation, Title-24 recognizes the significant energy (and thus environmental) benefits of demand reductions during peak demand periods.

Environmental Benefits - District cooling helps the environment by increasing energy efficiency and reducing environmental emissions including air pollution, the "greenhouse gas" carbon dioxide (CO2) and ozone-destroying refrigerants. The emissions footprint of the power grid is highly variable depending on the capacity mix being used to meet grid demand in any given hour in the year. This is especially relevant in view of the ability of district cooling to reduce power demand during on-peak times. Utilization of thermal storage, in particular, can provide substantial reductions in emissions of pollutants and greenhouse gases by shifting chilled water production to off-peak times when electricity is produced by cleaner and more efficient "base-load" production facilities, versus "peaking" facilities.

Comfort - District cooling helps keep people more comfortable because industrial grade equipment is used to provide a consistent source of cooling. In addition, specialist attention is focused on optimal operation and maintenance of cooling systems, providing better temperature and humidity control than typical building cooling equipment. This provides a healthier indoor environment as well as a quieter building with less vibration.

Convenience - District cooling is a far more convenient way to cool a building because cooling is always available in the pipeline, thus avoiding the need to start and stop building cooling units. From the building manager's standpoint, it is attractive to be able to provide reliable comfort without the worries of managing the equipment, labor and materials required for operating and maintaining chiller systems. This allows the manager to focus resources on more critical, bottom-line tasks, such as attracting and retaining tenants.

Flexibility - The pattern and timing of cooling requirements in a building vary depending on building use and weather. With building chiller systems, meeting air conditioning requirements at night or on weekends can be difficult and costly, particularly when the load is small. With district cooling, these needs can be met easily and cost-effectively whenever they occur. Each building can use as much or as little cooling as needed, whenever needed, without worrying about chiller size or capacity.

Reliability - The building manager has a critical interest in reliability because he/she wants to keep the occupants happy and wants to avoid dealing with problems relating to maintaining comfort. District cooling is more reliable than the conventional approach because these systems use highly reliable industrial equipment and can cost-effectively provide equipment redundancy. With professional operators round-the-clock, district cooling suppliers are specialists with expert operations and preventive maintenance programs. A survey conducted by the International District Energy Association (IDEA) shows that district cooling systems have a documented reliability exceeding 99.94%.

Cost Effectiveness - District cooling has fundamental cost advantages. For instance, not all buildings have their peak demand at the same time. This "diversity" means that when cooling loads are combined in the district cooling system, more buildings can be reliably served at lower cost. In addition, with district cooling, equipment can be operated at the most efficient levels, whereas with building cooling equipment the units operate for many hours each year at less than optimal levels. District cooling also offers economies of scale to implement more efficient and advanced technologies, such as TES, and to reliably serve many buildings with less manpower. For the real estate developer, district cooling systems reduce capital risk because no capital is tied up in the building for cooling equipment. Operating risks are also reduced, with more predictable costs. In a competitive real estate market, buildings that consistently provide superior comfort will attract and keep tenants, thereby maintaining a higher market value.

Again, most of the other energy technology and community design options modeled in this research project produce many of the same benefits. When considered at the initial stage of site design the optimal mix of these options can be determined and they can then be integrated in the planning process to ensure the best prospects for energy efficiency and emissions reductions on the site.

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Chapter 6. Glossary

Acronym	Definition
3-D	**Three dimensional visual representation of a design**
BAU	**Business-As-Usual, or a conventional approach to development**
BEA	**Building Energy Analyzer – proprietary tool of the Gas Technology Institute**
Btu	**British Thermal Unit**
BPB	**Builder's Proposed Baseline**
CBIA	**California Building Industry Association**
CCHP	**Combined Cooling Heat and Power technology**
CEC	**California Energy Commission**
CPUC	**California Public Utility Commission**
CARB	**California Air Resources Board**
CO_2	**Carbon Dioxide**
CSI	**California Solar Initiative**
CVRP	**Chula Vista Research Project**
DG	**Distributed Generation technologies**
DR	**Demand Response**
EE	**Energy Efficiency**
EE-PB	**Energy-Efficiency and Photovoltaic technology option**
EE-DG	**Energy-Efficiency and Distributed Generation technology option**
ET&CD	**Energy Technology and Community Design options**
ETS	**Energy Transfer Stations**
GHG	**Greenhouse Gas emissions**
GTI	**Gas Technology Institute**
HVAC	**Heating, Ventilation and Air Conditioning equipment**
IC	**Internal Combustion Engine**
kWh	**Kilowatt hours**
LEED	**Leadership in Energy and Environmental Design**
MIST	**Mitigation Impact Screening Tool**
NOx	**Nitrogen Oxides**
PAC	**Project Advisory Committee**
RE	**Renewable Energy**
ROI	**Return-On-Investment**

TTP	**Transit Priority Projects**
SANDAG	**San Diego Association of Governments**
SBIC	**Sustainable Building Industry Council**
SDG&E	**San Diego Gas and Electric**
SDSU	**San Diego State University**
SOx	**Sulfur Oxide**
SPA	**Specific Planning Area Plan**
SPV	**Solar Photovoltaic**
STH	**Solar Thermal**
T-24	**California's Title-24 building energy efficiency standard, 2005**
TBD	**To-Be-Determined**
TDV	**Time Dependent Valuation**
TDVI	**Time Dependent Valuation Inclusive**
TES	**Thermal Energy Storage**
UCC-1	**Uniform Commercial Code**
UFORE	**Urban Forest Effects model**
UHI	**Urban Heat Island effect**
USDOE	**US Department of Energy**
USEPA	**US Environmental Protection Agency**
USDA	**US Department of Agriculture**
VMT	**Vehicle Miles Traveled**
ZNE	**Zero Net Energy**

Appendices

A. Site-A: Technical Modeling Assumptions and Results

B. Site-B: Technical Modeling Assumptions Manual and Results

C. SDG&E Gas System Plan w/o Site-A & B Loads / Baseline Piping

D. SDG&E Gas System Plan w Site-A & B EE-Loads / Baseline Piping

E. SDG&E Gas System Plan w Site-A & B EE-Loads / Optimized Piping

F. SDG&E Gas System Plan w Site-A & B EE-DG Loads / Optimized Piping

G. SDG&E Gas System Plan w Site-A & -B Loads /Optimized w/Regulator

H. Site-A: Baseline & Optimum Scenarios -- Prototype Building Data

I. Site-A: Load Profiles and TES Analysis - “Builder Baseline” Scenario

J. Site-A: Load Profiles and TES Analysis - “Optimum Configuration” Scenario

K. Site-A: Distribution Piping System Layout

L. Distribution Piping System Capital Costs

M. Chiller Selections Performance Data

N. Electric Rate Tariff Information

O. District Cooling Plant Annual Electric Cost Calculations

P. Site-A: Spatial Modeling Inputs, Outputs & Assumptions

Q. Site-X: Spatial Modeling Inputs, Outputs & Assumptions

R. Curve numbers for land use and soil types

S. Coefficients by Rainfall Type

T. Soil Types

U. Chula Vista Research Project Advisory Committee

V. Stakeholder Input on Barriers and Solutions

Appendix A.

Site-A: Technical Modeling Assumptions and Results

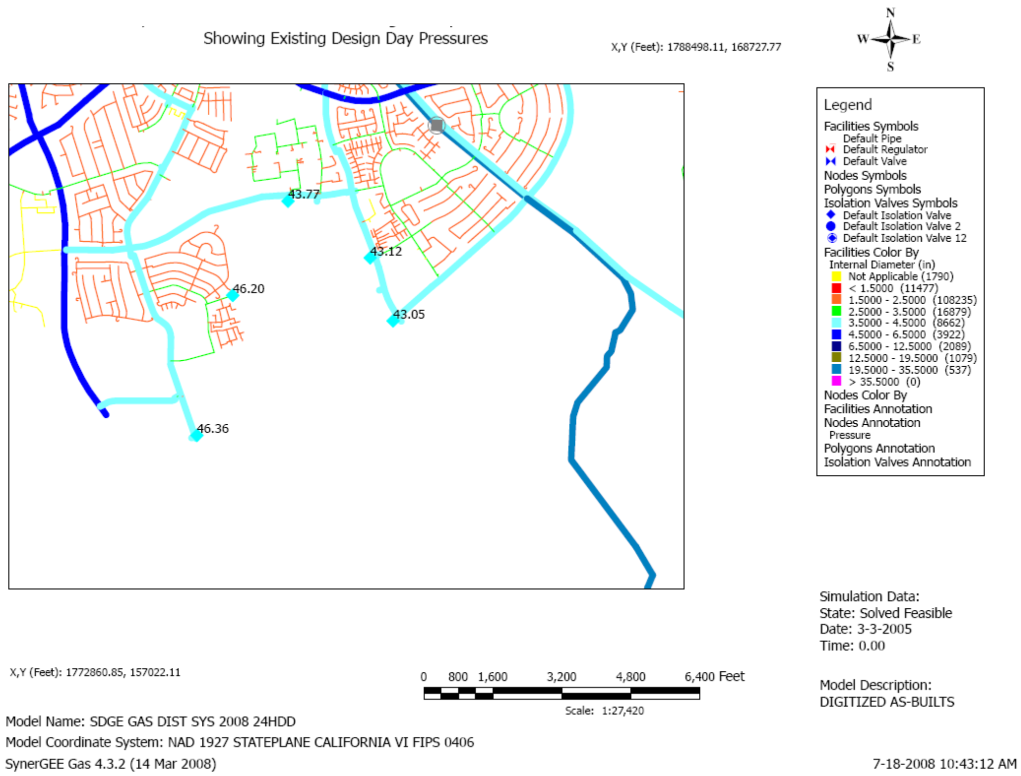
See Separate PDF Document

Appendix B.

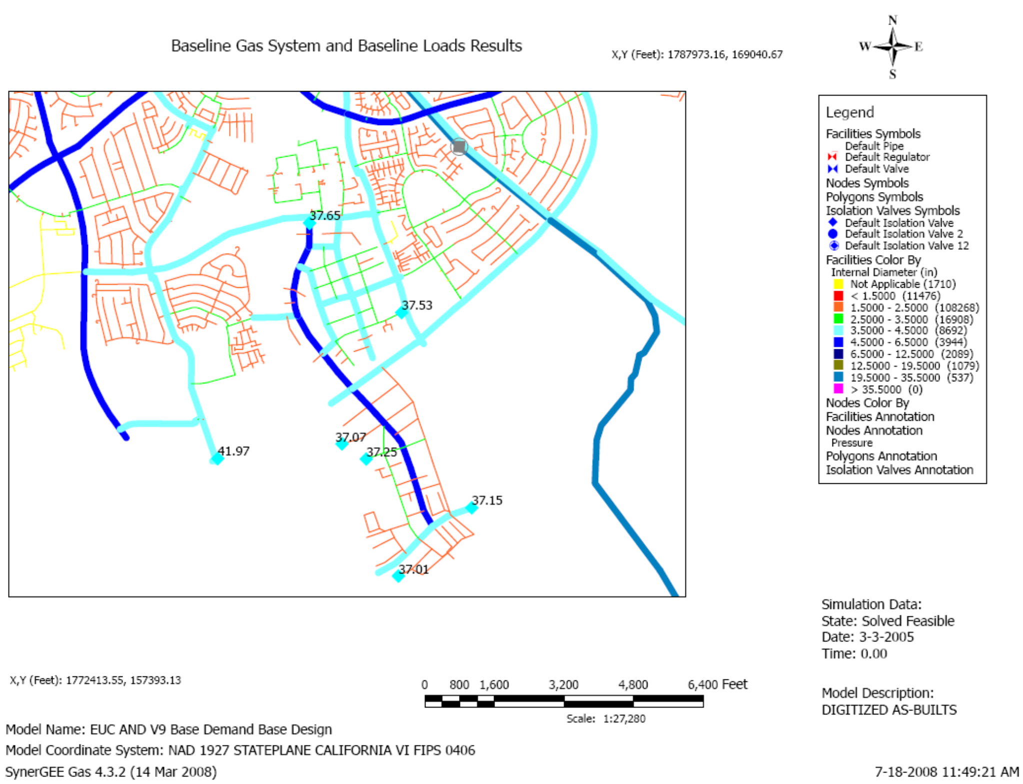
Site-B: Technical Modeling Assumptions and Results

See Separate PDF Document

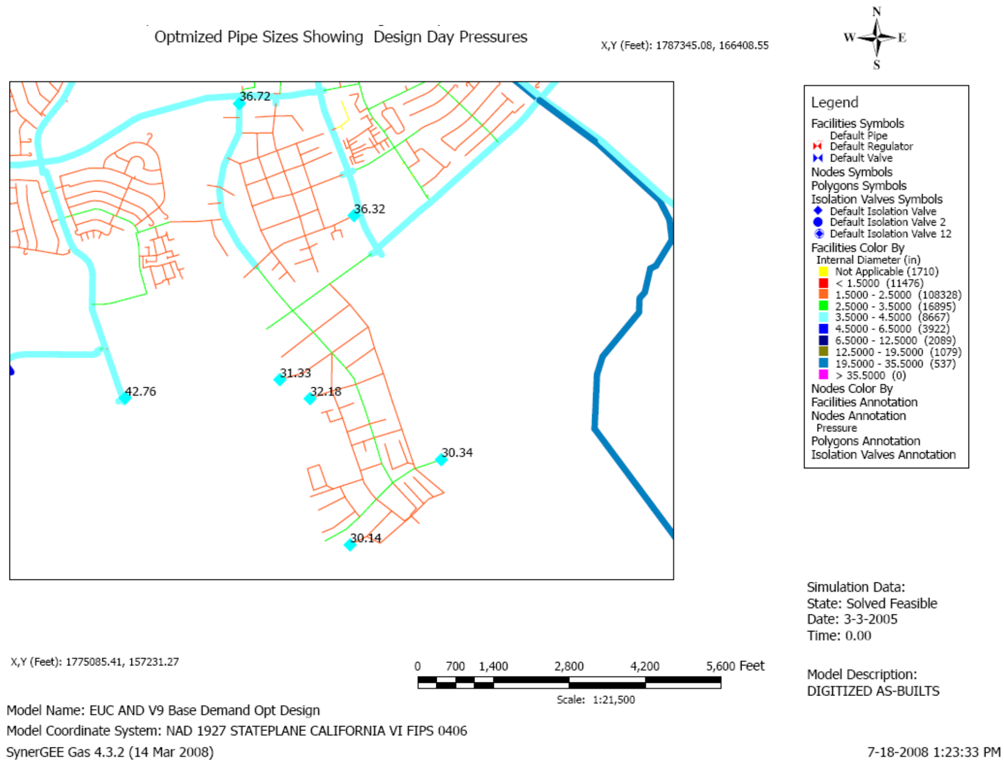
Appendix C. SDG&E Gas System Plan w/o Site-A & -B Loads / Baseline Piping



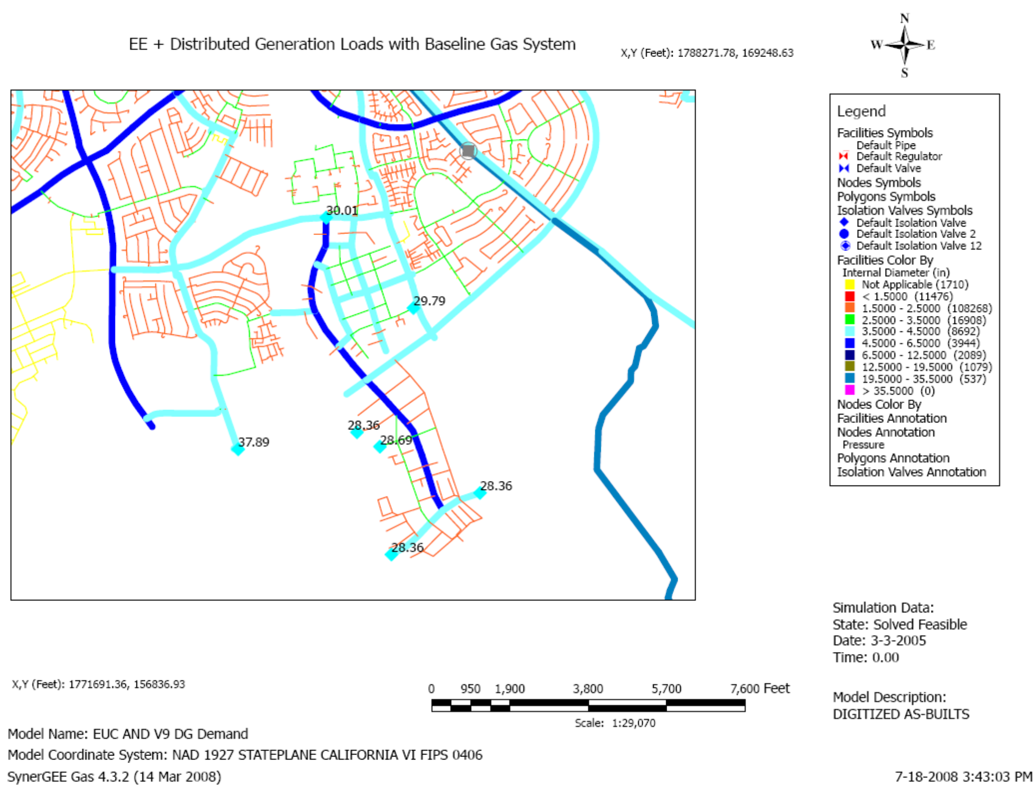
Appendix D. SDG&E Gas System Plan w Site-A & -B EE-Loads / Baseline Piping



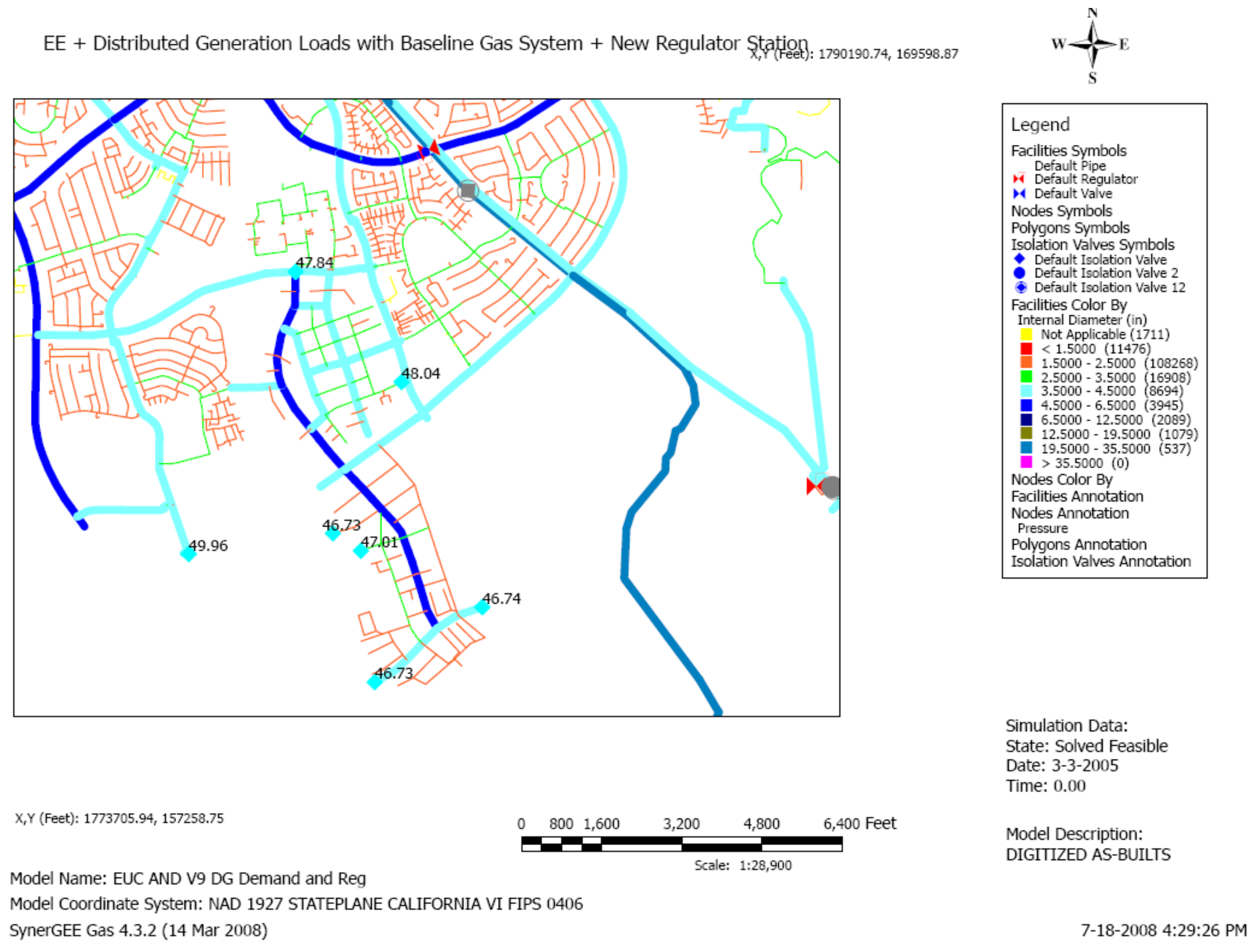
Appendix E. SDG&E Gas System Plan w Site-A & -B EE-Loads / Optimized Piping



Appendix F. SDG&E Gas System Plan w Site-A & -B EE-DG Loads / Optimized Piping



Appendix G. SDG&E Gas System Plan w Site-A & -B Loads /Optimized w/Regulator



Appendix H. Prototype Building Data

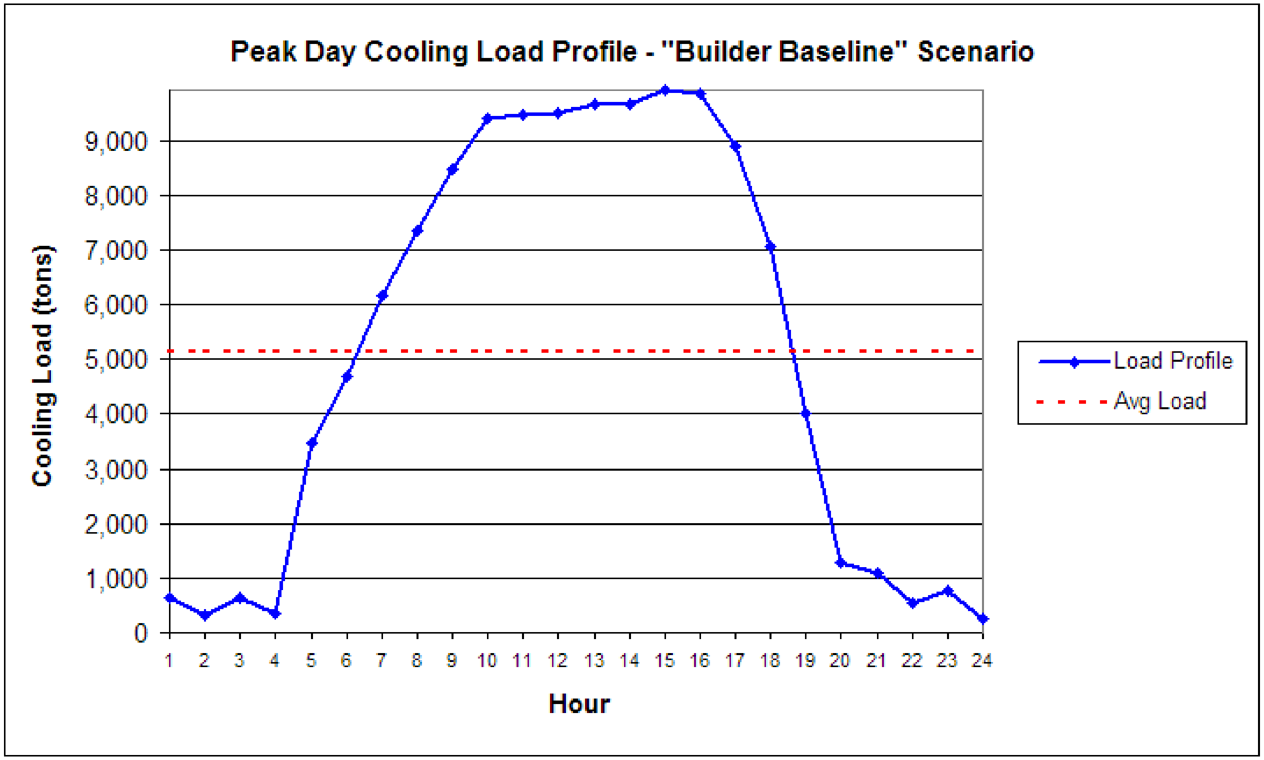
Site-A: Builder Baseline Scenario -- Prototype Building Data

Bldg Proto-type ID	Building Prototype Description	Building Prototype Cooling System (Stand-alone Cooling Production)	# of Bldgs	Square Feet per Building	Total Square Feet	Peak Cooling Load Per Building (tons)	Total Peak Cooling Load (tons)	Cooling Load Density (SF/ton)	Annual Cooling Consump-tion Per Building (ton-hrs)	Total Annual Cooling Consump-tion (ton-hrs)	Total Annual space cooling related electric consumption including heat rejection (kWh)	Average unit electric cost for building ($/kWh)	Est. Total Annual cost of space cooling related electric consumption including heat rejection	Annual space cooling related electric consumption including heat rejection (kWh/ton-hr)
1	Free Standing Restuarant	Unitary Packaged AC	4	7,396	29,584	31.7	127	233.4	39,430	157,718	139,770	$0.147	$20,482	0.89
2	Multi Tenant Retail	Individual Split System Heat Pumps	1	19,656	19,656	74.2	74	265.0	57,862	57,862	70,124	$0.175	$12,255	1.21
3	Major Retailer	Central Chiller, Positive Disp.	3	32,400	97,200	92.8	278	349.3	150,495	451,484	546,678	$0.152	$83,250	1.21
4	Low Rise Office	Individual Split System Heat Pumps	4	29,920	119,680	74.3	297	402.7	87,267	349,067	282,741	$0.174	$49,146	0.81
5	Mid Rise Office	Central Chiller, Positive Disp.	7	99,880	699,160	228.5	1,600	437.1	295,339	2,067,375	2,289,281	$0.175	$400,978	1.11
6	High Rise Office	Central Chiller, Centrifugal	7	224,640	1,572,480	521.5	3,650	430.8	816,947	5,718,626	4,152,479	$0.169	$703,123	0.73
7	Hotel	Central Chiller, Centrifugal	1	121,662	121,662	198.5	199	612.8	331,326	331,326	278,109	$0.139	$38,644	0.84
8	Hotel/Comm/Retail	Central Chiller, Centrifugal	3	152,031	456,092	372.2	1,117	408.5	546,913	1,640,739	1,380,381	$0.153	$210,671	0.84
9	Retail/Commercial	Individual Split System Heat Pumps	3	101,088	303,264	262.8	788	384.7	359,630	1,078,889	1,043,761	$0.176	$183,663	0.97
10	Retail/Residential	Central Chiller, Centrifugal	2	137,035	274,070	157.2	314	871.8	293,947	587,894	473,697	$0.212	$100,459	0.81
11	Retail/Residentail	Individual Split System Heat Pumps	8	77,713	621,701	125.8	1,006	617.9	208,631	1,669,045	1,291,554	$0.195	$252,207	0.77
12	Civic/Commercial	Central Chiller, Positive Disp.	1	133,000	133,000	322.5	322	412.4	412,769	412,769	468,606	$0.176	$82,250	1.14
13	Res Multi Family Town Home	Individual Split System Heat Pumps	123	9,800	1,205,350	6.0	734	1643.1	4,550	559,644	571,040	$0.231	$131,760	1.02
14	Residential Low Rise	Individual Split System Heat Pumps	11	62,498	687,477	32.4	357	1927.3	52,684	579,528	577,207	$0.244	$140,681	1.00
15	Residential Mid Rise	Central Chiller, Centrifugal	2	130,171	260,342	71.7	143	1814.3	145,710	291,420	273,281	$0.244	$66,740	0.94
TOTALS / AVERAGES For "All bldgs"			180		6,600,719		11,006	599.7		15,953,387	13,838,708	$0.179	$2,476,308	0.87
TOTALS / AVERAGES For "All bldgs less Types 13 & 14"			46		4,707,891		9,916	474.8		14,814,215	12,690,461	$0.174	$2,203,867	0.86

Site-A: Optimum (EE-PV) Scenario -- Prototype Building Data

Bldg Proto-type ID	Building Prototype Description	Building Prototype Cooling System (Stand-alone Cooling Production)	# of Bldgs	Square Feet per Building	Total Square Feet	Peak Cooling Load Per Building (tons)	Total Peak Cooling Load (tons)	Cooling Load Density (SF/ton)	Annual Cooling Consump-tion Per Building (ton-hrs)	Total Annual Cooling Consump-tion (ton-hrs)	Total Annual space cooling related electric consumption including heat rejection (kWh)	Average unit electric cost for building ($/kWh)	Est. Total Annual cost of space cooling related electric consumption including heat rejection	Annual space cooling related electric consumption including heat rejection (kWh/ton-hr)
1	Free Standing Restuarant	Unitary Packaged AC	4	7,396	29,584	29.9	120	247.2	39,736	158,942	97,408	$0.152	$14,766	0.61
2	Multi Tenant Retail	Individual Split System Heat Pumps	1	19,656	19,656	44.0	44	447.2	53,543	53,543	37,738	$0.265	$9,993	0.70
3	Major Retailer	Central Chiller, Positive Disp.	3	32,400	97,200	84.7	254	382.4	151,275	453,826	386,613	$0.182	$70,524	0.85
4	Low Rise Office	Individual Split System Heat Pumps	4	29,920	119,680	59.0	236	506.7	73,723	294,890	187,710	$0.208	$39,017	0.64
5	Mid Rise Office	Central Chiller, Positive Disp.	7	99,880	699,160	192.6	1,348	518.6	249,684	1,747,789	1,548,435	$0.178	$276,198	0.89
6	High Rise Office	Central Chiller, Centrifugal	7	224,640	1,572,480	449.1	3,143	500.2	699,576	4,897,029	2,904,563	$0.168	$488,673	0.59
7	Hotel	Central Chiller, Centrifugal	1	121,662	121,662	197.3	197	616.7	315,726	315,726	219,049	$0.140	$30,704	0.69
8	Hotel/Comm/Retail	Central Chiller, Centrifugal	3	152,031	456,092	323.0	969	470.7	450,330	1,350,990	937,163	$0.151	$141,112	0.69
9	Retail/Commercial	Individual Split System Heat Pumps	3	101,088	303,264	209.8	630	481.7	272,825	818,475	659,648	$0.177	$116,842	0.81
10	Retail/Residential	Central Chiller, Centrifugal	2	137,035	274,070	132.3	265	1035.6	224,108	448,217	314,441	$0.237	$74,583	0.70
11	Retail/Residentail	Individual Split System Heat Pumps	8	77,713	621,701	101.1	808	769.0	144,679	1,157,434	775,069	$0.210	$162,580	0.67
12	Civic/Commercial	Central Chiller, Positive Disp.	1	133,000	133,000	270.6	271	491.6	340,078	340,078	306,963	$0.176	$53,974	0.90
13	Res Multi Family Town Home	Individual Split System Heat Pumps	123	9,800	1,205,350	5.0	610	1976.6	3,705	455,688	386,037	$0.194	$74,822	0.85
14	Residential Low Rise	Individual Split System Heat Pumps	11	62,498	687,477	29.3	323	2130.5	48,937	538,304	445,682	$0.241	$107,333	0.83
15	Residential Mid Rise	Central Chiller, Centrifugal	2	130,171	260,342	61.6	123	2111.7	134,399	268,799	209,311	$0.243	$50,892	0.78
TOTALS / AVERAGES			180		6,600,719		9,341	706.7		13,299,730	9,415,830	$0.182	$1,712,012	0.71
TOTALS / AVGS FOR "All bldgs less Types 13 & 14"			46		4,707,891		8,408	559.9		12,305,738	8,584,112	$0.178	$1,529,857	0.70

Appendix I. Site-A: Load Profiles and TES Analysis - “Builder Baseline” Scenario



Hour	Thermal Storage Charge (ton-hrs)	Thermal Storage Discharge (ton-hrs)	Compression (ton-hrs)	
1	4,506		5,146	Off-peak
2	4,829		5,146	
3	4,491		5,146	
4	4,795		5,146	
5	1,690		5,146	
6	471		5,146	
7		1,026	5,146	Semi-peak
8		2,207	5,146	
9		3,341	5,146	
10		4,247	5,146	
11		4,314	5,146	
12		4,350	5,146	On-peak
13		4,523	5,146	
14		4,506	5,146	
15		4,777	5,146	
16		4,710	5,146	
17		3,757	5,146	
18		1,924	5,146	
19	1,124		5,146	Semi-peak
20	3,873		5,146	
21	4,044		5,146	
22	4,604		5,146	
23	4,372		5,146	Off
24	4,885		5,146	

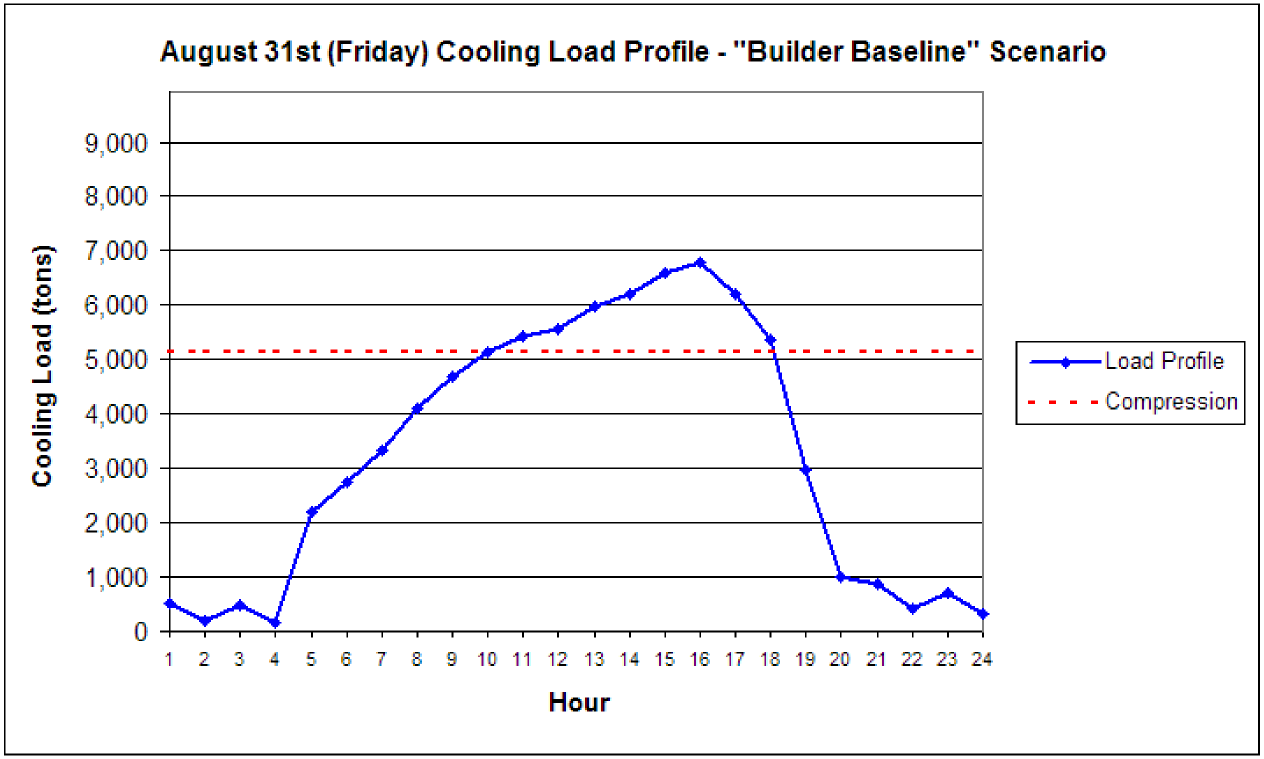
Thermal Storage Charge/Discharge

43,684 Thermal storage charging, ton-hrs

43,684 Thermal storage discharging, ton-hrs

Ton-hrs at On-peak utility rate, % of total	29%
Ton-hrs at Semi-peak utility rate, % of total	38%
Ton-hrs at Off-peak utility rate, % of total	33%

Appendix I. Site-A: Load Profiles and TES Analysis - “Builder Baseline” Scenario / August 31st

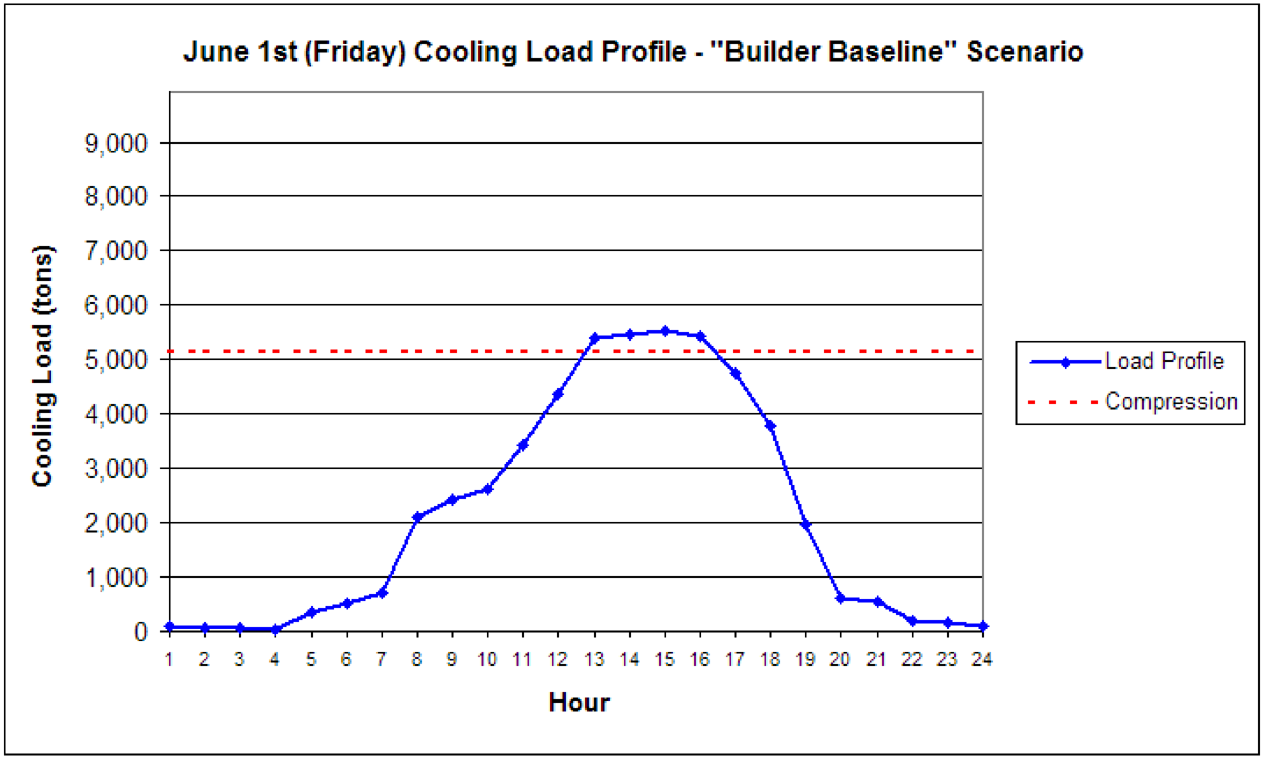


Hour	Thermal Storage Charge (ton-hrs)	Thermal Storage Discharge (ton-hrs)	Compression (ton-hrs)	
1	4,634		5,146	Off-peak
2	4,952		5,146	
3	4,652		5,146	
4	4,986		5,146	
5	2,946		5,146	
6	2,410		5,146	
7	1,801		5,146	Semi-peak
8	1,041		5,146	
9	467		5,146	
10	14		5,146	
11		294	5,146	
12		5,566	0	On-peak
13		5,964	0	
14		6,205	0	
15		6,582	0	
16		6,782	0	
17		6,217	0	
18		5,352	0	
19		723	2,260	Semi-peak
20	1,200		2,210	
21	2,000		2,861	
22	3,333		3,761	
23	4,421		5,146	Off
24	4,828		5,146	

Thermal Storage Charge/Discharge
43,684 Thermal storage charging, ton-hrs
43,684 Thermal storage discharging, ton-hrs

Ton-hrs at On-peak utility rate, % of total 0%
Ton-hrs at Semi-peak utility rate, % of total 47%
Ton-hrs at Off-peak utility rate, % of total 53%

Appendix I. Site-A: Load Profiles and TES Analysis - "Builder Baseline" Scenario / June 1st

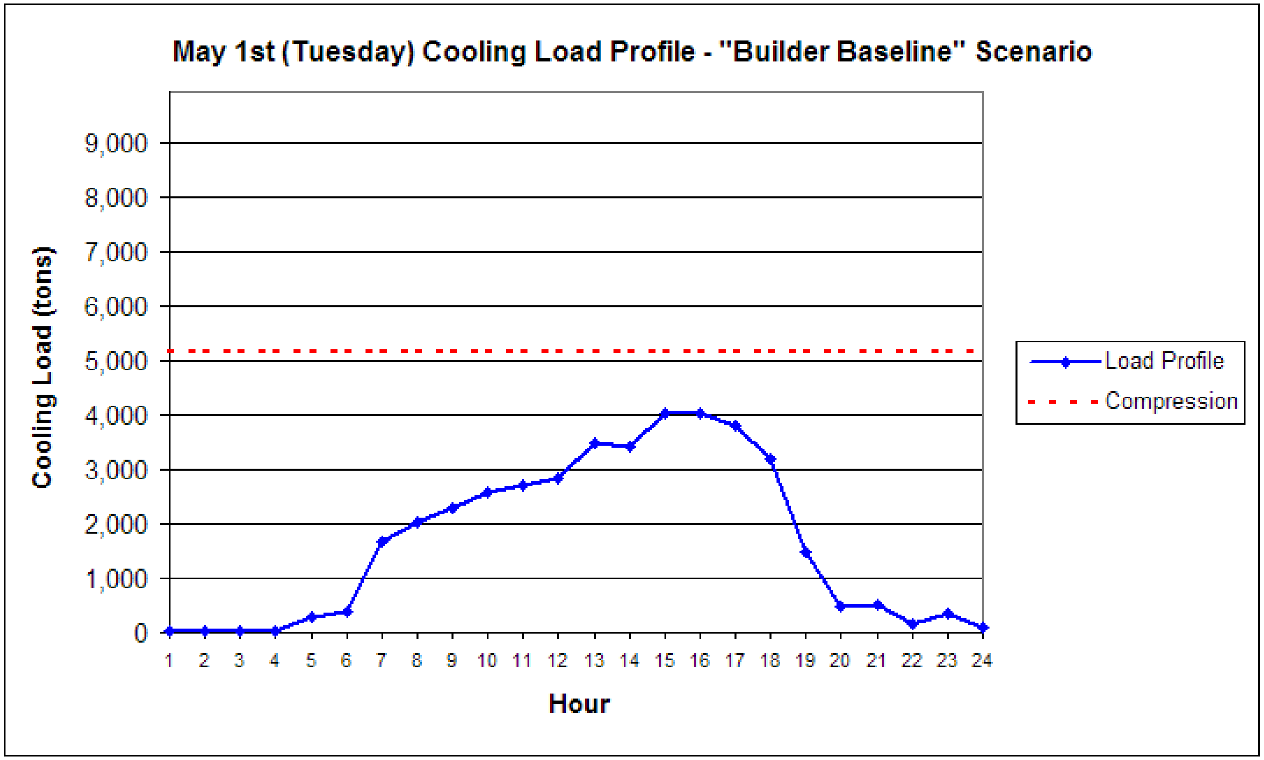


Hour	Thermal Storage Charge (ton-hrs)	Thermal Storage Discharge (ton-hrs)	Compression (ton-hrs)	
1	5,055		5,146	Off-peak
2	5,066		5,146	Off-peak
3	5,079		5,146	Off-peak
4	5,111		5,146	Off-peak
5	4,778		5,146	Off-peak
6	4,637		5,146	Off-peak
7	2,420		3,125	Semi-peak
8			2,087	Semi-peak
9		1,007	1,421	Semi-peak
10		2,622	0	Semi-peak
11		3,418	0	Semi-peak
12		4,351	0	On-peak
13		5,388	0	On-peak
14		5,464	0	On-peak
15		5,512	0	On-peak
16		5,426	0	On-peak
17		4,745	0	On-peak
18		3,785	0	On-peak
19		1,965	0	Semi-peak
20			615	Semi-peak
21	500		1,050	Semi-peak
22	1,000		1,207	Semi-peak
23	4,998		5,146	Off
24	5,040		5,146	Off

Thermal Storage Charge/Discharge
43,684 Thermal storage charging, ton-hrs
43,684 Thermal storage discharging, ton-hrs

Ton-hrs at On-peak utility rate, % of total 0%
Ton-hrs at Semi-peak utility rate, % of total 19%
Ton-hrs at Off-peak utility rate, % of total 81%

Appendix I. Site-A: Load Profiles and TES Analysis - "Builder Baseline" Scenario / May 1st

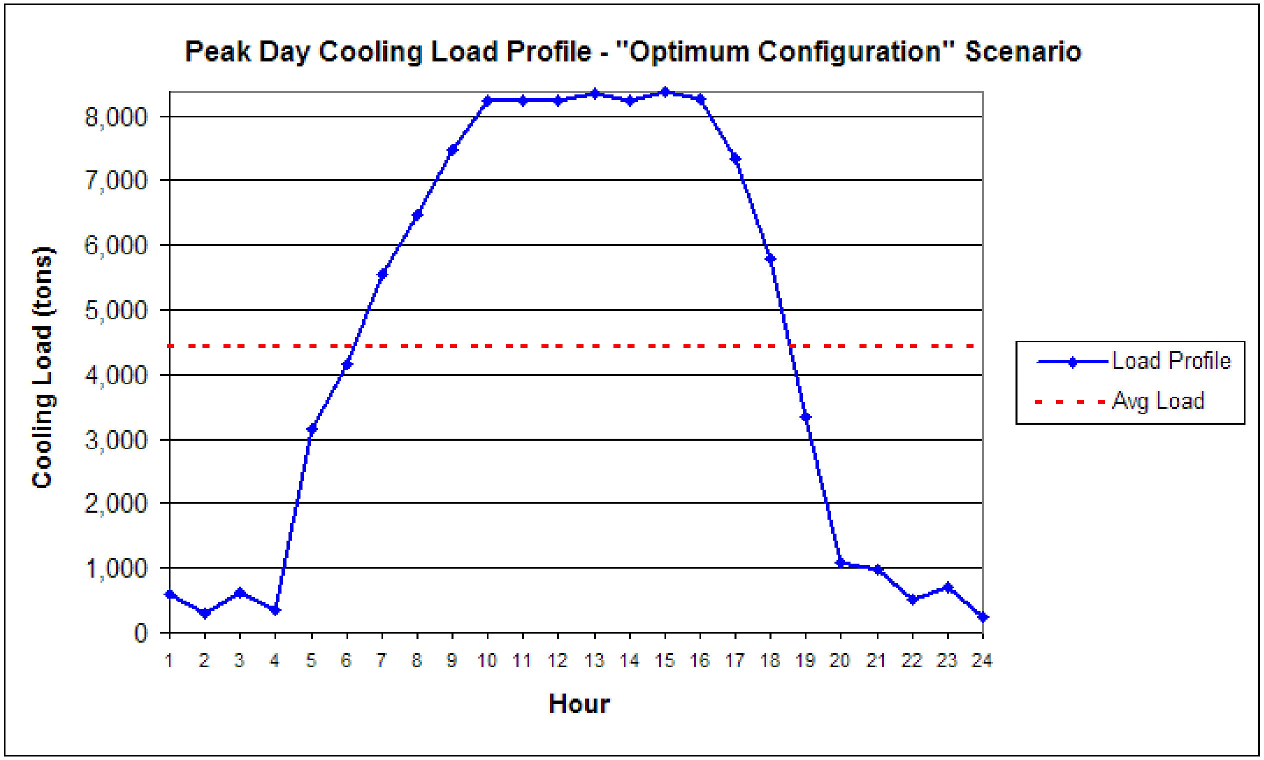


Hour	Thermal Storage Charge (ton-hrs)	Thermal Storage Discharge (ton-hrs)	Compression (ton-hrs)	
1	5,107		5,146	Off-peak
2	5,114		5,146	
3	5,121		5,146	
4	5,123		5,146	
5	4,855		5,146	
6	4,775		5,146	
7		1,669	0	Semi-peak
8		2,029	0	
9		2,273	0	
10		2,562	0	
11		2,691	0	
12		2,833	0	On-peak
13		3,473	0	
14		3,429	0	
15		4,027	0	
16		4,027	0	
17		3,800	0	
18		3,190	0	
19		1,473	0	Semi-peak
20		491	0	
21		522	0	
22		171	0	
23	3,511		3,853	Off
24	5,055		5,146	

Thermal Storage Charge/Discharge
38,660 Thermal storage charging, ton-hrs
38,660 Thermal storage discharging, ton-hrs

Ton-hrs at On-peak utility rate, % of total 0%
Ton-hrs at Semi-peak utility rate, % of total 0%
Ton-hrs at Off-peak utility rate, % of total 100%

Appendix J. Site-A: Load Profiles and TES Analysis for “Optimum Configuration” Scenario



Hour	Thermal Storage Charge (ton-hrs)	Thermal Storage Discharge (ton-hrs)	Compression (ton-hrs)	
1	3,852		4,440	Off-peak
2	4,132		4,440	
3	3,825		4,440	
4	4,094		4,440	
5	1,285		4,440	
6	272		4,440	
7		1,112	4,440	Semi-peak
8		2,035	4,440	
9		3,032	4,440	
10		3,782	4,440	
11		3,781	4,440	
12		3,796	4,440	On-peak
13		3,891	4,440	
14		3,787	4,440	
15		3,927	4,440	
16		3,814	4,440	
17		2,902	4,440	
18		1,351	4,440	
19	1,100		4,440	Semi-peak
20	3,341		4,440	
21	3,453		4,440	
22	3,924		4,440	
23	3,736		4,440	Off
24	4,196		4,440	

Thermal Storage Charge/Discharge

37,210 Thermal storage charging, ton-hrs

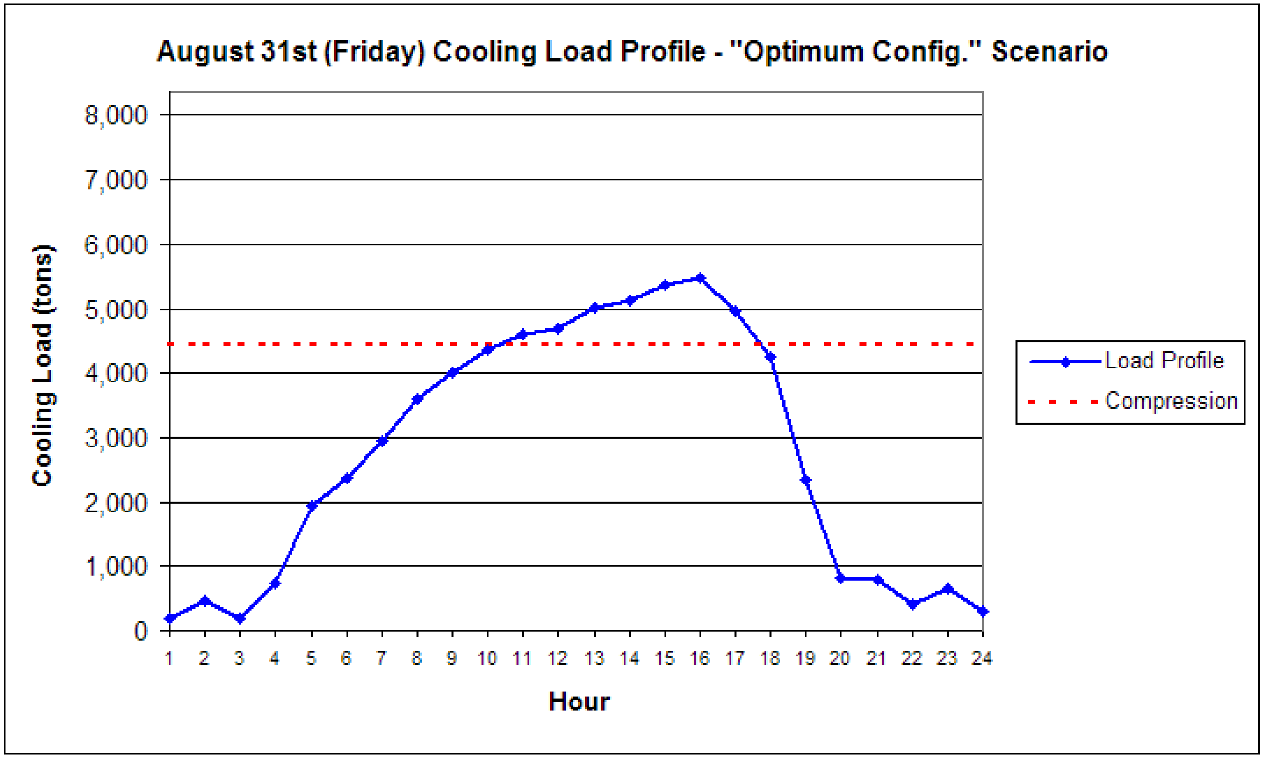
37,210 Thermal storage discharging, ton-hrs

Ton-hrs at On-peak utility rate, % of total 29%

Ton-hrs at Semi-peak utility rate, % of total 38%

Ton-hrs at Off-peak utility rate, % of total 33%

Appendix J. Site-A: Load Profiles and TES Analysis for "Optimum Configuration" Scenario / August 31st



Hour	Thermal Storage Charge (ton-hrs)	Thermal Storage Discharge (ton-hrs)	Compression (ton-hrs)	
1	4,247		4,440	Off-peak
2	3,977		4,440	Off-peak
3	4,245		4,440	Off-peak
4	3,712		4,440	Off-peak
5	2,492		4,440	Off-peak
6	2,065		4,440	Off-peak
7	1,493		4,440	Semi-peak
8	853		4,440	Semi-peak
9	420		4,440	Semi-peak
10	67		4,440	Semi-peak
11		1,000	3,608	Semi-peak
12		4,690	0	On-peak
13		5,004	0	On-peak
14		5,134	0	On-peak
15		5,373	0	On-peak
16		5,482	0	On-peak
17		4,956	0	On-peak
18		4,240	0	On-peak
19		1,330	1,021	Semi-peak
20	1,200		2,024	Semi-peak
21	2,000		2,779	Semi-peak
22	2,517		2,922	Semi-peak
23	3,786		4,440	Off
24	4,137		4,440	Off

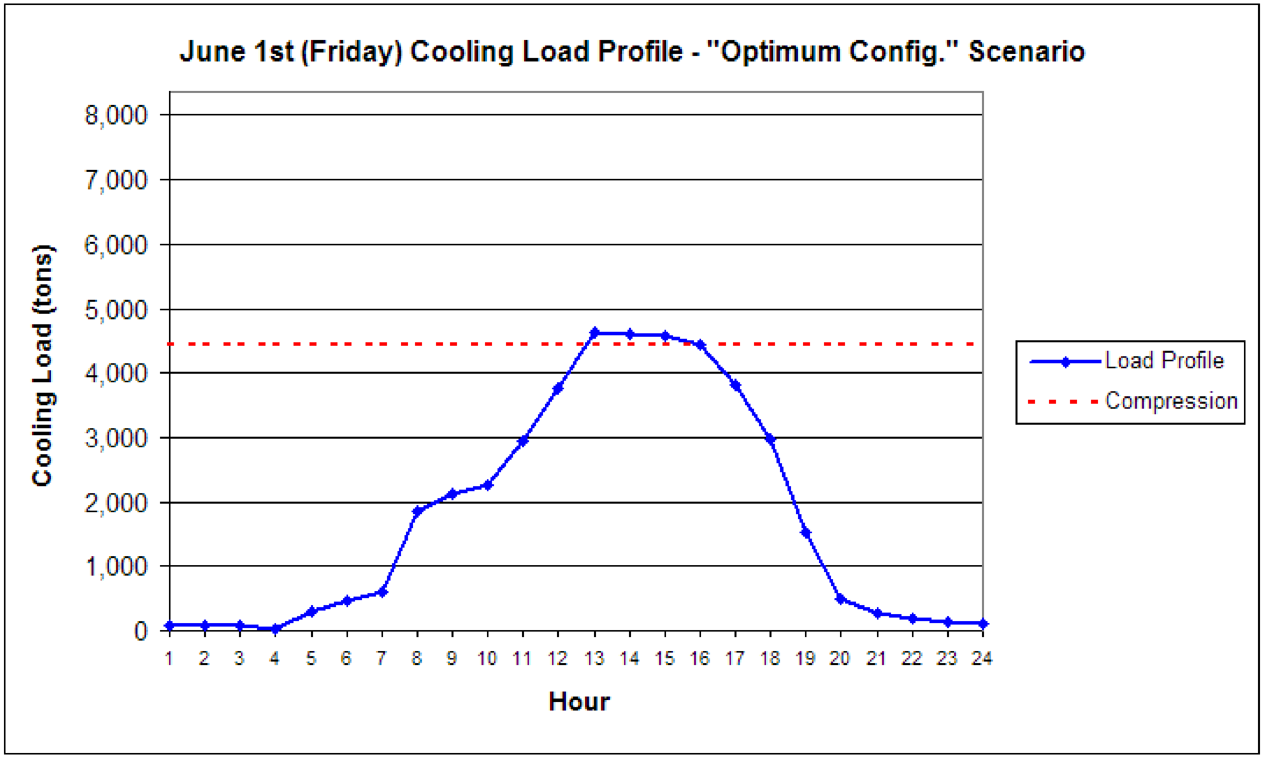
Thermal Storage Charge/Discharge

37,210 Thermal storage charging, ton-hrs

37,210 Thermal storage discharging, ton-hrs

Ton-hrs at On-peak utility rate, % of total	0%
Ton-hrs at Semi-peak utility rate, % of total	46%
Ton-hrs at Off-peak utility rate, % of total	54%

Appendix J. Site-A: Load Profiles and TES Analysis for “Optimum Configuration” Scenario / June 1st

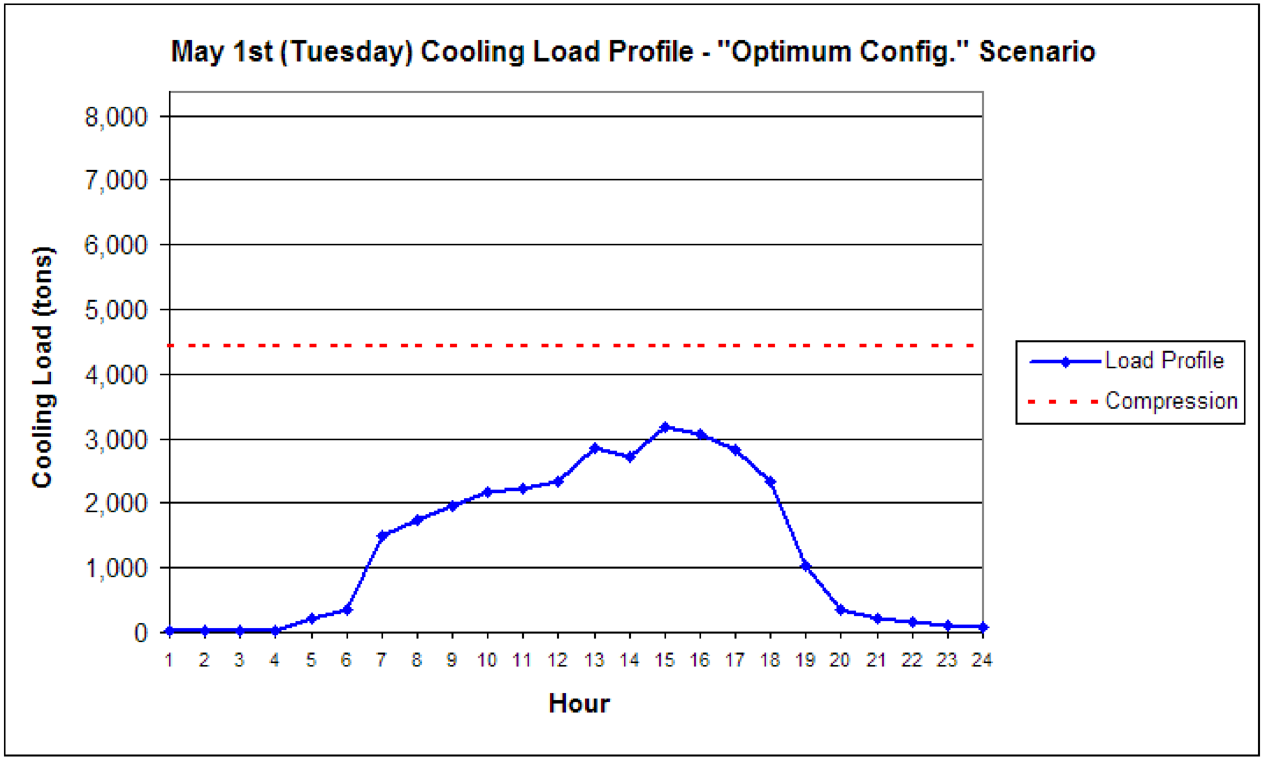


Hour	Thermal Storage Charge (ton-hrs)	Thermal Storage Discharge (ton-hrs)	Compression (ton-hrs)	
1	4,352		4,440	Off-peak
2	4,361		4,440	Off-peak
3	4,366		4,440	Off-peak
4	4,402		4,440	Off-peak
5	4,130		4,440	Off-peak
6	3,974		4,440	Off-peak
7	1,484		2,079	Semi-peak
8			1,847	Semi-peak
9		1,640	486	Semi-peak
10		2,251	0	Semi-peak
11		2,950	0	Semi-peak
12		3,759	0	On-peak
13		4,634	0	On-peak
14		4,619	0	On-peak
15		4,579	0	On-peak
16		4,449	0	On-peak
17		3,808	0	On-peak
18		2,984	0	On-peak
19		1,537	0	Semi-peak
20			496	Semi-peak
21	500		784	Semi-peak
22	1,000		1,191	Semi-peak
23	4,303		4,440	Off
24	4,340		4,440	Off

Thermal Storage Charge/Discharge
37,210 Thermal storage charging, ton-hrs
37,210 Thermal storage discharging, ton-hrs

Ton-hrs at On-peak utility rate, % of total 0%
Ton-hrs at Semi-peak utility rate, % of total 16%
Ton-hrs at Off-peak utility rate, % of total 84%

Appendix J. Site-A: Load Profiles and TES Analysis for "Optimum Configuration" Scenario / May 1st



Hour	Thermal Storage Charge (ton-hrs)	Thermal Storage Discharge (ton-hrs)	Compression (ton-hrs)	
1	4,403		4,440	Off-peak
2	4,411		4,440	
3	4,418		4,440	
4	4,418		4,440	
5	4,218		4,440	
6	4,080		4,440	
7		1,501	0	Semi-peak
8		1,730	0	
9		1,956	0	
10		2,167	0	
11		2,232	0	
12		2,338	0	On-peak
13		2,861	0	
14		2,723	0	
15		3,175	0	
16		3,078	0	
17		2,824	0	
18		2,347	0	
19		1,043	0	Semi-peak
20		366	0	
21		231	0	
22		156	0	
23	1,780		1,887	Off
24	3,000		3,087	

Thermal Storage Charge/Discharge

30,727 Thermal storage charging, ton-hrs

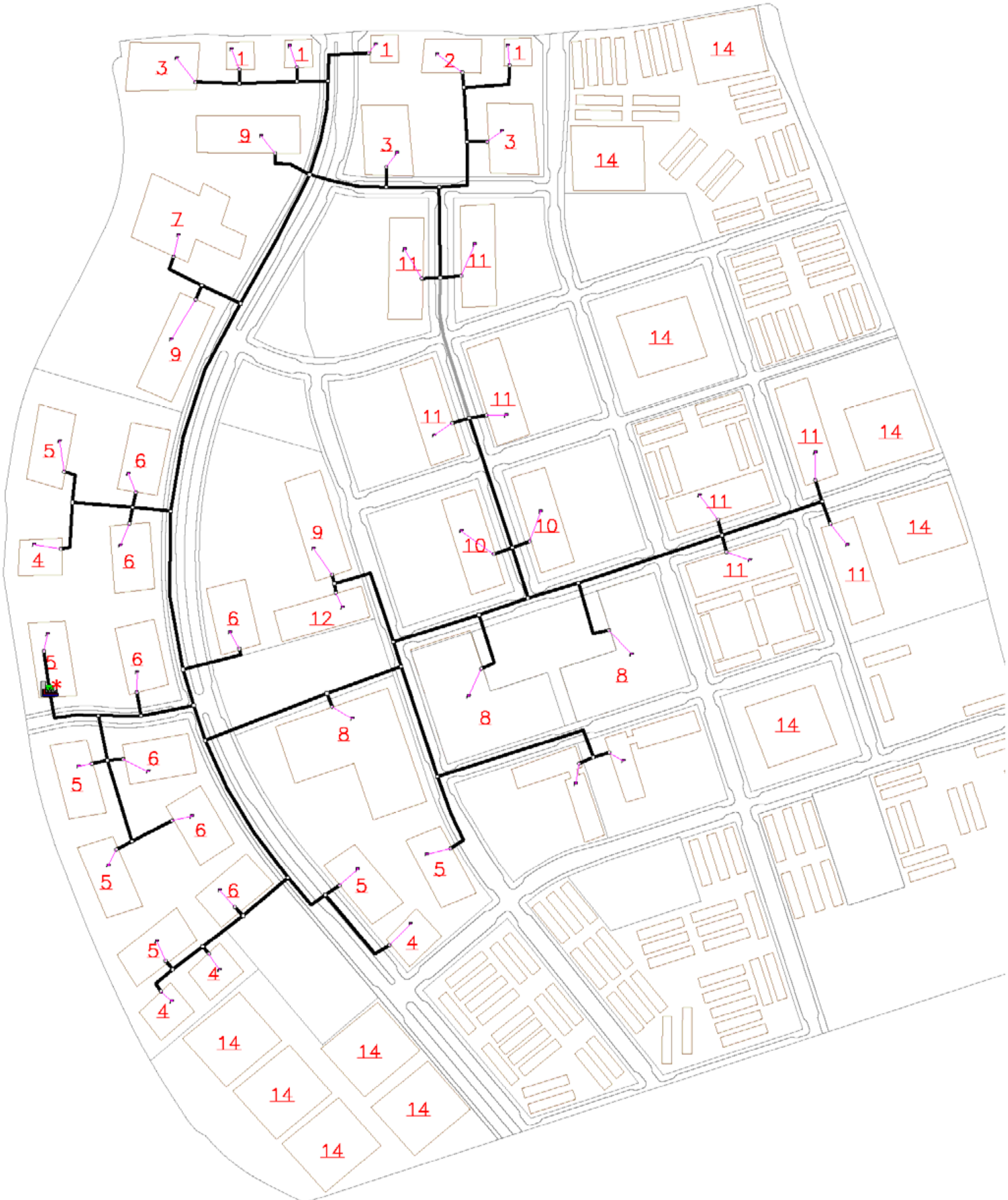
30,727 Thermal storage discharging, ton-hrs

Ton-hrs at On-peak utility rate, % of total 0%

Ton-hrs at Semi-peak utility rate, % of total 0%

Ton-hrs at Off-peak utility rate, % of total 100%

Appendix K. Distribution Piping System Layout (from the hydraulic model)



Appendix L. Distribution Piping System Capital Costs

Chula Vista EUC Developmemt
Chilled Water Distribution Piping System -
Preliminary Capital Cost Estimate
July 8, 2008

		Cost Est ($)
Construction Costs: 14540 trench ft of pre-insulated chilled water piping (sizes range from 3 in to 24 in)		
Mechanical - Material & Installation	14,540 TF	$3,014,000
Civil - Excavation, Backfill & Reinstatement	14,540 TF	$4,001,000
Contractor Admin., Bonding, Insurance		$351,000
Construction Management & Site Supervision	4.1%	$302,000
Construction Changes	3.0%	$221,000
Construction Costs Subtotal		**$7,889,000**
Owner's Costs:		
Engineering (Design & Construction Support)	9.8%	$773,000
Contingency	10.0%	$789,000
Capital Cost Total		**$9,451,000**

Appendix M. Chiller Selections Performance Data

		Parallel w/o VFDs (Base)		Parallel with VFDs		Series-CF with VFDs	
% Load	ECWT	KW/TR	% Diff, Base	KW/TR	% Diff, Base	KW/TR	% Diff, Base
100	80	0.541		0.534	-1.3%	0.512	-5.4%
100	75	0.495		0.482	-2.6%	0.459	-7.2%
100	70	0.457		0.429	-6.1%	0.410	-10.3%
100	65	0.424		0.383	-9.7%	0.368	-13.2%
100	60	0.395		0.345	-12.7%	0.326	-17.3%
100	55	0.369		0.301	-18.4%	0.290	-21.5%
90	80	0.531		0.518	-2.6%	0.497	-6.4%
90	75	0.489		0.462	-5.6%	0.441	-9.8%
90	70	0.453		0.409	-9.8%	0.393	-13.2%
90	65	0.420		0.365	-13.1%	0.349	-16.9%
90	60	0.392		0.321	-18.1%	0.306	-21.8%
90	55	0.366		0.280	-23.7%	0.265	-27.6%
80	80	0.531		0.507	-4.4%	0.489	-7.9%
80	75	0.490		0.448	-8.4%	0.431	-12.0%
80	70	0.454		0.395	-13.0%	0.379	-16.4%
80	65	0.423		0.347	-17.9%	0.332	-21.5%
80	60	0.394		0.302	-23.4%	0.288	-26.7%
80	55	0.367		0.260	-29.0%	0.248	-32.3%
70	80	0.538		0.511	-5.1%	0.491	-8.7%
70	75	0.497		0.443	-10.8%	0.426	-14.2%
70	70	0.461		0.384	-16.6%	0.370	-19.7%
70	65	0.429		0.333	-22.4%	0.320	-25.3%
70	60	0.399		0.288	-27.9%	0.276	-30.8%
70	55	0.371		0.245	-34.0%	0.233	-37.3%
60	80	0.552		0.518	-6.0%	0.502	-9.0%
60	75	0.509		0.451	-11.4%	0.433	-14.8%
60	70	0.472		0.386	-18.2%	0.371	-21.4%
60	65	0.439		0.329	-25.0%	0.317	-27.7%
60	60	0.409		0.278	-31.8%	0.269	-34.2%
60	55	0.380		0.231	-39.1%	0.229	-39.7%
50	80	0.573		0.537	-6.3%	0.521	-9.1%
50	75	0.528		0.459	-13.0%	0.446	-15.4%
50	70	0.489		0.399	-18.5%	0.385	-21.2%
50	65	0.455		0.334	-26.6%	0.323	-29.2%
50	60	0.423		0.279	-34.1%	0.268	-36.7%
50	55	0.395		0.235	-40.5%	0.228	-42.2%
40	80	0.581		0.561	-3.3%	0.509	-12.4%
40	75	0.537		0.482	-10.2%	0.451	-16.1%
40	70	0.518		0.413	-20.2%	0.399	-22.9%
40	65	0.482		0.348	-27.8%	0.352	-26.9%
40	60	0.450		0.289	-35.8%	0.308	-31.5%
40	55	0.421		0.244	-42.1%	0.268	-36.4%
30	80	0.622		0.598	-3.8%	0.515	-17.1%
30	75	0.576		0.512	-11.2%	0.446	-22.6%
30	70	0.542		0.452	-16.7%	0.385	-29.0%
30	65	0.512		0.378	-26.1%	0.330	-35.5%
30	60	0.490		0.314	-36.0%	0.282	-42.5%
30	55	0.471		0.267	-43.4%	0.234	-50.2%
20	80	0.723		0.687	-4.9%	0.565	-21.9%
20	75	0.674		0.584	-13.4%	0.481	-28.7%
20	70	0.635		0.506	-20.3%	0.411	-35.3%
20	65	0.603		0.429	-28.9%	0.348	-42.2%
20	60	0.581		0.355	-38.9%	0.289	-50.3%
20	55	0.565		0.313	-44.6%	0.242	-57.1%
15	80	0.832		0.794	-4.6%	0.687	-17.4%
15	75	0.772		0.669	-13.3%	0.584	-24.4%
15	70	0.729		0.575	-21.2%	0.506	-30.6%
15	65	0.695		0.485	-30.2%	0.429	-38.3%
15	60	0.674		0.403	-40.1%	0.368	-45.4%
15	55	0.661		0.343	-48.1%	0.313	-52.6%

Appendix N. Electric Rate Tariff Information

SDGE Schedule AL-TOU Secondary Rate Tariff Including EECC & DWR-BC Charges

Basic service fee, >500kW ($/Mo)	$ 194.06	
Non-Coincident Demand Charge ($/kW)	$ 10.01	
Summer On-Peak Demand Charge ($/kW)	$ 4.54	(May-Sep)
Winter On-Peak Demand Charge ($/kW)	$ 3.61	(Oct-Apr)

	UDC Total ($/kWh)	EECC Commod. Rate ($/kWh)	DWR-BC Charge ($/kWh)	Total Variable ($/kWh)
Summer On-Peak	0.00590	0.14033	0.00477	0.15100
Summer Semi-Peak	0.00534	0.08283	0.00477	0.09294
Summer Off-Peak	0.00518	0.05807	0.00477	0.06802
Winter On-peak	0.00568	0.14033	0.00477	0.15078
Winter Semi-Peak	0.00534	0.08283	0.00477	0.09294
Winter Off-Peak	0.00518	0.05807	0.00477	0.06802

Time Periods:
All time periods listed are applicable to local time. The definition of time will be based upon the date service is rendered.

	Summer May 1 - Sept 30	Winter All Other
On-Peak	11 a.m. - 6 p.m. Weekdays	5 p.m. - 8 p.m. Weekdays
Semi-Peak	6 a.m. - 11 a.m. Weekdays 6 p.m. - 10 p.m. Weekdays	6 a.m. - 5 p.m. Weekdays 8 p.m. - 10 p.m. Weekdays
Off-Peak	10 p.m. - 6 a.m. Weekdays Plus Weekends & Holidays	10 p.m. - 6 a.m. Weekdays Plus Weekends & Holidays

Appendix O. District Cooling Plant Annual Electric Cost Calculations

District Cooling Plant Electricity Cost Calcs for "Builder Baseline" for "All bldgs less Types 13 & 14" WITHOUT Thermal Storage

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Peak Demand (tons)	4,071	4,332	4,520	5,342	5,421	7,354	9,923	8,572	7,990	7,007	5,318	4,506
Monthly Peak kW/ton	0.60	0.60	0.60	0.60	0.60	0.735	0.773	0.773	0.735	0.735	0.60	0.60
Monthly Peak Demand (kW)	2,442	2,599	2,712	3,205	3,253	5,405	7,671	6,626	5,873	5,150	3,191	2,703
Monthly Fixed Charges ($/Mo)	$52,433	$52,433	$52,433	$52,433	$56,000	$78,839	$111,805	$96,602	$85,642	$70,339	$52,433	$52,433

	Period Consump-tion (ton-hrs)	Period Average kW/ton	Period Energy Use (kWh)	Tariff Variable Cost ($/kWh)	Subtotal Variable Cost
Summer On-Peak	4,165,532	0.64	2,665,941	0.15100	$402,557
Summer Semi-Peak	2,650,251	0.60	1,590,150	0.09294	$147,789
Summer Off-Peak	2,216,744	0.58	1,285,711	0.06802	$87,454
Winter On-peak	615,551	0.55	338,553	0.15078	$51,047
Winter Semi-Peak	4,141,244	0.55	2,277,684	0.09294	$211,688
Winter Off-Peak	1,099,024	0.55	604,463	0.06802	$41,116

Total Variable Consumption Charges	$941,650
Total Fixed Demand Charges	$813,821
Total Electricity Cost	**$1,755,472**
Total DC Plant Energy Use (kWh)	8,762,503
Average Electricity Cost per kWh	$0.200
Average kWh/ton-hr	0.589
Average Electricity Cost per ton-hr	$0.118

Appendix O. District Cooling Plant Annual Electric Cost Calculations

District Cooling Plant Electricity Cost Calcs for "Builder Baseline" for "All bldgs less Types 13 & 14" WITH Thermal Storage

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Peak Demand (tons)	4,071	4,332	4,520	5,146	5,146	5,146	5,146	5,146	5,146	5,146	5,146	4,506
Monthly Peak kW/ton	0.60	0.60	0.60	0.60	0.60	0.735	0.773	0.773	0.735	0.735	0.60	0.60
Monthly Peak Demand (kW)	2,442	2,599	2,712	3,088	3,088	3,782	3,978	3,978	3,782	3,782	3,088	2,703
Monthly Fixed Charges ($/Mo)	$33,460	$35,598	$37,134	$42,248	$45,120	$55,228	$58,073	$58,073	$55,228	$51,710	$42,248	$37,014

	Period Consump-tion (ton-hrs)	Period Average kW/ton	Period Energy Use (kWh)	Tariff Variable Cost ($/kWh)	Subtotal Variable Cost
Summer On-Peak	1,071,891	0.64	686,010	0.15100	$103,588
Summer Semi-Peak	2,781,059	0.60	1,668,635	0.09294	$155,083
Summer Off-Peak	5,179,577	0.58	3,004,155	0.06802	$204,343
Winter On-peak	0	0.55	0	0.15078	$0
Winter Semi-Peak	142,212	0.55	78,217	0.09294	$7,269
Winter Off-Peak	5,713,607	0.55	3,142,484	0.06802	$213,752

Total Variable Consumption Charges	$684,034
Total Fixed Demand Charges	$551,132
Total Electricity Cost	**$1,235,167**
Total DC Plant Energy Use (kWh)	8,579,501
Average Electricity Cost per kWh	$0.144
Average kWh/ton-hr	0.576
Average Electricity Cost per ton-hr	$0.083

Appendix O. District Cooling Plant Annual Electric Cost Calculations

District Cooling Plant Electricity Cost Calcs for "Optimum Configuration" for "All bldgs less Types 13 & 14" WITHOUT Thermal Storage

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Peak Demand (tons)	3,174	3,365	3,367	4,239	4,243	6,323	8,367	7,185	6,760	5,669	4,272	3,581
Monthly Peak kW/ton	0.51	0.51	0.51	0.51	0.51	0.677	0.731	0.731	0.677	0.677	0.51	0.51
Monthly Peak Demand (kW)	1,619	1,716	1,717	2,162	2,164	4,280	6,116	5,252	4,577	3,838	2,179	1,826
Monthly Fixed Charges ($/Mo)	$41,845	$41,845	$41,845	$41,845	$44,689	$62,474	$89,184	$76,610	$66,785	$52,463	$41,845	$41,845

	Period Consump-tion (ton-hrs)	Period Average kW/ton	Period Energy Use (kWh)	Tariff Variable Cost ($/kWh)	Subtotal Variable Cost
Summer On-Peak	3,454,835	0.55	1,900,159	0.15100	$286,924
Summer Semi-Peak	2,296,368	0.50	1,148,184	0.09294	$106,712
Summer Off-Peak	1,877,736	0.45	844,981	0.06802	$57,476
Winter On-peak	477,385	0.40	190,954	0.15078	$28,792
Winter Semi-Peak	3,406,085	0.40	1,362,434	0.09294	$126,625
Winter Off-Peak	854,907	0.40	341,963	0.06802	$23,260

Total Variable Consumption Charges	$629,789
Total Fixed Demand Charges	$643,274
Total Electricity Cost	**$1,273,063**
Total DC Plant Energy Use (kWh)	5,788,675
Average Electricity Cost per kWh	$0.220
Average kWh/ton-hr	0.468
Average Electricity Cost per ton-hr	$0.103

Appendix O. District Cooling Plant Annual Electric Cost Calculations

District Cooling Plant Cost Electricity Calcs for "Optimum Configuration" for "All bldgs less Types 13 & 14" WITH Thermal Storage

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Peak Demand (tons)	3,174	3,365	3,367	4,239	4,243	4,440	4,440	4,440	4,440	4,440	4,272	3,581
Monthly Peak kW/ton	0.51	0.51	0.51	0.51	0.51	0.677	0.731	0.731	0.677	0.677	0.51	0.51
Monthly Peak Demand (kW)	1,619	1,716	1,717	2,162	2,164	3,006	3,245	3,245	3,006	3,006	2,179	1,826
Monthly Fixed Charges ($/Mo)	$22,295	$23,567	$23,582	$29,639	$31,678	$43,925	$47,413	$47,413	$43,925	$41,130	$29,865	$25,069

	Period Consump-tion (ton-hrs)	Period Average kW/ton	Period Energy Use (kWh)	Tariff Variable Cost ($/kWh)	Subtotal Variable Cost
Summer On-Peak	904,894	0.55	497,692	0.15100	$75,151
Summer Semi-Peak	2,314,849	0.50	1,157,425	0.09294	$107,571
Summer Off-Peak	4,409,197	0.45	1,984,139	0.06802	$134,961
Winter On-peak	0	0.40	0	0.15078	$0
Winter Semi-Peak	118,444	0.40	47,378	0.09294	$4,403
Winter Off-Peak	4,619,933	0.40	1,847,973	0.06802	$125,699

Total Variable Consumption Charges	$447,786
Total Fixed Demand Charges	$409,502
Total Electricity Cost	**$857,288**
Total DC Plant Energy Use (kWh)	5,534,605
Average Electricity Cost per kWh	$0.155
Average kWh/ton-hr	0.448
Average Electricity Cost per ton-hr	$0.069

Appendix P. Site-A: Spatial Modeling Inputs, Outputs & Assumptions

Data Inputs:

- Outputs from the preceding building, infrastructure, and green infrastructure analysis
- SDG&E power distribution plans and emission data for the energy distribution system that will be modeled for this area.

Adjustable Variables:

- Building, infrastructure, and green infrastructure assumptions from previous analysis.
- Transit frequency

Data Outputs:

- Dynamic (automatically updated) impact indicators for energy and resource analysis.
- Transportation Air Emission Reductions
    - Auto PM-10
    - Auto PM-2.5
    - Auto SO2
    - Auto CO
    - Auto VOC
    - Auto NH3
    - Auto CO2
    - Auto CH4
    - Auto N2O
    - Petroleum Costs
- Building/Industrial Air Emission Reductions
    - CO
    - Cooling Energy
    - CO2
    - NOx
    - SOx
    - Particulates
- Common Impacts - Population
- Common Impacts - School Children
- Common Impacts - Labor Force
- Common Impacts - Commercial Jobs
- Common Impacts - Vehicle Trips per Day
- Common Impacts - Residential Energy Use
- Common Impacts - Residential Dwelling Units
- Common Impacts - Total Commercial Floor Area
- Common Impacts - Commercial Jobs to Housing Ratio

Modeling Constraints/Limitations:

The following components were fixed, and could not be modified for or based upon the analysis:

- Limited site changes were possible
- Site uses (intensity ranges and land use designations) were restricted
- Grading plan set
- Alignment of external arterials fixed
- Design and alignment of internal street system, including block sizes, fixed
- Bus rapid transit alignment and design fixed
- Bus stop locations and functions set
- Regional trail system determined by General Development Plan
- Park location sizes/design set
- Village pathway determined by General Development Plan
- Access points required to stay open
- Infrastructure must not conflict with current design

Appendix Q. Site-X: Spatial Modeling Inputs, Outputs & Assumptions

Data Inputs:

- Outputs from the preceding building, infrastructure, and green infrastructure analysis
- SDG&E power distribution plans and emission data for the energy distribution system that will be modeled for this area.

Adjustable Variables:

- Building, infrastructure, and green infrastructure assumptions from previous analysis.
- Transit frequency

Data Outputs:

- Dynamic (automatically updated) impact indicators for energy and resource analysis.
- Transportation Air Emission Reductions
    - Auto PM-10
    - Auto PM-2.5
    - Auto SO2
    - Auto CO
    - Auto VOC
    - Auto NH3
    - Auto CO2
    - Auto CH4
    - Auto N2O
    - Petroleum Costs
- Building/Industrial Air Emission Reductions
    - CO
    - Cooling Energy
    - CO2
    - NOx
    - SOx
    - Particulates
- Common Impacts - Population
- Common Impacts - School Children
- Common Impacts - Labor Force
- Common Impacts - Commercial Jobs
- Common Impacts - Vehicle Trips per Day
- Common Impacts - Residential Energy Use
- Common Impacts - Residential Dwelling Units
- Common Impacts - Total Commercial Floor Area
- Common Impacts - Commercial Jobs to Housing Ratio

Modeling Constraints/Limitations:

The following components were fixed, and could not be modified for or based upon the analysis:

- Limited site changes were possible
- Site uses (intensity ranges and land use designations) were restricted
- Grading plan set
- Alignment of external arterials fixed
- Design and alignment of internal street system, including block sizes, fixed
- Bus rapid transit alignment and design fixed
- Bus stop locations and functions set
- Regional trail system determined by General Development Plan
- Park location sizes/design set
- Village pathway determined by General Development Plan
- Access points required to stay open
- Infrastructure must not conflict with current design

Appendix R. Curve Numbers for Land Use and Soil Types

Curve Numbers by Land Use and Hydrological Soil Group						
Land Use Description			Hydrological Soil Group			
			A	B	C	D
Cultivated land	Without conservation treatment		72	81	88	91
	With conservation treatment		62	71	78	81
Pasture or range land	Poor condition		68	79	86	89
	Good condition		39	61	74	80
Meadow			30	58	71	78
Wood or forest land	Thin stand, poor cover, no mulch		45	66	77	83
	Good cover		25	55	70	77
Open spaces, lawns, parks, golf courses, cemeteries, etc.	Good condition: grass cover on 75% or more of the area		39	61	74	80
	Fair condition: 50-75% of the area		49	69	79	84
	Commercial and business areas (85% impervious)		89	92	94	95
	Industrial districts (72% impervious)		81	88	91	93
Residential	Average lot size	Average % Impervious				
	1/8 acre or less	65	77	85	90	92
	1/4 acre	38	61	75	83	87
	1/3 acre	30	57	72	81	86
	1/2 acre	25	54	70	80	85
	1 acre	20	51	68	79	84
Paved parking lots, roofs, driveways, etc.			98	98	98	98
Streets and roads	Paved with curbs and storm sewers		98	98	98	98
	Gravel		76	85	89	91
	Dirt		72	82	87	89
Open water			0	0	0	0

Appendix S. Coefficients by Rainfall Type

Coefficient Values by Raintype				
Rainfall type	I_a/P[74]	C_0	C_1	C_2
I	0.1	2.3055	-0.51429	-0.1175
	0.2	2.23537	-0.50387	-0.08929
	0.25	2.18219	-0.48488	-0.06589
	0.3	2.10624	-0.45695	-0.02835
	0.35	2.00303	-0.40769	0.01983
	0.4	1.87733	-0.32274	0.05754
	0.45	1.76312	-0.15644	0.00453
	0.5	1.67889	-0.0693	0
IA	0.1	2.0325	-0.31583	-0.13748
	0.2	1.91978	-0.28215	-0.0702
	0.25	1.83842	-0.25543	-0.02597
	0.3	1.72657	-0.19826	0.02633
	0.5	1.63417	-0.091	0
II	0.1	2.55323	-0.61512	-0.16403
	0.3	2.46532	-0.62257	-0.11657
	0.35	2.41896	-0.61594	-0.0882
	0.4	2.36409	-0.59857	-0.05621
	0.45	2.29238	-0.57005	-0.02281
	0.5	2.20282	-0.51599	-0.01259
III	0.1	2.47317	-0.51848	-0.17083
	0.3	2.39628	-0.51202	-0.13245
	0.35	2.35477	-0.49735	-0.11985
	0.4	2.30726	-0.46541	-0.11094
	0.45	2.24876	-0.41314	-0.11508
	0.5	2.17772	-0.36803	-0.09525

[74] $I_a = .2 \times S$

Appendix T. Soil Types

Group A is sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.

Group B is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.

Group C soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.

Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This hydraulic soil group has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.

Appendix U. Chula Vista Research Project Advisory Committee

AESC, Inc.	Ronald K. Ishii	Vice President
Brummitt Energy Associates	Beth Brummitt	Principal
California Sierra Club	Carl Zichella	Regional Director
CA Building Industry Assn.	Alan Nevin	Chief Economist
Charles Angyal & Associates	Charles Angyal	Principal
City of Chula Vista	Brad Remp	Chief Building Official
Community Fuels	Lisa Mortenson	CEO & Apollo Alliance Member
Efficiency Valuation Org.	Larisa Dobriansky	Board Member
Endurant Energy	John Kelly	Vice President
CA Local Gov't. Commission	Judy Corbett	Executive Director
National Assn. of Realtors	Lawrence Yun	Dir. Research. & Senior Economist
National Renewable Energy Lab	Nancy Carlisle	Dir. Energy Mngt. & Federal Mkts.
Mortgage Bankers Association	Doug Duncan	Chief Economist
Mortgage Bankers Association	Jamie Woodwell	Senior Staff
Pacific Gas & Electric	Darren Bouton	Mngr. Sustainable Communities
Sempra/ SDG&E	Julie Ricks	Energy Programs Advisor
Schweitzer & Associates	Judi Schweitzer	Principal
Sempra / SDG&E	Chris Yunker	Manager, Emerging Technologies
Southern California Edison	David Jacot	Mngr. Sustainable Communities
U.S. Dept. of Energy	David Berg	Senior Policy Advisor
UC-Davis Inst. Transp. Studies	Susan Handy	Professor & Researcher
UC – San Diego	Paul Linden	Chair, Mech. Engineering

BURNHAM–MOORES
CENTER FOR REAL ESTATE
UNIVERSITY OF SAN DIEGO

Chula Vista Research Project
Real Estate Industry Workshop Questions & Responses

On January 29th 2008, senior representatives from the real estate development, and building industries and the three independently owned utilities assembled at the University of San Diego to provide input on the CVRP research questions previously approved by the Project Advisory Committee. A list of the attendees, their organizations and their question assignments is provided at the end of this document. This document summarizes that input and provides commentary on the implications for further research of these subjects under the CVRP.

Key Definition: Energy-Efficient Community Development is defined as development of residential, commercial, institutional and mixed use structures and infrastructure that integrate renewable and advanced energy- efficient technologies, and performance enhancing urban design, to substantially reduce energy consumption and greenhouse gas emissions.

CVRP Research Questions:

1. What are the most significant perceived policy, regulatory and market barriers to investment in energy-efficient community development projects in California?
2. What are the perceived and real additional costs associated with the design and construction of energy-efficient community development projects? What potential public policies, incentives and other financial assistance could reduce these costs?
3. What do you perceive to the current market demand and/or acceptance level to be for energy-efficient development projects and what is necessary to increase the demand and acceptance?
4. What are the perceived benefits for developing energy-efficient homes and buildings, and communities? What are the effective means to increase the identified perceived benefits?
5. What are the most important trade organizations and channels (publications, conferences, events) to tap to effectively disseminate the final research findings?

Participant Responses & Commentary:

1. ***What are the most significant perceived policy, regulatory and market barriers to investment in energy-efficient community development projects in California****?*

Return on Investment (ROI) - The single most important barrier to energy-efficient community development identified by the participants is the generally held perception that it won't produce a return on the capital investment for the developer/builder. This barrier entails corollary concerns relating to:

- The uncertainty of the additional/first costs to design an energy-efficient product, to purchase and install the energy-saving equipment and materials and the related construction process, permitting and inspection costs;
- The perception that there is an insufficient demand for such a product among property buyers and tenants. Specifically, the perception that buyers and tenants aren't willing to pay more to own or rent energy-efficient properties;
- The fear that these first costs will further reduce already narrowing profit margins, particularly in the current market, and further narrow the size of the market able to afford the more expensive, energy-efficient product.

A related concern is that the real benefit of an energy-efficient real estate product - energy cost savings over time, doesn't inure to developer/builder that bore the first cost, unless they are able to recover that cost at the point-of-sale or through premium leases.

This input suggests that the researchers need to examine alternative financing mechanisms to both reduce/"buy down" the first costs to the developer/builder and to recover their investment in the remaining costs at the point-of-sale and through lease arrangements over time. A variety of third-party financing mechanisms should be examined.

Needed Market Transformation – One participant suggested the need to transform the present model for energy-efficient real estate products in today's market from one of high margin / premium products sold at a low volume, to a model based on low margin products sold at a high volume. Discussion among participants suggested that a new economy-of-scale will be needed to enable such a model to be viable and that an effort is needed to explore the means of doing so.

Regulatory Constraints & NIMBY Opposition – One participant noted that local governmental regulations and citizen Not-In-My-Back-Yard (NIMBY) opposition often precludes consideration of advanced energy-efficient technologies such as onsite power generation, wind and solar photovoltaic and thermal equipment in large-scale development projects.

Inconsistent Rules & Processes – There is no consistent set of standards for what constitutes a sustainable or energy-efficient development project and currently municipal project planning and building approval processes don't typically recognize the value of this form of development. There needs to be a credible set of bench marks established that both define what an energy-efficient community looks like and a roadmap that will show the development community how to get there in a way that is cost-effective.

Lack of A Compelling Business Case – All discussion groups at the workshop cited the need for compelling examples of developer/builder successes stories or case studies of profitable experiences building and selling energy-efficient development projects in California. In the absence of this, the development community is not likely to pursue this form of development.

During the discussion a number of ideas were offered to address these barriers. These include the following

a) Creation of a municipal preferred tax treatment districts for developers and buyers of properties in new development/redevelopment districts designed and built to maximize energy, water and resource efficiency.
b) Development of a carbon emission reduction credit and trading system at the local level to provide a monetary benefit to developers and builders producing low-carbon communities and construction projects.
c) Expedited plan check and approval for developers and builders
d) Utility rate structures that encourage, rather than discourage interconnection of distributed energy technologies into the existing electric utility grid.

2. What are the perceived and real additional costs associated with the design and construction of energy-efficient community development projects? What potential public policies, incentives and other financial assistance could reduce these costs?

The participants identified the following <u>real</u> additional costs:

a) Increases in development cycle times due to the novelty of this type of construction and because neither the public or private development players know how to do this.
b) Increased design and engineering expenses
c) Increased material and equipment costs
d) Increased installation and inspection costs
e) Narrowing of the consumer market! Every $5-10k added to a property's sales price to cover the incremental cost of energy efficient features, the market of potential buyers for that property shrinks.
f) Interconnection charges and difficulty and time to negotiate them with the utilities
g) Potential market rejection of homes that are oversold as "green", particularly if green features are added at the expense (over the loss) of conventional amenities

Potential means of reducing costs offered by participants included the following:

a) An expedited planning process for these energy-efficient development projects
b) Education of all public and private players in the development transaction chain
c) Subsidies for the cost of permitting
d) Municipal development incentives and concessions for energy-efficient developers and

builders

e) Re-design/re-writing local building and zoning codes

f) Allow individual building solar PV energy metering

3. *What do you perceive to the current market demand and/or acceptance level to be for energy-efficient development projects and what is necessary to increase the demand and acceptance?*

There does appear to be growing consumer interest in "green" buildings and communities but real market demand **is not** there yet. Perceived factors affecting consumer demand include the notion that energy-efficient structures are:

a) more expensive to buy

b) less aesthetically appealing (referencing unappealing PV & solar thermal installations of the past),

c) limited in style and features

d) devoid of other amenities (i.e. granite, premium finishes, etc.)

e) little more efficient than other Title-24,'05 compliant structures on the market

Participants suggested that an increase in market demand will require

a) builder and consumer education

b) measurable benefits demonstrated to prospective buyers

c) increase in the design options

d) increase in financing and lease options that make these properties more affordable

e) some sort of rating system that will allow relative efficiencies of properties to be evaluated by potential buyers

f) ultimately lower costs to the consumer, perhaps by increased incentives

g) making energy-efficiency an optional add-on package for buyers

4. *What are the perceived benefits for developing energy-efficient homes and buildings, and communities? What are the effective means to increase the identified perceived benefits?*

The general perception of the development and building industry participants is that "the benefits just aren't there!" The benefits that need to exist to engage the industry in this pursuit are the following:

a) Increased rate of real estate sales and a decreased rental turn-over rate directly associated with buyer/lessee perception of the value of owning/renting an energy efficient building. These are presented as the first of the two key indicators that will signal that a market for energy-efficient development is emerging.

b) Increased developer/builder sales profits and rental premiums directly associated with buyer/lessee perception of the aforementioned value. This is the second of indicator that will signal the emergence of the new market.

c) Broader media recognition of the value of energy-efficient development projects and widespread branding and marketing to build consumer demand

d) Increased municipal incentives that encourage the industry to pursue these projects such as lower development and building permitting fees, expedited processing time and other mechanisms that will shorten the development cycle and enable these products to get to the market quicker.

e) Evidence that the pursuit of these projects actually increases productivity (Lou & Charles – does this jive with your notes?)

f) Increased government subsidies, tax credits, development concessions and private capital made available to the development and building industries.

The means of putting these benefits in place follow logically and must include:

a) Consumer education and broad public and private marketing campaigns

b) Compelling peer-to-peer success stories of energy-efficient projects that have proven to be both marketable and profitable.

c) Detailed case studies that tell the development and building industries how to pursue these projects.

d) Increased public programs and private capital as suggested in f.) above

e) Increased research and development of energy-efficient building technologies.

5. ***What are the most important trade organizations and channels (publications, conferences, events) to tap to effectively disseminate the final research findings?***

- Urban Land Institute
- California Building Industry Association
- California Investor Owned Utilities
- Building Manufacturers & their Association
- American Planning Association
- California League of Cities
- California Code Officials
- California Fire Marshals Association
- Trade Contractors
- Engineers & General Contractors

- <u>Environmental Organizations</u>
- <u>BOMA / CCDC / ICMA</u>
- Media

GTI PROJECT NUMBER: 20144/20543

Energy efficient Community Development in California: Chula Vista Research Project

APPENDIX C

Creating Energy-Efficient Communities in California: A Technical Reference Guide to Building and Site Design

Prepared by the National Energy Center for Sustainable Communities

Sponsored by the City of Chula Vista, California And San Diego Gas and Electric

CITY OF CHULA VISTA

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Chapter 1. Introduction

1.1 The Opportunity

Within the next 20-25 years, the United States will design, construct, and remodel more than half of all structures in the country. This equates to 213 billion square feet of built space, half of it in new homes, which have yet to be designed and constructed.[1] This presents an unprecedented opportunity to design and build our homes, offices, public facilities and whole communities to a new level of energy and resource efficiency.

Although technologies exist that can improve the energy efficiency of individual buildings and processes, little research has been conducted on how to optimize the efficiency of these technologies in relation to one another or in the aggregate, to achieve community-scale energy efficiency. Further, little or no research has sought to determine how to maximize the performance of energy efficiency, demand response, renewable energy, and distributed energy technologies and strategies through energy-efficient community planning, design and development.

Historically, California has been one of the leading states promoting energy efficiency and resource conservation, and has now become the lead state in the emerging national effort to reduce greenhouse gas emissions and global warming. The California Energy Action Plan, the Integrated Energy Policy Report of 2007, the Global Warming Solutions Act of 2006 (AB 32), Executive Order S-3-05 and California's Strategic Plan for Energy Efficiency all contain strategies and goals that will continue to move the state forward in each of these key areas of sustainable energy management and toward the realization of zero-net-energy structures. However if the State is to reach the ambitious goals contained in these documents, it must determine how to optimize energy-efficient community development. It must also engage the private sector, and in particular the development industry, in the pursuit of this supporting objective.

In 2007, the U.S. Department of Energy joined the California Energy Commission in funding a project to begin to examine the technical, economic and institutional (policy and regulatory) aspects of energy-efficient community development. That research project was known as the Chula Vista Research Project (CVRP) for the host California community that co-sponsored the initiative. The contents of this reference guide are derived from that research initiative and are presented here to encourage public and private development practitioners to consider alternatives that will increase the energy efficiency of their large-scale projects.

[1] Nelson, Arthur C. 2004. *Toward A New Metropolis: The Opportunity to Rebuild America*. A Discussion Paper Prepared for The Brookings Institution Metropolitan Policy Program Virginia Polytechnic Institute and State University

1.2 Recent Research

The goal of the CVRP was to determine which actions and technologies in the California loading order could be combined with enabling community design features to increase the energy efficiency and air quality of California communities.[2]

To achieve the goal, the application of a number of building energy technologies and community design features were modeled on two large-scale development sites on the eastern side of Chula Vista, California. One site was planned to be a predominantly commercial mixed-use development on 206-acres of land; the other was planned to be a predominantly residential mixed-use development on 418-acres of land.

In the case of the advanced building energy technologies, three alternative development options were modeled for each distinct building prototype on each site. These included the use of: advanced, highly efficient building envelope features, appliances and space conditioning equipment (the EE option); the EE option with the addition of solar photovoltaic panels (the EE-PV option); and the use of the EE option with the addition of distributed generation technologies (the EE-DG option).

In the case of the advanced community design features, four alternative options were modeled for the two development sites. These included the use of: moderate-density/mixed-use development; stormwater runoff mitigation measures; carbon sequestration measures; and urban heat island mitigation measures. Additionally, passive solar building orientation was also modeled for the predominantly residential development site. The researchers refer to the collective use of these advanced energy technologies and community design features as *Energy-Efficient Community Development* (EECD).

Once the incremental costs of the energy technology options were determined, the researchers conducted online surveys with developers, builders and brokers to determine their acceptability in today's marketplace. Additionally, the researchers surveyed capital market and development industry practitioners to determine the perceived barriers and risks associated with the use of these technologies and design features in large-scale development projects, and needed financial and business models and public policy incentives that would accelerate their adoption.

The following section summarizes the key findings of the energy technology and community design modeling. The detailed findings are available in the full technical report entitled: *Energy-Efficient Community Development in California: The Chula Vista Research Project.* The key findings of the market and policy analysis can be found in the companion document to this guide entitled: *Creating Energy-Efficient Communities in California: Barriers,*

[2] The California Energy Action Plan, adopted in 2003 by the California Energy Commission, the Public Utilities Commission, and the Consumer Power and Conservation Financing Authority, envisioned a "loading order" of energy resources to guide decisions made by these same agencies. This loading order is as follows:

1. Optimize all strategies for increasing conservation & energy efficiency to minimize increases in electricity & natural gas demand;
2. Meet generation needs first by renewable energy resources & distributed generation;
3. Support additional clean, fossil fuel, central-station generation.

Solutions and Resources, available from San Diego Gas and Electric and the City of Chula Vista, California.

1.3 Key Findings

The CVRP modeling findings indicated that use of these advanced building energy technologies and community design features in a large-scale development project can reduce aggregate electric energy consumption (kWh) by ~43%; peak demand (kW) by 45%; and CO_2 emissions by 35%, compared to a project designed for minimum compliance with California's Title-24, 2005 building energy efficiency standard. The key component findings include the following:

- The strategic integration of EE, EE-PV and EE-DG building energy technologies produced significant reductions in aggregate energy consumption, peak demand and emissions, compared to a developer/builder's conventional (baseline) approach; however
- Central power plant emission reductions achieved through use of the EE-DG option would significantly increase local emissions unless driven by renewable fuel sources;
- The utility infrastructure impacts associated with the use of the EE and EE-PV options were deemed relatively insignificant while use of the EE-DG option would result in a significant reduction of necessary electric distribution facilities to serve a large-scale development project;
- The mixed-use/moderate density development alternative facilitates the cost-effective performance of combined cooling heat and power (CCHP) technologies and district cooling systems and significantly reduces vehicular petroleum consumption and emissions, household energy consumption and it increases land use efficiency;
- Mixed-use/moderate density development, stormwater runoff mitigation, carbon sequestration and urban heat island mitigation measures all produce significant reductions in energy consumption and energy-related emissions in large-scale development projects.

1.4 Performance Profiles & Technical Assumptions

The performance profiles presented in the next two chapters contain the optimal mix of alternative energy-efficient building materials and advanced energy technologies for 40 building types and space uses common to urban and residential development projects in California. This includes 15 distinct urban-site building prototypes and 5 district residential-site building prototypes. The applicable construction types for these buildings are as follows:

- Type I: Structural steel frame with exterior metal studs skinned with stone tiles on a cement plaster system. Mineral fiber batts are placed between the framing studs and Gypsum board is used for the interior. Roofs are flat lightweight concrete poured into metal decking with a 3-ply BUR over the concrete;

- Type II: Reinforced "poured-in-place" concrete exterior walls with plaster exterior finish. Steel framing is attached to the inside of the concrete walls with mineral fiber batts between the studs and Gypsum board on the interior. Roofs are flat 3-ply BUR over 2" rigid insulation boards over metal decking;

- Type III: Wood framed walls with lath/plaster and brick veneer exterior. The walls are filled with mineral fiber batts between the studs and Gypsum board on the interior. Roofs are flat wood trusses with rigid insulation over plywood decking. A 3-ply built-up-roof covers the rigid insulation;

- Type V: Wood framed with plaster exterior finish, fiberglass batts within the framing, and Gypsum interior. Roofs are flat wood trusses with fiberglass batt insulation below the wood decking. A 3-ply built-up-roof covers the wood decking. If the roofs are pitched with an attic, fiberglass batt insulation is placed on the attic floor and flat concrete tiles cover the roof exterior.

The performance profiles for each prototype begin with a description of its construction type and a dimensional drawing or photograph. A black and white table follows describing the building materials, design configurations and energy technologies commonly used in the industry for each prototype (referred to as the builder's baseline), and a set of alternative energy-efficient building materials, configurations and energy technologies modeled under three different scenarios. This table is followed by a set of three tables containing information on the energy savings, installation costs and paybacks for each alternative as well as the total energy consumption and an assessment of the alternative relative to the State of California's building energy efficiency standard.[3] Specifically, the three tables contain the following information for each building prototype and distinct space use:

- Utility & Installation Costs & Paybacks for each Energy-Efficient (EE) Alternative
    - Annual electric utility costs
    - Annual natural gas costs
    - Annual combined electricity and natural gas utility costs
    - Alternative energy efficiency measure installation costs
    - Payback period for each alternative measured in years

- Annual Electric, Gas and Total Energy Consumption for each Alternative
    - Electricity consumption in annual kWh
    - Electricity consumption expressed as a thousand, thousand British thermal units (MMbtu)
    - Natural gas consumption expressed in MMbtu

[3] Paybacks = < than useful life of the alternative (material, equipment, feature) being implemented

- o Total energy saved in MMbtu from the use of the alternative over the use of conventional building materials and energy technologies (builder's baseline approach)

- <u>Annual Electricity and Natural Gas Consumption and Savings Expressed in Time Dependent Valuation Inclusive (TDVI) Units for each Alternative</u>[4]
  - o Total square feet of each prototype
  - o Electric TDVI energy consumption
  - o Natural Gas TDVI energy consumption
  - o Total combined electricity and natural gas TDVI energy consumption
  - o Amount of TDVI units saved from the use of the alternative over the use of conventional building materials and energy technologies

The tables enable the reader to determine the performance impact of each alternative for each building prototype and specific space use (e.g. residential, office, retail buildings and space uses) and to determine which proved to be economically feasible (in yellow shading) on a simple payback basis, and which did not prove to be feasible (unshaded).

In addition, the first 3 rows of each table indicate what the building energy costs, consumption and TDVI performance would be under the following three scenarios: 1) use of conventional building materials and equipment (the builder's baseline approach); 2) use of all the economically feasible energy-efficient alternatives (the EE option); and 3) use of the EE option with the addition of photovoltaic onsite power generation. In the case of several of the commercial building prototypes, an additional row has been added to show the performance impact of onsite fossil-fueled distributed generation technologies.[5] The performance information under all three of these scenarios is shaded in green.

<u>Modeling Assumptions</u>: The performance profiles were derived from the results of the Chula Vista Research Project and are based on the technical modeling assumptions contained in Appendix-A and -B of this document.

<u>Key Qualifier:</u> The performance profiles in the next two chapters and the information contained in chapter four were based on modeling assuming atmospheric conditions

4 Time Dependent Valuation (TDV) is the new method for valuing energy under the performance approach in the 2005 Building Energy Efficiency Standard known as Title-24. Under TDV the value of electricity differs depending on the time-of-use (hourly, daily, seasonal), and the value of natural gas differs depending on season. TDV is based on the cost for utilities to provide the energy at different times. TDVI is an enhanced version of the performance approach for valuing energy consumption and savings that accounts for all energy consumption in a building including those not specifically included under the Title-24 residential standard such as energy consumed by appliances, plug-in loads and lights. It should however be noted that the Title-24 commercial building TDV method does however account for lights and receptacles load.

5 However, it should be noted that given a recent change in San Diego Gas and Electric's Self-Generation Incentive Program (SGIP), distributed generation technologies are no longer being incentivized and thus become economically infeasible to consider. The performance data is nonetheless included here as they may once again be incentivized with rebates in the future.

characteristic of Climate Zone 10. Performance of these alternative building materials, advanced energy technologies and community design alternatives will vary by climate zone.

The Following Chapters

The next two chapters provide the performance characteristics for alternative energy-efficient building materials and technologies for 40 common building prototypes and space uses and for the community site development alternatives modeled in the research project. The final chapter provides additional information that public and private development practitioners and utility personnel may find useful as they seek to advance energy-efficient community development in their own projects.

Chapter 2. Alternatives for 28-Building Types & Spaces: Urban-Sites

2.1 Freestanding Full-Service Restaurant

Type III construction, approximately 7,400 sf single-story slab on grade, typical of a national-chain casual full-service restaurant with three independently controlled zone types (Dining Room, Kitchen, and Hood). The floor-to-floor height is 13'-0" and 50% of the roof area is available for solar cells.

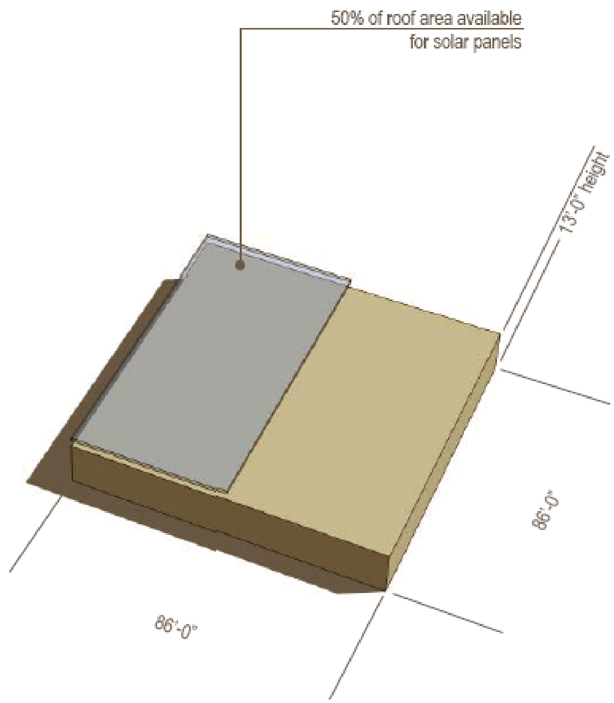

Figure 1. Freestanding Full-Service Restaurant

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	No Alternative
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=80%	Heating - AFUE=94%	None	None	Alternative 1
Space Cooling	HVAC - EER 9.5	HVAC - EER 10.5	HVAC - EER 11.5	HVAC - EER 12.5	Alternative 3
Photovoltaics	No PV	PV - 3698 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 rigid	Roof - U=R15 rigid	Roof - U=R20 rigid	None	No Alternative
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 3
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 1
DG	No DG	DG - 30kW microturbine	None	None	No Alternative

Table 1. Freestanding Full-Service Restaurant (FFSR) Alternatives

Prototype #1 Freestanding Full-Service Restaurant					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$48,946	$25,480	$74,426	-	-
Package - Optimum EE	$46,975	$23,286	$70,260	$23,084	5.5
Package - Optimum EE + PV	$39,858	$23,286	$63,144	$206,937	19.0
CoolRoof - Abs=0.25	$48,812	$25,542	$74,354	$2,441	33.9
DHW - EF=0.640	$48,946	$24,362	$73,308	$620	0.6
DHW - EF=0.823	$48,946	$23,936	$72,882	$741	0.5
Heating - AFUE=94%	$48,946	$24,856	$73,802	$1,000	1.6
HVAC - EER 10.5	$48,195	$25,480	$73,675	$16,098	21.4
HVAC - EER 11.5	$47,578	$25,480	$73,058	$18,007	13.2
HVAC - EER 12.5	$47,063	$25,480	$72,543	$19,178	10.2
PV - 3698 sqft	$41,793	$25,480	$67,272	$183,853	25.7
Roof - U=R15 rigid	$48,943	$25,429	$74,372	$1,849	34.2
Roof - U=R20 rigid	$48,940	$25,419	$74,359	$3,328	49.7
Walls - R19 batt	$48,916	$25,488	$74,403	$394	17.1
Walls - R21 batt	$48,908	$25,485	$74,393	$537	16.3
Walls - R21 batt + R5 rigid	$48,881	$25,477	$74,358	$1,431	21.0
Windows - U=0.43, SHGC=0.39	$48,928	$25,463	$74,390	$733	20.4
Windows - U=0.26, SHGC=0.37	$48,911	$25,424	$74,335	$2,191	24.1
Windows - U=0.22, SHGC=0.22	$48,788	$25,504	$74,293	$6,690	50.3
DG - 30kW microturbine	$43,966	$29,033	$73,336	$44,709	59.4

Table 2. FFSR - Alternatives Impact on Utility Costs & Paybacks

Prototype #1 Freestanding Full-Service Restaurant					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	334,010	1,140	1,875	3,015	-
Package - Optimum EE	323,160	1,103	1,679	2,782	233
Package - Optimum EE + PV	262,936	897	1,679	2,577	438
CoolRoof - Abs=0.25	333,244	1,137	1,880	3,017	-2
DHW - EF=0.640	334,010	1,140	1,775	2,915	100
DHW - EF=0.823	334,010	1,140	1,737	2,877	138
Heating - AFUE=94%	334,010	1,140	1,819	2,959	56
HVAC - EER 10.5	329,874	1,126	1,875	3,000	15
HVAC - EER 11.5	326,458	1,114	1,875	2,989	26
HVAC - EER 12.5	323,588	1,104	1,875	2,979	36
PV - 3698 sqft	273,785	934	1,875	2,809	206
Roof - U=R15 rigid	334,140	1,140	1,871	3,011	4
Roof - U=R20 rigid	334,226	1,140	1,870	3,010	5
Walls - R19 batt	333,900	1,139	1,876	3,015	0
Walls - R21 batt	333,879	1,139	1,876	3,015	0
Walls - R21 batt + R5 rigid	333,742	1,139	1,875	3,013	2
Windows - U=0.43, SHGC=0.39	333,853	1,139	1,873	3,013	2
Windows - U=0.26, SHGC=0.37	333,685	1,139	1,870	3,008	7
Windows - U=0.22, SHGC=0.22	333,202	1,137	1,877	3,014	1
DG - 30kW microturbine	300,342	1,025	2,192	3,217	-202

Table 3. FFSR - Alternatives Impact on Energy Consumption

Prototype #1 Freestanding Full-Service Restaurant					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	7,396	848	278	1,126	-
Package - Optimum EE	7,396	817	249	1,066	60
Package - Optimum EE + PV	7,396	652	249	901	225
CoolRoof - Abs=0.25	7,396	847	279	1,126	0
DHW - EF=0.640	7,396	848	263	1,112	14
DHW - EF=0.823	7,396	848	258	1,106	20
Heating - AFUE=94%	7,396	848	270	1,118	8
HVAC - EER 10.5	7,396	836	278	1,114	12
HVAC - EER 11.5	7,396	826	278	1,104	22
HVAC - EER 12.5	7,396	818	278	1,096	30
PV - 3698 sqft	7,396	683	278	961	165
Roof - U=R15 rigid	7,396	849	277	1,126	0
Roof - U=R20 rigid	7,396	849	277	1,126	0
Walls - R19 batt	7,396	848	278	1,126	0
Walls - R21 batt	7,396	848	278	1,126	0
Walls - R21 batt + R5 rigid	7,396	848	278	1,126	0
Windows - U=0.43, SHGC=0.39	7,396	848	278	1,126	0
Windows - U=0.26, SHGC=0.37	7,396	848	277	1,125	1
Windows - U=0.22, SHGC=0.22	7,396	846	278	1,125	1
DG - 30kW microturbine	7,396	747	326	1,073	53

Table 4. FFSR - Alternatives Impact on TDVI

2.2 Multi-Tenant Retail Building – Corner Tenant

Type III construction, approximately 20,000 sf single-story slab on grade, accommodating 14 individual tenants averaging 1,400 sf each. The floor-to-floor height is 13'-0". 60% of the roof area is available for solar cells.

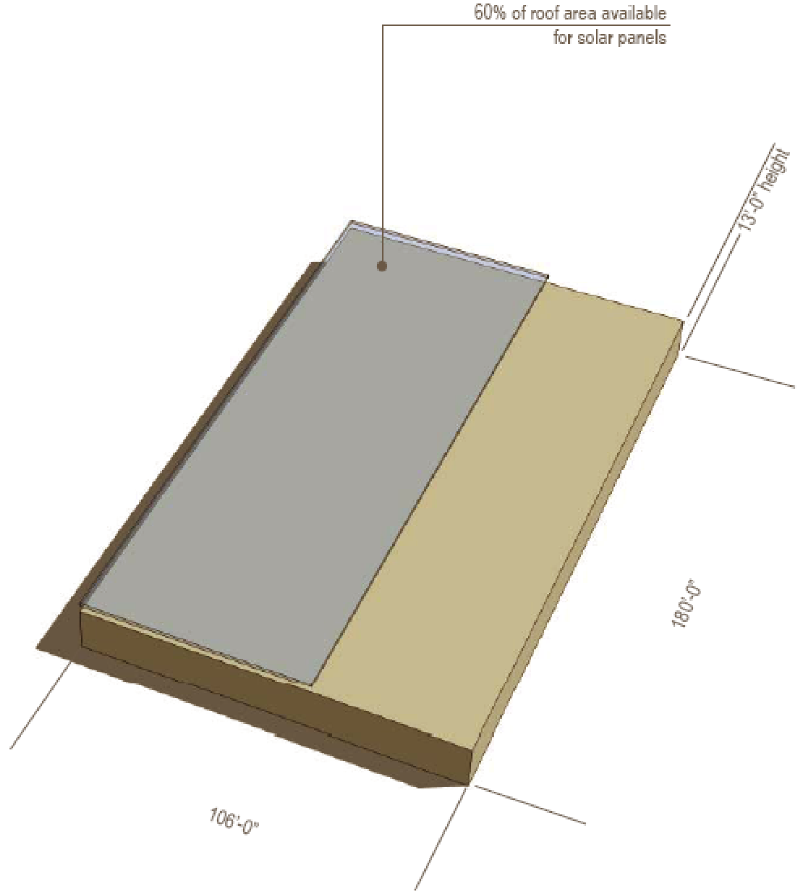

Figure 2. Multi-Tenant Retail Building

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 1
Photovoltaics	No PV	PV - 842 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 rigid	Roof - U=R15 rigid	Roof - U=R20 rigid	None	Alternative 2
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 2
Windows	Windows - U=0.57, SHGC=0.61	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 2
DG	None	None	None	None	No Alternative

Table 5. Multi-Tenant Retail Shop (MTRS) - Corner Tenant Alternatives

Prototype #2 Multi-Tenant Retail Shop - Corner Tenant					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$4,081	$1,698	$5,779	-	-
Package - Optimum EE	$3,912	$1,629	$5,541	$2,984	12.5
Package - Optimum EE + PV	$2,165	$1,629	$3,794	$44,402	22.9
CoolRoof - Abs=0.25	$4,061	$1,698	$5,759	$463	23.2
DHW - EF=0.640	$4,081	$1,678	$5,759	$310	15.5
DHW - EF=0.823	$4,081	$1,629	$5,710	$371	5.4
HVAC - EER 12.19, COP 3.52	$4,002	$1,698	$5,700	$443	5.6
HVAC - EER 12.06, COP 3.48	$4,021	$1,698	$5,719	$1,328	22.1
HVAC - EER 12.80, COP 3.66	$3,980	$1,698	$5,678	$2,213	21.9
PV - 842 sqft	$2,371	$1,698	$4,069	$41,881	21.4
Roof - U=R15 rigid	$4,070	$1,698	$5,768	$351	31.9
Roof - U=R20 rigid	$4,063	$1,698	$5,761	$632	35.1
Walls - R19 batt	$4,072	$1,698	$5,770	$192	21.4
Walls - R21 batt	$4,071	$1,698	$5,769	$262	26.2
Walls - R21 batt + R5 rigid	$4,067	$1,698	$5,765	$699	49.9
Windows - U=0.43, SHGC=0.39	$4,041	$1,698	$5,739	$272	6.8
Windows - U=0.26, SHGC=0.37	$4,040	$1,698	$5,738	$813	19.8
Windows - U=0.22, SHGC=0.22	$3,989	$1,698	$5,687	$2,483	27.0

Table 6. MTRS - Corner Tenant Alternatives Impact on Utility Costs & Paybacks

Prototype #2 Multi-Tenant Retail Shop - Corner Tenant					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	23,388	80	18	98	-
Package - Optimum EE	22,531	77	13	90	8
Package - Optimum EE + PV	8,282	28	13	41	57
CoolRoof - Abs=0.25	23,227	79	18	98	0
DHW - EF=0.640	23,388	80	17	97	1
DHW - EF=0.823	23,388	80	13	93	5
HVAC - EER 12.19, COP 3.52	23,028	79	18	97	1
HVAC - EER 12.06, COP 3.48	23,069	79	18	97	1
HVAC - EER 12.80, COP 3.66	22,863	78	18	96	2
PV - 842 sqft	9,517	32	18	51	47
Roof - U=R15 rigid	23,356	80	18	98	0
Roof - U=R20 rigid	23,331	80	18	98	0
Walls - R19 batt	23,342	80	18	98	0
Walls - R21 batt	23,328	80	18	98	0
Walls - R21 batt + R5 rigid	23,317	80	18	98	0
Windows - U=0.43, SHGC=0.39	23,076	79	18	97	1
Windows - U=0.26, SHGC=0.37	23,130	79	18	97	1
Windows - U=0.22, SHGC=0.22	22,790	78	18	96	2

Table 7. MTRS - Corner Tenant Alternatives Impact on Energy Consumption

Prototype #2 Multi-Tenant Retail Shop - Corner Tenant					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	1,404	317	14	331	-
Package - Optimum EE	1,404	302	10	312	19
Package - Optimum EE + PV	1,404	98	10	109	222
CoolRoof - Abs=0.25	1,404	314	14	329	2
DHW - EF=0.640	1,404	317	13	330	1
DHW - EF=0.823	1,404	317	10	327	4
HVAC - EER 12.19, COP 3.52	1,404	310	14	325	6
HVAC - EER 12.06, COP 3.48	1,404	311	14	325	6
HVAC - EER 12.80, COP 3.66	1,404	307	14	322	9
PV - 842 sqft	1,404	117	14	131	200
Roof - U=R15 rigid	1,404	316	14	330	1
Roof - U=R20 rigid	1,404	316	14	330	1
Walls - R19 batt	1,404	316	14	330	1
Walls - R21 batt	1,404	316	14	330	1
Walls - R21 batt + R5 rigid	1,404	316	14	330	1
Windows - U=0.43, SHGC=0.39	1,404	312	14	326	5
Windows - U=0.26, SHGC=0.37	1,404	313	14	327	4
Windows - U=0.22, SHGC=0.22	1,404	307	14	322	9

Table 8. MTRS - Corner Tenant Alternatives Impact on TDVI

2.3 Multi-Tenant Retail Shop – Internal Tenant

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Photovoltaics	No PV	PV - 842 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 rigid	Roof - U=R15 rigid	Roof - U=R20 rigid	None	Alternative 2
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 2
Windows	Windows - U=0.57, SHGC=0.61	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3
DG	None	None	None	None	No Alternative

Table 9. Multi-Tenant Retail Shop (MTRS) - Internal Tenant Alternatives

Prototype #2 Multi-Tenant Retail Shop - Internal Tenant					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$4,025	$1,698	$23,018	-	-
Package - Optimum EE	$3,632	$1,629	$20,580	$5,241	11.3
Package - Optimum EE + PV	$1,982	$1,629	$7,379	$46,659	19.8
CoolRoof - Abs=0.25	$3,983	$1,698	$22,740	$463	11.0
DHW - EF=0.640	$4,025	$1,678	$23,018	$310	15.5
DHW - EF=0.823	$4,025	$1,629	$23,018	$371	5.4
HVAC - EER 12.19, COP 3.52	$3,935	$1,698	$22,654	$388	4.3
HVAC - EER 12.06, COP 3.48	$3,940	$1,698	$22,691	$1,163	13.7
HVAC - EER 12.80, COP 3.66	$3,904	$1,698	$22,420	$1,939	16.0
PV - 842 sqft	$2,378	$1,698	$9,700	$41,881	22.1
Roof - U=R15 rigid	$3,999	$1,698	$22,922	$351	13.5
Roof - U=R20 rigid	$3,972	$1,698	$22,759	$632	11.9
Walls - R19 batt	$4,006	$1,698	$22,950	$206	10.8
Walls - R21 batt	$4,005	$1,698	$22,940	$281	14.0
Walls - R21 batt + R5 rigid	$4,004	$1,698	$22,943	$748	35.6
Windows - U=0.43, SHGC=0.39	$3,982	$1,698	$22,746	$171	4.0
Windows - U=0.26, SHGC=0.37	$3,964	$1,698	$22,652	$510	8.4
Windows - U=0.22, SHGC=0.22	$3,928	$1,698	$22,474	$1,556	16.0

Table 10. MTRS - Internal Tenant Alternatives Impact on Utility Costs & Paybacks

Prototype #2 Multi-Tenant Retail Shop - Internal Tenant					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	23,018	79	18	97	-
Package - Optimum EE	20,580	70	13	83	14
Package - Optimum EE + PV	7,379	25	13	38	59
CoolRoof - Abs=0.25	22,740	78	18	96	1
DHW - EF=0.640	23,018	79	17	95	2
DHW - EF=0.823	23,018	79	13	92	5
HVAC - EER 12.19, COP 3.52	22,654	77	18	96	1
HVAC - EER 12.06, COP 3.48	22,691	77	18	96	1
HVAC - EER 12.80, COP 3.66	22,420	76	18	95	2
PV - 842 sqft	9,700	33	18	51	46
Roof - U=R15 rigid	22,922	78	18	96	1
Roof - U=R20 rigid	22,759	78	18	96	1
Walls - R19 batt	22,950	78	18	97	0
Walls - R21 batt	22,940	78	18	97	0
Walls - R21 batt + R5 rigid	22,943	78	18	97	0
Windows - U=0.43, SHGC=0.39	22,746	78	18	96	1
Windows - U=0.26, SHGC=0.37	22,652	77	18	96	1
Windows - U=0.22, SHGC=0.22	22,474	77	18	95	2

Table 11. MTRS - Internal Tenant Alternatives Impact on Energy Consumption

Prototype #2 Multi-Tenant Retail Shop - Internal Tenant					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	1,404	311	14	325	-
Package - Optimum EE	1,404	278	10	288	37
Package - Optimum EE + PV	1,404	85	10	96	229
CoolRoof - Abs=0.25	1,404	306	14	321	4
DHW - EF=0.640	1,404	311	13	324	1
DHW - EF=0.823	1,404	311	10	321	4
HVAC - EER 12.19, COP 3.52	1,404	304	14	318	7
HVAC - EER 12.06, COP 3.48	1,404	305	14	319	6
HVAC - EER 12.80, COP 3.66	1,404	300	14	315	10
PV - 842 sqft	1,404	117	14	132	193
Roof - U=R15 rigid	1,404	309	14	323	2
Roof - U=R20 rigid	1,404	307	14	321	4
Walls - R19 batt	1,404	310	14	324	1
Walls - R21 batt	1,404	310	14	324	1
Walls - R21 batt + R5 rigid	1,404	310	14	324	1
Windows - U=0.43, SHGC=0.39	1,404	306	14	321	4
Windows - U=0.26, SHGC=0.37	1,404	305	14	319	6
Windows - U=0.22, SHGC=0.22	1,404	302	14	317	8

Table 12. MTRS - Internal Tenant Alternatives Impact on TDVI

2.4 Major Retailer

Type III construction, approximately 32,500 sf free standing single-story slab on grade, typical of a larger department store with 25'-0" floor height and 75% of the roof area available for solar cells.

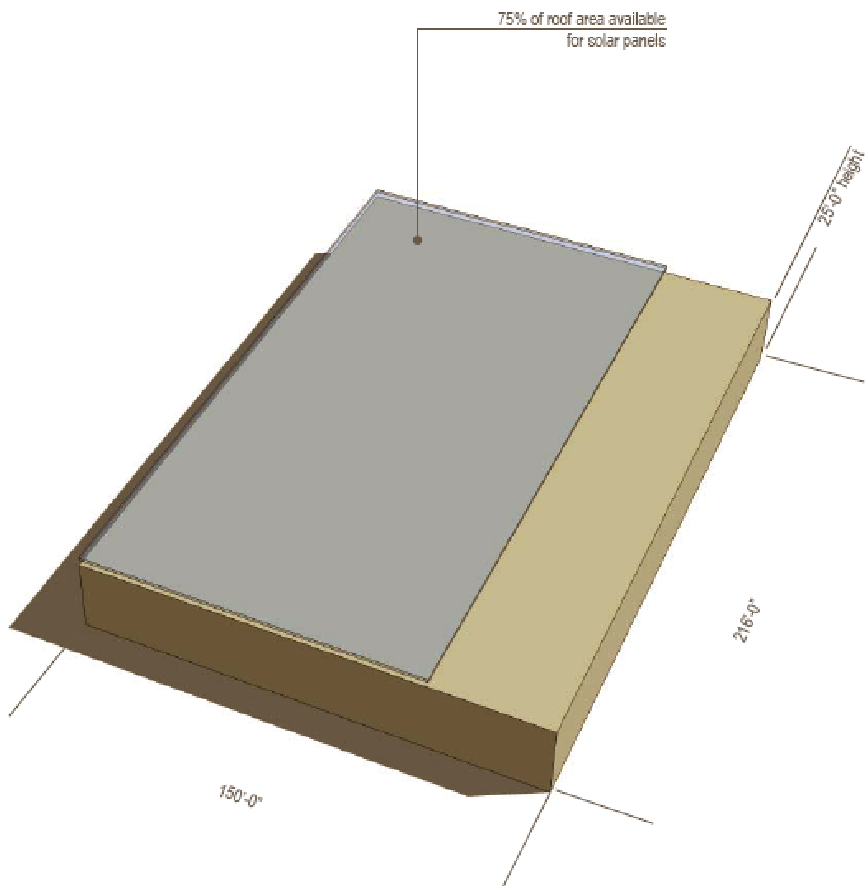

Figure 3. Major Retailer

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=75%	Heating - AFUE=85%	None	None	No Alternative
Space Cooling	HVAC - COP 4.90	HVAC - COP 6.13	None	None	Alternative 1
Photovoltaics	No PV	PV - 24300 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 rigid	Roof - U=R15 rigid	Roof - U=R20 rigid	None	Alternative 2
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 3
Windows	Windows - U=0.57, SHGC=0.61	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3
DG	None	DG - 60kW MT w/ 32 ton absorb	None	None	No Alternative
Thermal Strg	None	TS - 70% of max daily cooling load	None	None	No Alternative

Table 13. Major Retailer (MR) Alternatives

Prototype #3 Major Retailer					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$101,893	$7,292	$109,184	-	-
Package - Optimum EE	$91,124	$5,668	$96,793	$50,415	4.1
Package - Optimum EE + PV	$51,555	$5,663	$57,218	$1,247,840	21.9
CoolRoof - Abs=0.25	$99,992	$7,289	$107,281	$10,692	5.6
DHW - EF=0.640	$101,893	$6,876	$108,769	$310	0.7
DHW - EF=0.823	$101,893	$5,680	$107,572	$371	0.2
Heating - AFUE=85%	$101,893	$7,285	$109,178	$482	80.3
HVAC - COP 6.13	$96,201	$7,292	$103,493	$4,496	0.8
PV - 24300 sqft	$57,935	$7,299	$65,234	$1,208,117	24.6
Roof - U=R15 rigid	$101,264	$7,307	$108,572	$8,100	13.2
Roof - U=R20 rigid	$100,889	$7,306	$108,195	$14,580	14.7
Walls - R19 batt	$101,694	$7,295	$108,989	$1,812	9.3
Walls - R21 batt	$101,645	$7,295	$108,940	$2,471	10.1
Walls - R21 batt + R5 rigid	$101,384	$7,302	$108,686	$6,588	13.2
Windows - U=0.43, SHGC=0.39	$101,045	$7,293	$108,338	$1,501	1.8
Windows - U=0.26, SHGC=0.37	$101,140	$7,298	$108,438	$4,484	6.0
Windows - U=0.22, SHGC=0.22	$100,417	$7,298	$107,715	$13,688	9.3
DG - 60kW MT w/ 32 ton absorb	$83,776	$20,102	$104,551	$106,237	26.8
TS - 70% of max daily cooling load	-	-	$104,542	$62,878	13.5

Table 14. MR - Alternatives Impact on Utility Costs & Paybacks

Prototype #3 Major Retailer					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	669,102	2,283	426	2,709	-
Package - Optimum EE	608,177	2,075	308	2,383	326
Package - Optimum EE + PV	282,626	964	308	1,272	1,437
CoolRoof - Abs=0.25	657,589	2,244	426	2,670	39
DHW - EF=0.640	669,102	2,283	396	2,679	30
DHW - EF=0.823	669,102	2,283	309	2,592	117
Heating - AFUE=85%	669,102	2,283	426	2,709	0
HVAC - COP 6.13	635,823	2,169	426	2,596	113
PV - 24300 sqft	317,321	1,083	427	1,510	1,199
Roof - U=R15 rigid	666,808	2,275	427	2,702	7
Roof - U=R20 rigid	665,328	2,270	427	2,697	12
Walls - R19 batt	668,316	2,280	426	2,707	2
Walls - R21 batt	668,131	2,280	427	2,706	3
Walls - R21 batt + R5 rigid	666,985	2,276	427	2,703	6
Windows - U=0.43, SHGC=0.39	663,956	2,265	426	2,692	17
Windows - U=0.26, SHGC=0.37	664,780	2,268	427	2,695	14
Windows - U=0.22, SHGC=0.22	660,277	2,253	427	2,680	29
DG - 60kW MT w/ 32 ton absorb	556,236	1,898	1,421	3,319	-610
TS - 70% of max daily cooling load	Not Reported				

Table 15. MR - Alternatives Impact on Energy Consumption

Prototype #3 Major Retailer					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	32,400	398	14	412	-
Package - Optimum EE	32,400	359	10	369	43
Package - Optimum EE + PV	32,400	114	10	124	288
CoolRoof - Abs=0.25	32,400	391	14	405	7
DHW - EF=0.640	32,400	398	13	411	1
DHW - EF=0.823	32,400	398	10	408	4
Heating - AFUE=85%	32,400	398	14	412	0
HVAC - COP 6.13	32,400	377	14	391	21
PV - 24300 sqft	32,400	149	14	164	248
Roof - U=R15 rigid	32,400	396	14	411	1
Roof - U=R20 rigid	32,400	395	14	410	2
Walls - R19 batt	32,400	397	14	412	0
Walls - R21 batt	32,400	397	14	412	0
Walls - R21 batt + R5 rigid	32,400	396	14	411	1
Windows - U=0.43, SHGC=0.39	32,400	395	14	409	3
Windows - U=0.26, SHGC=0.37	32,400	395	14	410	2
Windows - U=0.22, SHGC=0.22	32,400	392	14	407	5
DG - 60kW MT w/ 32 ton absorb	32,400	322	49	371	41
TS - 70% of max daily cooling load	Not Reported				

Table 16. MR Alternatives Impact on TDVI

2.5 Office Building – Low-Rise

Type III construction, approximately 30,000 sf two-story slab on 15,000 sf grade, typical of a suburban office park. The floor-to-floor height is13'-0" and 60% of the roof area is available for solar cells.

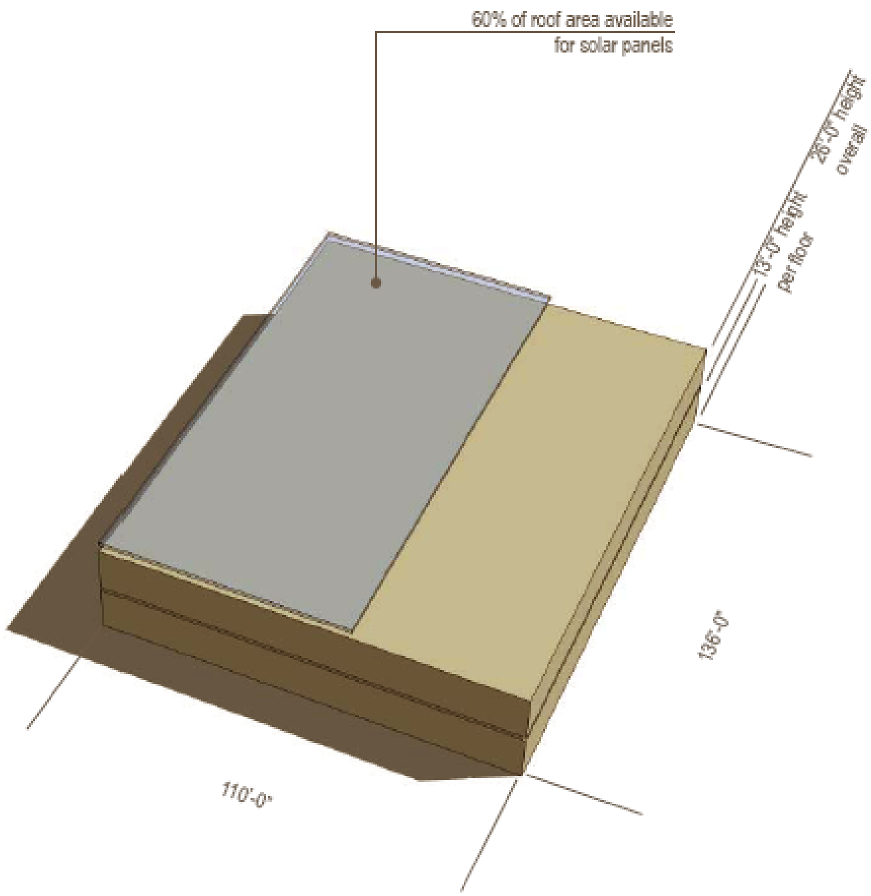

Figure 4. Office Building – Low-Rise

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Lighting	Lighting - 1.10 watts/sf	Lighting - 0.90 watts/sf	None	None	Alternative 1
Photovoltaics	No PV	PV - 8976 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 rigid	Roof - U=R15 rigid	Roof - U=R20 rigid	None	Alternative 2
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 2
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 17. Office Building - Low-Rise (OBLR) Alternatives

Prototype #4 Office Building - Low-Rise					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$57,790	$3,179	$60,969	-	-
Package - Optimum EE	$48,904	$2,727	$51,631	$90,874	9.7
Package - Optimum EE + PV	$29,187	$2,727	$31,914	$532,195	17.2
CoolRoof - Abs=0.25	$57,303	$3,179	$60,482	$4,937	10.1
DHW - EF=0.640	$57,790	$3,065	$60,855	$620	5.4
DHW - EF=0.823	$57,790	$2,727	$60,517	$741	1.6
HVAC - EER 12.19, COP 3.52	$55,995	$3,179	$59,174	$7,807	4.3
HVAC - EER 12.06, COP 3.48	$56,159	$3,179	$59,338	$23,422	14.4
HVAC - EER 12.80, COP 3.66	$55,163	$3,179	$58,342	$39,037	14.9
Lighting - 0.90 watts/sf	$54,017	$3,179	$57,196	$0	0.0
PV - 8976 sqft	$37,216	$3,179	$40,395	$446,258	19.4
Roof - U=R15 rigid	$57,633	$3,179	$60,812	$3,740	23.8
Roof - U=R20 rigid	$57,507	$3,179	$60,686	$6,732	23.8
Walls - R19 batt	$57,743	$3,179	$60,922	$844	18.0
Walls - R21 batt	$57,735	$3,179	$60,914	$1,151	20.9
Walls - R21 batt + R5 rigid	$57,709	$3,179	$60,888	$3,070	37.9
Windows - U=0.43, SHGC=0.39	$57,807	$3,179	$60,986	$4,196	Never
Windows - U=0.26, SHGC=0.37	$57,715	$3,179	$60,894	$12,537	167.2
Windows - U=0.22, SHGC=0.22	$55,447	$3,179	$58,626	$38,275	16.3

Table 18. OBLR - Alternatives Impact on Utility Costs & Paybacks

Prototype #4 Office Building - Low-Rise					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	332,469	1,134	249	1,384	-
Package - Optimum EE	285,304	973	215	1,188	196
Package - Optimum EE + PV	140,418	479	215	694	690
CoolRoof - Abs=0.25	330,023	1,126	249	1,375	9
DHW - EF=0.640	332,469	1,134	241	1,375	9
DHW - EF=0.823	332,469	1,134	215	1,349	35
HVAC - EER 12.19, COP 3.52	324,079	1,106	249	1,355	29
HVAC - EER 12.06, COP 3.48	324,940	1,109	249	1,358	26
HVAC - EER 12.80, COP 3.66	320,072	1,092	249	1,341	43
Lighting - 0.90 watts/sf	311,084	1,061	249	1,311	73
PV - 8976 sqft	186,338	636	249	885	499
Roof - U=R15 rigid	332,158	1,133	249	1,383	1
Roof - U=R20 rigid	331,336	1,131	249	1,380	4
Walls - R19 batt	332,247	1,134	249	1,383	1
Walls - R21 batt	332,188	1,133	249	1,383	1
Walls - R21 batt + R5 rigid	332,098	1,133	249	1,382	2
Windows - U=0.43, SHGC=0.39	332,691	1,135	249	1,384	0
Windows - U=0.26, SHGC=0.37	332,701	1,135	249	1,384	0
Windows - U=0.22, SHGC=0.22	320,189	1,092	249	1,342	42

Table 19. OBLR - Alternatives Impact on Energy Consumption

Prototype #4 Office Building - Low-Rise					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	29,920	214	9	223	-
Package - Optimum EE	29,920	182	8	190	33
Package - Optimum EE + PV	29,920	84	8	92	131
CoolRoof - Abs=0.25	29,920	212	9	221	2
DHW - EF=0.640	29,920	214	9	223	0
DHW - EF=0.823	29,920	214	8	222	1
HVAC - EER 12.19, COP 3.52	29,920	208	9	217	6
HVAC - EER 12.06, COP 3.48	29,920	209	9	218	5
HVAC - EER 12.80, COP 3.66	29,920	205	9	214	9
Lighting - 0.90 watts/sf	29,920	200	9	209	14
PV - 8976 sqft	29,920	115	9	124	99
Roof - U=R15 rigid	29,920	214	9	223	0
Roof - U=R20 rigid	29,920	213	9	222	1
Walls - R19 batt	29,920	214	9	223	0
Walls - R21 batt	29,920	214	9	223	0
Walls - R21 batt + R5 rigid	29,920	214	9	223	0
Windows - U=0.43, SHGC=0.39	29,920	214	9	223	0
Windows - U=0.26, SHGC=0.37	29,920	214	9	223	0
Windows - U=0.22, SHGC=0.22	29,920	205	9	215	8

Table 20. OBLR - Alternatives Impact on TDVI

2.6 Office Building – Mid-Rise

Type II construction, approximately 100,000 sf four-story slab on 25,000 sf grade, typical of a suburban office park. The floor-to-floor height is 13'-0" and 60% of the roof area available for solar cells.

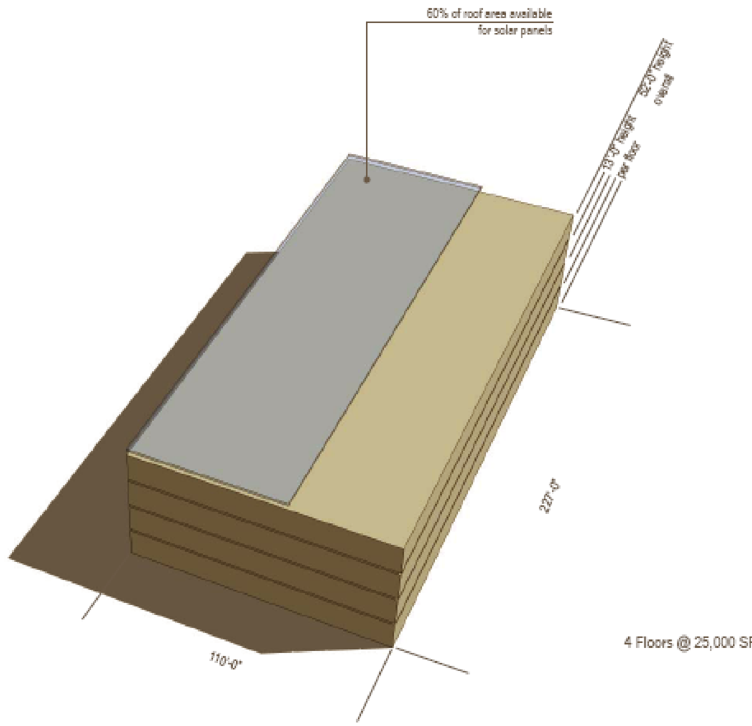

Figure 5. Office Building – Mid-Rise

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=75%	Heating - AFUE=85%	None	None	No Alternative
Space Cooling	HVAC - COP 4.90	HVAC - COP 6.13	None	None	Alternative 1
Lighting	Lighting - 1.10 watts/sf	Lighting - 0.90 watts/sf	None	None	Alternative 1
Photovoltaics	No PV	PV - 14982 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 rigid	Roof - R15 rigid	Roof - R20 rigid	None	Alternative 2
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 3
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3
DG	None	DG - 180 kW MT w/ 78 ton absorb	None	None	No Alternative
Thermal Strg	None	TS - 65% of max daily cooling load	None	None	No Alternative

Table 21. Office Building - Mid-Rise (OBMR) Alternatives

Prototype #5 Office Building - Mid-Rise					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$219,910	$13,085	$232,995	-	-
Package - Optimum EE	$181,419	$11,385	$192,805	$136,780	3.4
Package - Optimum EE + PV	$147,838	$11,383	$159,221	$873,397	11.7
CoolRoof - Abs=0.25	$218,164	$13,088	$231,252	$8,240	4.7
DHW - EF=0.640	$219,910	$12,677	$232,586	$620	1.5
DHW - EF=0.823	$219,910	$11,509	$231,419	$741	0.5
Heating - AFUE=85%	$219,910	$13,056	$232,966	$3,113	107.3
HVAC - COP 6.13	$208,294	$13,085	$221,379	$5,602	0.5
Lighting - 0.90 watts/sf	$205,226	$13,116	$218,341	$0	0.0
PV - 14982 sqft	$183,667	$13,085	$196,752	$744,856	19.5
Roof - R15 rigid	$219,254	$13,040	$232,294	$6,243	8.9
Roof - R20 rigid	$218,762	$13,008	$231,769	$11,237	9.2
Walls - R19 batt	$219,697	$13,060	$232,757	$2,313	9.7
Walls - R21 batt	$219,676	$13,056	$232,733	$3,154	12.0
Walls - R21 batt + R5 rigid	$219,498	$13,034	$232,532	$6,098	13.2
Windows - U=0.43, SHGC=0.39	$219,753	$13,030	$232,783	$11,496	54.2
Windows - U=0.26, SHGC=0.37	$219,348	$12,965	$232,314	$34,347	50.4
Windows - U=0.22, SHGC=0.22	$208,107	$13,012	$221,119	$104,862	8.8
DG - 180 kW MT w/ 78 ton absorb	$104,987	$102,209	$212,077	$267,538	17.8
TS - 65% of max daily cooling load	-	-	$221,873	$138,483	12.5

Table 22. OBMR - Alternatives Impact on Utility Costs & Paybacks

Prototype #5 Office Building - Mid-Rise					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	1,255,518	4,284	849	5,133	-
Package - Optimum EE	1,049,509	3,581	724	4,305	828
Package - Optimum EE + PV	828,819	2,828	724	3,552	1,581
CoolRoof - Abs=0.25	1,245,931	4,251	849	5,100	33
DHW - EF=0.640	1,255,518	4,284	819	5,103	30
DHW - EF=0.823	1,255,518	4,284	734	5,018	115
Heating - AFUE=85%	1,255,518	4,284	847	5,131	2
HVAC - COP 6.13	1,196,117	4,081	849	4,930	203
Lighting - 0.90 watts/sf	1,171,319	3,997	851	4,848	285
PV - 14982 sqft	1,028,241	3,508	849	4,357	776
Roof - R15 rigid	1,252,773	4,274	846	5,120	13
Roof - R20 rigid	1,250,958	4,268	843	5,111	22
Walls - R19 batt	1,254,671	4,281	847	5,128	5
Walls - R21 batt	1,254,584	4,281	847	5,128	5
Walls - R21 batt + R5 rigid	1,253,766	4,278	845	5,123	10
Windows - U=0.43, SHGC=0.39	1,255,808	4,285	845	5,130	3
Windows - U=0.26, SHGC=0.37	1,255,242	4,283	840	5,123	10
Windows - U=0.22, SHGC=0.22	1,192,964	4,070	843	4,914	219
DG - 180 kW MT w/ 78 ton absorb	525,098	1,792	8,630	10,422	-5,289
TS - 65% of max daily cooling load	Not Reported				

Table 23. OBMR - Alternatives Impact on Energy Consumption

Prototype #5 Office Building - Mid-Rise					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	99,880	244	9	253	-
Package - Optimum EE	99,880	202	8	210	3
Package - Optimum EE + PV	99,880	153	8	161	12
CoolRoof - Abs=0.25	99,880	242	9	251	5
DHW - EF=0.640	99,880	244	9	253	2
DHW - EF=0.823	99,880	244	8	252	0
Heating - AFUE=85%	99,880	244	9	253	107
HVAC - COP 6.13	99,880	232	9	241	0
Lighting - 0.90 watts/sf	99,880	228	9	237	0
PV - 14982 sqft	99,880	194	9	204	20
Roof - R15 rigid	99,880	243	9	253	9
Roof - R20 rigid	99,880	243	9	252	9
Walls - R19 batt	99,880	244	9	253	10
Walls - R21 batt	99,880	244	9	253	12
Walls - R21 batt + R5 rigid	99,880	243	9	253	13
Windows - U=0.43, SHGC=0.39	99,880	244	9	253	54
Windows - U=0.26, SHGC=0.37	99,880	244	9	253	50
Windows - U=0.22, SHGC=0.22	99,880	231	9	240	9
DG - 180 kW MT w/ 78 ton absorb	99,880	103	96	198	18
TS - 65% of max daily cooling load	99,880	Not Reported			12

Table 24. OBMR - Alternatives Impact on TDVI

2.7 Office Building – High-Rise

Type I construction, approximately 225,000 sf nine-story at 25,000 sf per floor, two floors of subterranean parking. The floor-to-floor height is 13'-6" and 25% of the roof area is available for solar cells.

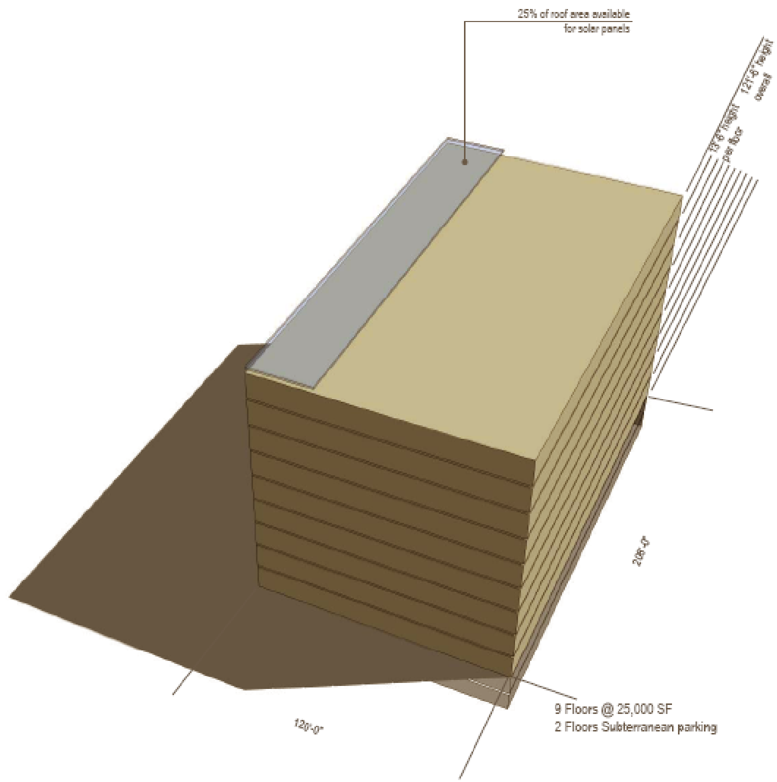

Figure 6. Office Building – High-Rise

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=75%	Heating - AFUE=85%	None	None	No Alternative
Space Cooling	HVAC - COP 6.10	HVAC - COP 7.63	None	None	Alternative 1
Lighting	Lighting - 1.10 watts/sf	Lighting - 0.90 watts/sf	None	None	Alternative 1
Photovoltaics	No PV	PV - 5616 sqft	None	None	Alternative 1
Roof Insulation	Roof - Light wt. Concrete	Roof R5 rigid	Roof R10 rigid	None	No Alternative
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 3
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3
DG	None	DG - 800 kW Eng w/ 177 ton absorb	None	None	Alternative 1
Thermal Strg	None	TS - 55% of max daily cooling load	None	None	No Alternative

Table 25 Office Building - High-Rise (OBHR) Alternatives

Prototype #6 Office Building - High-Rise					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$536,318	$26,576	$562,894	-	-
Package - Optimum EE	$462,457	$22,968	$485,426	$281,601	3.6
Package - Optimum EE + PV	$448,746	$22,851	$471,597	$553,397	6.1
Package - Optimum EE + DG	$135,471	$248,886	$384,356	$1,099,699	6.2
CoolRoof - Abs=0.25	$534,868	$26,685	$561,553	$7,413	5.5
DHW - EF=0.640	$536,318	$25,830	$562,149	$1,239	1.7
DHW - EF=0.823	$536,318	$23,693	$560,011	$1,483	0.5
Heating - AFUE=85%	$536,318	$26,431	$562,750	$5,587	38.8
HVAC - COP 7.63	$516,287	$26,576	$542,863	$33,308	1.7
Lighting - 0.90 watts/sf	$507,155	$26,690	$533,845	$0	0.0
PV - 5616 sqft	$519,585	$26,576	$546,160	$279,209	16.7
Roof R5 rigid	$536,530	$26,370	$562,900	$5,616	Never
Roof R10 rigid	$536,689	$26,330	$563,019	$10,109	Never
Walls - R19 batt	$535,625	$26,439	$562,064	$4,990	6.0
Walls - R21 batt	$535,393	$26,390	$561,783	$6,805	6.1
Walls - R21 batt + R5 rigid	$533,781	$26,134	$559,915	$13,157	4.4
Windows - U=0.43, SHGC=0.39	$535,700	$26,223	$561,923	$24,802	25.5
Windows - U=0.26, SHGC=0.37	$535,638	$25,823	$561,461	$74,103	51.7
Windows - U=0.22, SHGC=0.22	$512,457	$25,908	$538,365	$226,240	9.2
DG - 800 kW Eng w/ 177 ton absorb	$150,079	$275,477	$425,555	$818,098	7.4
TS - 55% of max daily cooling load	-	-	$548,060	$264,297	17.8

Table 26. OBHR Alternatives Impact on Utility Costs & Paybacks

Prototype #6 Office Building - High-Rise					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	3,167,371	10,807	1,972	12,779	-
Package - Optimum EE	2,750,753	9,386	1,651	11,036	38
Package - Optimum EE + PV	2,667,247	9,101	1,640	10,741	45
Package - Optimum EE + DG	684,148	2,334	21,807	24,141	0
CoolRoof - Abs=0.25	3,159,191	10,779	1,982	12,761	0
DHW - EF=0.640	3,167,371	10,807	1,906	12,713	0
DHW - EF=0.823	3,167,371	10,807	1,715	12,522	1
Heating - AFUE=85%	3,167,371	10,807	1,960	12,767	0
HVAC - COP 7.63	3,064,212	10,455	1,972	12,427	9
Lighting - 0.90 watts/sf	2,997,716	10,228	1,983	12,211	14
PV - 5616 sqft	3,065,739	10,460	1,972	12,433	9
Roof R5 rigid	3,167,991	10,809	1,954	12,763	0
Roof R10 rigid	3,168,821	10,812	1,950	12,762	0
Walls - R19 batt	3,165,485	10,801	1,960	12,761	0
Walls - R21 batt	3,165,240	10,800	1,956	12,756	0
Walls - R21 batt + R5 rigid	3,161,814	10,788	1,933	12,721	1
Windows - U=0.43, SHGC=0.39	3,168,383	10,811	1,941	12,752	0
Windows - U=0.26, SHGC=0.37	3,180,638	10,852	1,905	12,757	-1
Windows - U=0.22, SHGC=0.22	3,022,895	10,314	1,913	12,227	12
DG - 800 kW Eng w/ 177 ton absorb	794,409	2,711	24,203	26,914	102
TS - 55% of max daily cooling load	Not Reported				

Table 27. OBHR Alternatives Impact on Energy Consumption

Table 28. OBHR Alternatives Impact on TDVI

Prototype #6 Office Building - High-Rise					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	224,640	271	10	280	-
Package - Optimum EE	224,640	234	8	242	38
Package - Optimum EE + PV	224,640	227	8	235	45
Package - Optimum EE + DG	224,640	50	107	158	0
CoolRoof - Abs=0.25	224,640	270	10	280	0
DHW - EF=0.640	224,640	271	9	280	0
DHW - EF=0.823	224,640	271	8	279	1
Heating - AFUE=85%	224,640	271	10	280	0
HVAC - COP 7.63	224,640	261	10	271	9
Lighting - 0.90 watts/sf	224,640	256	10	266	14
PV - 5616 sqft	224,640	262	10	271	9
Roof R5 rigid	224,640	271	10	280	0
Roof R10 rigid	224,640	271	10	280	0
Walls - R19 batt	224,640	271	10	280	0
Walls - R21 batt	224,640	271	10	280	0
Walls - R21 batt + R5 rigid	224,640	270	9	279	1
Windows - U=0.43, SHGC=0.39	224,640	271	9	280	0
Windows - U=0.26, SHGC=0.37	224,640	271	9	281	-1
Windows - U=0.22, SHGC=0.22	224,640	259	9	268	12
DG - 800 kW Eng w/ 177 ton absorb	224,640	59	119	178	102
TS - 55% of max daily cooling load	224,640	0	0	0	0

2.8 Large Hotel – Hotel Space

Type II construction, approximately 171,000 sf, six-story slab on 54,000 sf grade. First floor at 16,000 sf includes a 7,400 sf restaurant and meeting rooms. Five upper floors at 16,000 sf each are guest rooms. Two-story adjacent sports club at 37,500 sf per floor. The floor-to-floor height is 14’-0” except guest rooms are 9’-6”. 45% of the roof area is available for solar cells.

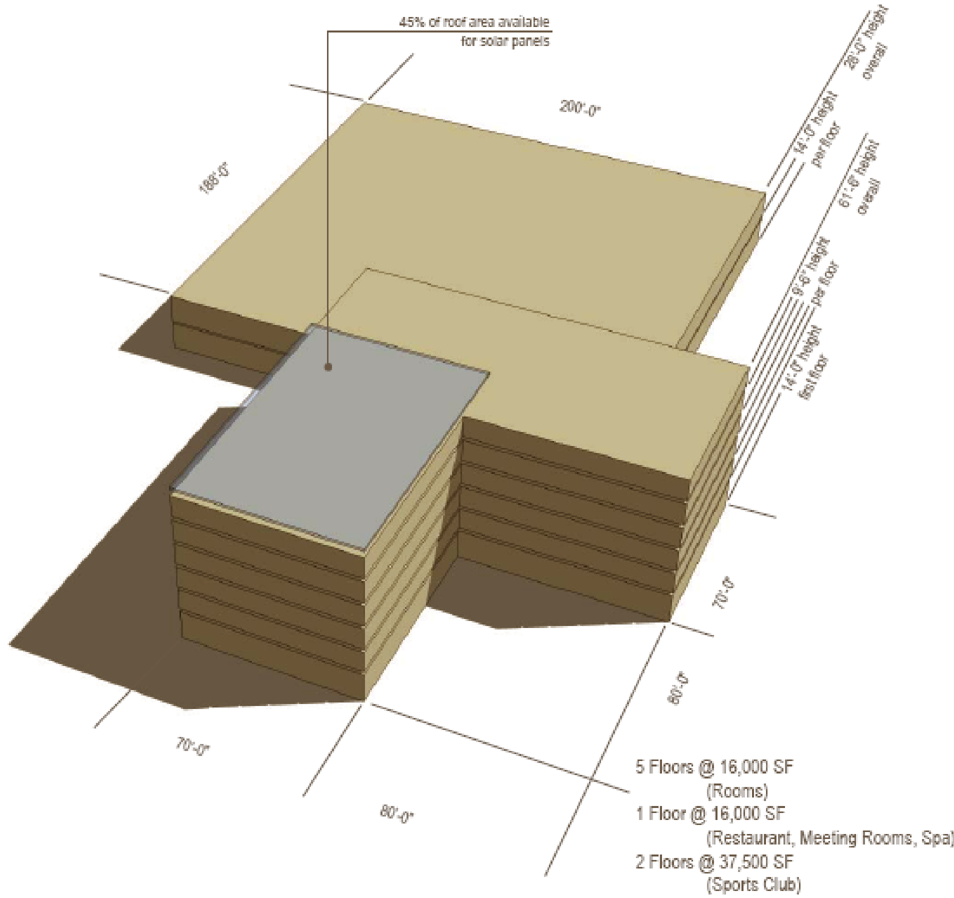

Figure 7. Large Hotel

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	No Alternative
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=75%	Heating - AFUE=85%	None	None	Alternative 1
Space Cooling	HVAC - COP 6.10	HVAC - COP 7.63	None	None	Alternative 1
Lighting	Lighting - 1.40 watts/sf	Lighting - 1.19 watts/sf	None	None	Alternative 1
Photovoltaics	No PV	PV - 7199 sqft	None	None	Alternative 1
Roof Insulation	Roof - R20 rigid	Roof - R25 rigid	Roof - R30 rigid	None	No Alternative
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	None	No Alternative
DG	None	DG - 120 kW MT w/ 35 ton absorb	None	None	No Alternative
Thermal Strg	None	TS - 20% of max daily cooling load	None	None	No Alternative

Table 29. Large Hotel - Hotel Space (LHHS) Alternatives

Prototype #7 Large Hotel - Hotel Space					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$202,183	$57,107	$259,289	-	-
Package - Optimum EE	$186,438	$47,260	$233,698	$74,975	2.9
Package - Optimum EE + PV	$172,118	$47,260	$219,378	$432,868	11.0
CoolRoof - Abs=0.25	$202,386	$58,223	$260,609	$5,279	Never
DHW - EF=0.640	$202,183	$54,924	$257,107	$2,168	1.0
DHW - EF=0.823	$202,183	$48,653	$250,836	$2,594	0.3
Heating - AFUE=85%	$202,183	$55,709	$257,892	$1,157	0.8
HVAC - COP 7.63	$196,088	$57,107	$253,194	$11,374	1.9
Lighting - 1.19 watts/sf	$192,293	$57,117	$249,409	$59,850	6.1
PV - 7199 sqft	$185,145	$57,107	$242,252	$357,894	21.0
Roof - R25 rigid	$202,164	$57,108	$259,272	$3,999	235.3
Roof - R30 rigid	$202,158	$57,110	$259,267	$7,199	327.2
Walls - R19 batt	$202,255	$57,051	$259,306	$2,511	Never
Walls - R21 batt	$202,286	$57,032	$259,318	$6,620	Never
Walls - R21 batt + R5 rigid	$202,364	$56,967	$259,331	$6,620	Never
Windows - U=0.26, SHGC=0.37	$202,392	$57,002	$259,394	$35,726	Never
Windows - U=0.22, SHGC=0.22	$196,913	$57,289	$254,202	$109,073	21.4
DG - 120 kW MT w/ 35 ton absorb	-	-	$252,597	$107,971	60.4
TS - 20% of max daily cooling load	-	-	$256,470	$43,791	15.5

Table 30. LHHS Alternatives Impact on Utility Costs & Paybacks

Prototype #7 Large Hotel - Hotel Space					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	1,472,537	5,024	4,698	9,722	-
Package - Optimum EE	1,366,154	4,661	3,819	8,480	1,242
Package - Optimum EE + PV	1,248,903	4,261	3,819	8,080	1,642
CoolRoof - Abs=0.25	1,474,051	5,029	4,797	9,826	-104
DHW - EF=0.640	1,472,537	5,024	4,503	9,527	195
DHW - EF=0.823	1,472,537	5,024	3,943	8,967	755
Heating - AFUE=85%	1,472,537	5,024	4,573	9,597	125
HVAC - COP 7.63	1,431,645	4,885	4,698	9,582	140
Lighting - 1.19 watts/sf	1,405,196	4,795	4,699	9,493	229
PV - 7199 sqft	1,332,956	4,548	4,698	9,246	476
Roof - R25 rigid	1,472,607	5,025	4,698	9,722	0
Roof - R30 rigid	1,472,681	5,025	4,698	9,722	0
Walls - R19 batt	1,473,413	5,027	4,692	9,720	2
Walls - R21 batt	1,473,740	5,028	4,691	9,719	3
Walls - R21 batt + R5 rigid	1,474,734	5,032	4,685	9,717	5
Windows - U=0.26, SHGC=0.37	1,476,249	5,037	4,688	9,725	-3
Windows - U=0.22, SHGC=0.22	1,435,843	4,899	4,714	9,613	109
DG - 120 kW MT w/ 35 ton absorb	Not Reported				
TS - 20% of max daily cooling load	Not Reported				

Table 31. LHHS Alternatives Impact on Energy Consumption

Prototype #7 Large Hotel - Hotel Space					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	114,266	233	45	278	-
Package - Optimum EE	114,266	215	37	252	26
Package - Optimum EE + PV	114,266	195	37	231	47
CoolRoof - Abs=0.25	114,266	233	46	279	-1
DHW - EF=0.640	114,266	233	43	276	2
DHW - EF=0.823	114,266	233	38	271	7
Heating - AFUE=85%	114,266	233	44	277	1
HVAC - COP 7.63	114,266	226	45	271	7
Lighting - 1.19 watts/sf	114,266	222	45	267	11
PV - 7199 sqft	114,266	208	45	253	25
Roof - R25 rigid	114,266	233	45	278	0
Roof - R30 rigid	114,266	233	45	278	0
Walls - R19 batt	114,266	233	45	278	0
Walls - R21 batt	114,266	233	45	278	0
Walls - R21 batt + R5 rigid	114,266	233	45	278	0
Windows - U=0.26, SHGC=0.37	114,266	233	45	278	0
Windows - U=0.22, SHGC=0.22	114,266	227	45	272	6
DG - 120 kW MT w/ 35 ton absorb	Not Reported				
TS - 20% of max daily cooling load	Not Reported				

Table 32. LHHS Alternatives Impact on TDVI

2.9 Large Hotel – Restaurant Space

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	No Alternative
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=80%	Heating - AFUE=94%	None	None	Alternative 1
Space Cooling	HVAC - EER 9.5	HVAC - EER 10.5	HVAC - EER 11.5	HVAC - EER 12.5	Alternative 3
Photovoltaics	No PV	PV - 3698 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 rigid	Roof - U=R15 rigid	Roof - U=R20 rigid	None	No Alternative
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 1
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	No Alternative

Table 33. Large Hotel – Restaurant Space (LHRS) Alternatives

Prototype #7 Large Hotel - Restaurant					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	332,563	1,135	1,867	3,002	-
Package - Optimum EE	322,385	1,100	1,675	2,775	227
Package - Optimum EE + PV	262,161	894	1,675	2,569	433
CoolRoof - Abs=0.25	331,885	1,132	1,872	3,004	-2
DHW - EF=0.640	332,563	1,135	1,831	2,966	36
DHW - EF=0.823	332,563	1,135	1,729	2,864	138
Heating - AFUE=94%	332,563	1,135	1,812	2,947	55
HVAC - EER 10.5	328,551	1,121	1,867	2,988	14
HVAC - EER 11.5	325,236	1,110	1,867	2,977	25
HVAC - EER 12.5	322,452	1,100	1,867	2,967	35
PV - 3698 sqft	272,338	929	1,867	2,796	206
Roof - U=R15 rigid	333,078	1,136	1,858	2,994	8
Roof - U=R20 rigid	333,342	1,137	1,855	2,992	10
Walls - R19 batt	332,503	1,135	1,867	3,002	0
Walls - R21 batt	332,496	1,134	1,868	3,002	0
Walls - R21 batt + R5 rigid	332,504	1,135	1,868	3,002	0
Windows - U=0.43, SHGC=0.39	332,450	1,134	1,867	3,002	0
Windows - U=0.26, SHGC=0.37	332,337	1,134	1,863	2,997	5
Windows - U=0.22, SHGC=0.22	332,997	1,136	1,883	3,019	-17

Table 34. LHRS Alternatives Impact on Utility Costs & Paybacks

Prototype #7 Large Hotel - Restaurant					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$48,644	$25,387	$74,030	-	-
Package - Optimum EE	$46,811	$23,238	$70,049	$21,313	5.4
Package - Optimum EE + PV	$39,688	$23,238	$62,927	$205,166	19.1
CoolRoof - Abs=0.25	$48,525	$25,446	$73,971	$2,441	41.4
DHW - EF=0.640	$48,644	$24,989	$73,632	$620	1.6
DHW - EF=0.823	$48,644	$23,844	$72,488	$741	0.5
Heating - AFUE=94%	$48,644	$24,775	$73,419	$1,000	1.6
HVAC - EER 10.5	$47,924	$25,387	$73,311	$16,098	22.4
HVAC - EER 11.5	$47,329	$25,387	$72,716	$18,007	13.7
HVAC - EER 12.5	$46,830	$25,387	$72,217	$19,178	10.6
PV - 3698 sqft	$41,486	$25,387	$66,872	$183,853	25.7
Roof - U=R15 rigid	$48,696	$25,288	$73,984	$1,849	40.2
Roof - U=R20 rigid	$48,734	$25,254	$73,988	$3,328	79.2
Walls - R19 batt	$48,623	$25,393	$74,016	$394	28.1
Walls - R21 batt	$48,621	$25,394	$74,016	$537	38.3
Walls - R21 batt + R5 rigid	$48,612	$25,398	$74,009	$1,431	68.1
Windows - U=0.43, SHGC=0.39	$48,615	$25,396	$74,011	$733	38.6
Windows - U=0.26, SHGC=0.37	$48,593	$25,343	$73,935	$19,178	201.9
Windows - U=0.22, SHGC=0.22	$48,740	$25,574	$74,314	$19,178	Never

Table 35. LHRS Alternatives Impact on Energy Consumption

Prototype #7 Large Hotel - Restaurant					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	7,396	844	277	1,121	-
Package - Optimum EE	7,396	815	248	1,063	58
Package - Optimum EE + PV	7,396	650	248	898	223
CoolRoof - Abs=0.25	7,396	843	278	1,120	1
DHW - EF=0.640	7,396	844	272	1,116	5
DHW - EF=0.823	7,396	844	256	1,101	20
Heating - AFUE=94%	7,396	844	269	1,113	8
HVAC - EER 10.5	7,396	833	277	1,110	11
HVAC - EER 11.5	7,396	823	277	1,100	21
HVAC - EER 12.5	7,396	815	277	1,092	29
PV - 3698 sqft	7,396	679	277	956	165
Roof - U=R15 rigid	7,396	846	276	1,121	0
Roof - U=R20 rigid	7,396	846	275	1,122	-1
Walls - R19 batt	7,396	844	277	1,121	0
Walls - R21 batt	7,396	844	277	1,121	0
Walls - R21 batt + R5 rigid	7,396	844	277	1,121	0
Windows - U=0.43, SHGC=0.39	7,396	844	277	1,121	0
Windows - U=0.26, SHGC=0.37	7,396	844	276	1,120	1
Windows - U=0.22, SHGC=0.22	7,396	846	279	1,126	-5

Table 36. LHRS Alternatives Impact on TDVI

2.10 Small Hotel – Hotel Space

Type III construction, approximately 152,000 sf three-story slab on 102,600 sf grade. Guest rooms and commercial space are located at upper two levels. The first level includes a 7,400 sf restaurant, retail and the hotel lobby. Interior floor space demised to accommodate 19 individual retail tenants at street level averaging 2,700 sf each. The first level floor-to-floor height is 20'-0". The guest room levels are 9'-6". 60% of the roof area is available for solar cells. Adjacent to the hotel complex is a two-story parking structure, approximately 68,000 sf.

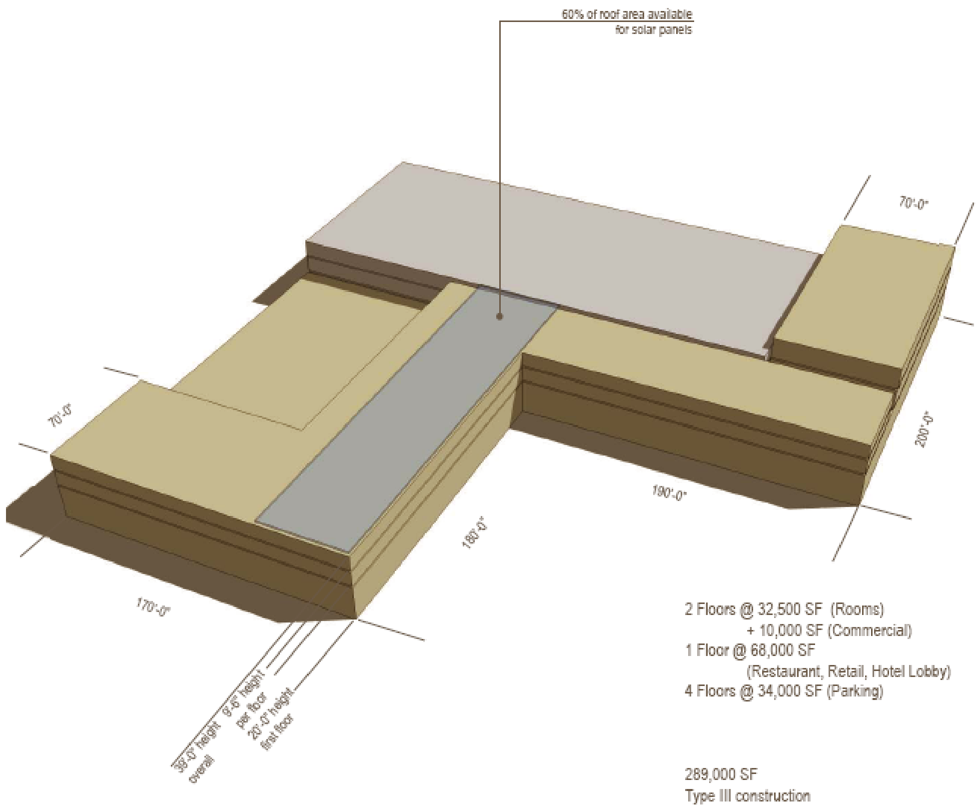

Figure 8. Small Hotel

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=75%	Heating - AFUE=85%	None	None	Alternative 1
Space Cooling	HVAC - COP 6.10	HVAC - COP 7.63	None	None	Alternative 1
Lighting	Lighting - 1.40 watts/sf	Lighting - 1.19 watts/sf	None	None	Alternative 1
Photovoltaics	No PV	PV - 11391 sqft	None	None	Alternative 1
Roof Insulation	Roof - R20 rigid	Roof - R25 rigid	Roof - R30 rigid	None	No Alternative
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 3
Windows	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	None	No Alternative

Table 37. Small Hotel – Hotel Space (SHHS) Alternatives

Prototype #8 Small Hotel - Hotel Space					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$131,231	$45,478	$176,710	-	-
Package - Optimum EE	$121,210	$37,570	$158,780	$68,415	3.8
Package - Optimum EE + PV	$98,960	$37,570	$136,530	$634,753	16.2
DHW - EF=0.640	$131,231	$43,750	$174,981	$1,859	1.1
DHW - EF=0.823	$131,231	$38,789	$170,021	$2,224	0.3
Heating - AFUE=85%	$131,231	$44,251	$175,483	$953	0.8
HVAC - COP 7.63	$127,378	$45,478	$172,856	$7,964	2.1
Lighting - 1.19 watts/sf	$124,915	$45,483	$170,398	$48,600	7.7
PV - 11391 sqft	$103,249	$45,478	$148,728	$566,339	20.1
Roof - R25 rigid	$131,219	$45,479	$176,699	$6,329	575.3
Roof - R30 rigid	$131,404	$45,476	$176,880	$11,391	Never
Walls - R19 batt	$131,203	$45,412	$176,615	$2,385	25.1
Walls - R21 batt	$131,183	$45,399	$176,582	$3,253	25.4
Walls - R21 batt + R5 rigid	$131,091	$45,350	$176,441	$8,674	32.2
Windows - U=0.26, SHGC=0.37	$131,394	$45,380	$176,773	$22,584	Never
Windows - U=0.22, SHGC=0.22	$127,922	$45,641	$173,562	$68,951	21.9

Table 38. SHHS Alternatives Impact on Utility Costs & Paybacks

Prototype #8 Small Hotel - Hotel Space					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	952,639	3,250	3,660	6,910	-
Package - Optimum EE	885,766	3,022	2,954	5,976	934
Package - Optimum EE + PV	700,295	2,389	2,954	5,344	1,566
DHW - EF=0.640	952,639	3,250	3,506	6,756	154
DHW - EF=0.823	952,639	3,250	3,063	6,314	596
Heating - AFUE=85%	952,639	3,250	3,551	6,801	109
HVAC - COP 7.63	927,470	3,165	3,660	6,825	85
Lighting - 1.19 watts/sf	909,740	3,104	3,660	6,764	146
PV - 11391 sqft	719,217	2,454	3,660	6,114	796
Roof - R25 rigid	952,947	3,251	3,660	6,911	-1
Roof - R30 rigid	953,927	3,255	3,660	6,915	-5
Walls - R19 batt	953,033	3,252	3,654	6,906	4
Walls - R21 batt	953,062	3,252	3,653	6,904	6
Walls - R21 batt + R5 rigid	952,927	3,251	3,648	6,900	10
Windows - U=0.26, SHGC=0.37	955,394	3,260	3,651	6,911	-1
Windows - U=0.22, SHGC=0.22	929,388	3,171	3,675	6,846	64

Table 39. SHHS Alternatives Impact on Energy Consumption

Prototype #8 Small Hotel - Hotel Space					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	72,327	238	55	294	-
Package - Optimum EE	72,327	221	45	266	28
Package - Optimum EE + PV	72,327	169	45	214	80
DHW - EF=0.640	72,327	238	53	291	3
DHW - EF=0.823	72,327	238	46	285	9
Heating - AFUE=85%	72,327	238	54	292	2
HVAC - COP 7.63	72,327	231	55	287	7
Lighting - 1.19 watts/sf	72,327	228	55	283	11
PV - 11391 sqft	72,327	172	55	228	66
Roof - R25 rigid	72,327	238	55	294	0
Roof - R30 rigid	72,327	239	55	294	0
Walls - R19 batt	72,327	238	55	294	0
Walls - R21 batt	72,327	238	55	294	0
Walls - R21 batt + R5 rigid	72,327	238	55	293	1
Windows - U=0.26, SHGC=0.37	72,327	239	55	294	0
Windows - U=0.22, SHGC=0.22	72,327	232	55	288	6

Table 40. SHHS Alternatives Impact on TDVI

2.11 Small Hotel – Office Space

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	No Alternative
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Lighting	Lighting - 1.10 watts/sf	Lighting - 0.90 watts/sf	None	None	Alternative 1
Photovoltaics	No PV	PV - 5005 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R20 rigid	Roof - R25 rigid	Roof - R30 rigid	None	No Alternative
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 41 Small Hotel - Office Space (SHOS) Alternatives

Prototype #8 Small Hotel - Office Space					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$38,018	$2,092	$40,110	-	-
Package - Optimum EE	$32,729	$1,787	$34,516	$46,157	8.3
Package - Optimum EE + PV	$21,478	$1,787	$23,265	$294,989	16.8
CoolRoof - Abs=0.25	$37,868	$2,092	$39,960	$3,303	22.0
DHW - EF=0.640	$38,018	$2,015	$40,033	$620	8.0
DHW - EF=0.823	$38,018	$1,787	$39,805	$741	2.4
HVAC - EER 12.19, COP 3.52	$36,841	$2,092	$38,933	$4,845	4.1
HVAC - EER 12.06, COP 3.48	$36,962	$2,092	$39,054	$14,534	13.8
HVAC - EER 12.80, COP 3.66	$36,318	$2,092	$38,410	$24,224	14.2
Lighting - 0.90 watts/sf	$35,445	$2,092	$37,537	$0	0.0
PV - 5005 sqft	$26,362	$2,092	$28,454	$248,832	19.4
Roof - R25 rigid	$38,014	$2,092	$40,106	$2,503	625.6
Roof - R30 rigid	$38,122	$2,092	$40,214	$4,505	Never
Walls - R19 batt	$38,002	$2,092	$40,094	$2,385	149.1
Walls - R21 batt	$37,985	$2,092	$40,077	$3,253	98.6
Walls - R21 batt + R5 rigid	$37,975	$2,092	$40,067	$8,674	201.7
Windows - U=0.43, SHGC=0.39	$38,044	$2,092	$40,136	$2,323	Never
Windows - U=0.26, SHGC=0.37	$37,957	$2,092	$40,049	$6,941	113.8
Windows - U=0.22, SHGC=0.22	$36,634	$2,092	$38,726	$21,191	15.3

Table 42. SHOS Alternatives Impact on Utility Costs & Paybacks

Prototype #8 Small Hotel - Office Space					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	218,013	744	167	911	-
Package - Optimum EE	190,128	649	144	792	119
Package - Optimum EE + PV	108,668	371	144	514	397
CoolRoof - Abs=0.25	217,215	741	167	908	3
DHW - EF=0.640	218,013	744	161	905	6
DHW - EF=0.823	218,013	744	144	888	23
HVAC - EER 12.19, COP 3.52	212,482	725	167	892	19
HVAC - EER 12.06, COP 3.48	213,048	727	167	894	17
HVAC - EER 12.80, COP 3.66	210,046	717	167	883	28
Lighting - 0.90 watts/sf	203,336	694	167	861	50
PV - 5005 sqft	136,390	465	167	632	279
Roof - R25 rigid	218,062	744	167	911	0
Roof - R30 rigid	218,518	746	167	912	-1
Walls - R19 batt	218,058	744	167	911	0
Walls - R21 batt	217,947	744	167	910	1
Walls - R21 batt + R5 rigid	217,978	744	167	911	0
Windows - U=0.43, SHGC=0.39	218,390	745	167	912	-1
Windows - U=0.26, SHGC=0.37	218,150	744	167	911	0
Windows - U=0.22, SHGC=0.22	210,882	720	167	886	25

Table 43. SHOS Alternatives Impact on Energy Consumption

Prototype #8 Small Hotel - Office Space					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	20,020	209	9	218	-
Package - Optimum EE	20,020	181	8	189	29
Package - Optimum EE + PV	20,020	99	8	107	111
CoolRoof - Abs=0.25	20,020	208	9	218	0
DHW - EF=0.640	20,020	209	9	218	0
DHW - EF=0.823	20,020	209	8	217	1
HVAC - EER 12.19, COP 3.52	20,020	203	9	213	5
HVAC - EER 12.06, COP 3.48	20,020	204	9	213	5
HVAC - EER 12.80, COP 3.66	20,020	201	9	210	8
Lighting - 0.90 watts/sf	20,020	195	9	204	14
PV - 5005 sqft	20,020	127	9	136	82
Roof - R25 rigid	20,020	209	9	218	0
Roof - R30 rigid	20,020	210	9	219	-1
Walls - R19 batt	20,020	209	9	218	0
Walls - R21 batt	20,020	209	9	218	0
Walls - R21 batt + R5 rigid	20,020	209	9	218	0
Windows - U=0.43, SHGC=0.39	20,020	209	9	219	-1
Windows - U=0.26, SHGC=0.37	20,020	209	9	218	0
Windows - U=0.22, SHGC=0.22	20,020	202	9	211	7

Table 44. SHOS Alternatives Impact on TDVI

2.12 Small Hotel – Restaurant Space

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	No Alternative
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=80%	Heating - AFUE=94%	None	None	Alternative 1
Space Cooling	HVAC - EER 9.5	HVAC - EER 10.5	HVAC - EER 11.5	HVAC - EER 12.5	Alternative 3
Photovoltaics	No PV	PV - 3698 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 rigid	Roof - U=R15 rigid	Roof - U=R20 rigid	None	Alternative 2
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 2
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 2

Table 45. Small Hotel – Restaurant Space (SHRS) Alternatives

Prototype #8 Small Hotel - Restaurant					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$48,864	$25,055	$73,919	-	-
Package - Optimum EE	$46,888	$22,823	$69,711	$26,976	6.4
Package - Optimum EE + PV	$39,749	$22,823	$62,572	$210,828	19.2
CoolRoof - Abs=0.25	$48,667	$25,111	$73,777	$2,441	17.2
DHW - EF=0.640	$48,864	$24,656	$73,520	$620	1.6
DHW - EF=0.823	$48,864	$23,511	$72,375	$741	0.5
Heating - AFUE=94%	$48,864	$24,492	$73,357	$1,000	1.8
HVAC - EER 10.5	$48,132	$25,055	$73,187	$16,098	22.0
HVAC - EER 11.5	$47,537	$25,055	$72,591	$18,007	13.6
HVAC - EER 12.5	$47,032	$25,055	$72,087	$19,178	10.5
PV - 3698 sqft	$41,687	$25,055	$66,742	$183,853	25.6
Roof - U=R15 rigid	$48,844	$24,985	$73,830	$1,849	20.8
Roof - U=R20 rigid	$48,814	$24,946	$73,760	$3,328	20.9
Walls - R19 batt	$48,839	$25,046	$73,885	$394	11.6
Walls - R21 batt	$48,834	$25,048	$73,881	$537	14.1
Walls - R21 batt + R5 rigid	$48,817	$25,055	$73,872	$1,431	30.4
Windows - U=0.43, SHGC=0.39	$48,832	$25,043	$73,876	$733	17.1
Windows - U=0.26, SHGC=0.37	$48,738	$24,984	$73,722	$2,191	11.1
Windows - U=0.22, SHGC=0.22	$48,616	$25,222	$73,837	$6,690	81.6

Table 46. SHRS Alternatives Impact on Utility Costs & Paybacks

Prototype #8 Small Hotel - Restaurant					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	333,775	1,139	1,837	2,976	-
Package - Optimum EE	323,017	1,102	1,638	2,740	236
Package - Optimum EE + PV	262,792	897	1,638	2,534	442
CoolRoof - Abs=0.25	332,627	1,135	1,842	2,977	-1
DHW - EF=0.640	333,775	1,139	1,801	2,940	36
DHW - EF=0.823	333,775	1,139	1,699	2,838	138
Heating - AFUE=94%	333,775	1,139	1,787	2,925	51
HVAC - EER 10.5	329,740	1,125	1,837	2,962	14
HVAC - EER 11.5	326,407	1,114	1,837	2,951	25
HVAC - EER 12.5	323,606	1,104	1,837	2,941	35
PV - 3698 sqft	273,550	933	1,837	2,770	206
Roof - U=R15 rigid	333,801	1,139	1,831	2,970	6
Roof - U=R20 rigid	333,739	1,139	1,827	2,966	10
Walls - R19 batt	333,648	1,138	1,836	2,975	1
Walls - R21 batt	333,624	1,138	1,836	2,975	1
Walls - R21 batt + R5 rigid	333,538	1,138	1,837	2,975	1
Windows - U=0.43, SHGC=0.39	333,667	1,138	1,836	2,975	1
Windows - U=0.26, SHGC=0.37	333,152	1,137	1,831	2,967	9
Windows - U=0.22, SHGC=0.22	332,126	1,133	1,852	2,985	-9

Table 47. SHRS Alternatives Impact on Energy Consumption

Prototype #8 Small Hotel - Restaurant					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	7,396	847	272	1,120	-
Package - Optimum EE	7,396	816	243	1,059	61
Package - Optimum EE + PV	7,396	651	243	894	226
CoolRoof - Abs=0.25	7,396	844	273	1,117	3
DHW - EF=0.640	7,396	847	267	1,114	6
DHW - EF=0.823	7,396	847	252	1,099	21
Heating - AFUE=94%	7,396	847	265	1,112	8
HVAC - EER 10.5	7,396	836	272	1,108	12
HVAC - EER 11.5	7,396	826	272	1,098	22
HVAC - EER 12.5	7,396	818	272	1,090	30
PV - 3698 sqft	7,396	682	272	954	166
Roof - U=R15 rigid	7,396	847	271	1,119	1
Roof - U=R20 rigid	7,396	847	271	1,118	2
Walls - R19 batt	7,396	847	272	1,119	1
Walls - R21 batt	7,396	847	272	1,119	1
Walls - R21 batt + R5 rigid	7,396	847	272	1,119	1
Windows - U=0.43, SHGC=0.39	7,396	847	272	1,119	1
Windows - U=0.26, SHGC=0.37	7,396	846	271	1,117	3
Windows - U=0.22, SHGC=0.22	7,396	843	275	1,118	2

Table 48. SHRS Alternatives Impact on TDVI

2.13 Small Hotel – External Retail Tenant

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.57, SHGC=0.61	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 49. Small Hotel – External Retail Tenant (SHERT) Alternatives

Prototype #8 Small Hotel - External Retail Tenant					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$8,112	$1,939	$10,051	-	-
Package - Optimum EE	$6,954	$1,802	$8,756	$9,556	7.4
DHW - EF=0.640	$8,112	$1,904	$10,016	$310	8.9
DHW - EF=0.823	$8,112	$1,802	$9,914	$371	2.7
HVAC - EER 12.19, COP 3.52	$7,830	$1,939	$9,769	$1,172	4.2
HVAC - EER 12.06, COP 3.48	$7,873	$1,939	$9,812	$3,517	14.7
HVAC - EER 12.80, COP 3.66	$7,740	$1,939	$9,679	$4,593	12.3
Walls - R19 batt	$8,103	$1,939	$10,042	$452	50.2
Walls - R21 batt	$8,102	$1,939	$10,041	$616	61.6
Walls - R21 batt + R5 rigid	$8,099	$1,939	$10,038	$1,642	126.3
Windows - U=0.43, SHGC=0.39	$7,754	$1,939	$9,693	$503	1.4
Windows - U=0.26, SHGC=0.37	$7,718	$1,939	$9,657	$1,504	3.8
Windows - U=0.22, SHGC=0.22	$7,418	$1,939	$9,357	$4,593	6.6

Table 50. SHERT Alternatives Impact on Utility Costs & Paybacks

Prototype #8 Small Hotel - External Retail Tenant					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	48,403	165	36	201	-
Package - Optimum EE	42,027	143	26	169	32
DHW - EF=0.640	48,403	165	33	198	3
DHW - EF=0.823	48,403	165	26	191	10
HVAC - EER 12.19, COP 3.52	47,256	161	36	197	4
HVAC - EER 12.06, COP 3.48	47,367	162	36	198	3
HVAC - EER 12.80, COP 3.66	46,775	160	36	195	6
Walls - R19 batt	48,495	165	36	201	0
Walls - R21 batt	48,474	165	36	201	0
Walls - R21 batt + R5 rigid	48,525	166	36	201	0
Windows - U=0.43, SHGC=0.39	46,439	158	36	194	7
Windows - U=0.26, SHGC=0.37	46,472	159	36	194	7
Windows - U=0.22, SHGC=0.22	44,857	153	36	189	12

Table 51. SHERT Alternatives Impact on Energy Consumption

Prototype #8 Small Hotel - External Retail Tenant					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	2,752	340	14	354	-
Package - Optimum EE	2,752	293	10	303	7
DHW - EF=0.640	2,752	340	13	353	9
DHW - EF=0.823	2,752	340	10	350	3
HVAC - EER 12.19, COP 3.52	2,752	330	14	344	4
HVAC - EER 12.06, COP 3.48	2,752	331	14	345	15
HVAC - EER 12.80, COP 3.66	2,752	326	14	340	12
Walls - R19 batt	2,752	340	14	354	50
Walls - R21 batt	2,752	340	14	354	62
Walls - R21 batt + R5 rigid	2,752	340	14	354	126
Windows - U=0.43, SHGC=0.39	2,752	325	14	339	1
Windows - U=0.26, SHGC=0.37	2,752	325	14	339	4
Windows - U=0.22, SHGC=0.22	2,752	313	14	327	7

Table 52. SHERT Alternatives Impact on TDVI

2.14 Small Hotel – Internal Retail Tenant

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.57, SHGC=0.61	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 53. Small Hotel – Internal Tenant (SHIRT) Alternatives

Prototype #8 Small Hotel - Internal Retail Tenant					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$7,838	$1,939	$9,777	-	-
Package - Optimum EE	$6,850	$1,802	$8,652	$8,881	7.9
DHW - EF=0.640	$7,838	$1,904	$9,742	$310	8.9
DHW - EF=0.823	$7,838	$1,802	$9,640	$371	2.7
HVAC - EER 12.19, COP 3.52	$7,572	$1,939	$9,511	$996	3.7
HVAC - EER 12.06, COP 3.48	$7,603	$1,939	$9,542	$2,988	12.7
HVAC - EER 12.80, COP 3.66	$7,490	$1,939	$9,429	$4,980	14.3
Walls - R19 batt	$7,841	$1,939	$9,780	$467	-155.8
Walls - R21 batt	$7,841	$1,939	$9,780	$637	-212.4
Walls - R21 batt + R5 rigid	$7,830	$1,939	$9,769	$1,699	212.4
Windows - U=0.43, SHGC=0.39	$7,553	$1,939	$9,492	$387	1.4
Windows - U=0.26, SHGC=0.37	$7,446	$1,939	$9,385	$1,156	3.0
Windows - U=0.22, SHGC=0.22	$7,099	$1,939	$9,038	$3,531	4.8

Table 54. SHIRT Alternatives Impact on Utility Costs & Paybacks

Prototype #8 Small Hotel - Internal Retail Tenant					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	47,488	162	36	198	-
Package - Optimum EE	41,746	142	26	168	30
DHW - EF=0.640	47,488	162	33	195	3
DHW - EF=0.823	47,488	162	26	188	10
HVAC - EER 12.19, COP 3.52	46,220	158	36	194	4
HVAC - EER 12.06, COP 3.48	46,338	158	36	194	4
HVAC - EER 12.80, COP 3.66	45,787	156	36	192	6
Walls - R19 batt	47,535	162	36	198	0
Walls - R21 batt	47,534	162	36	198	0
Walls - R21 batt + R5 rigid	47,558	162	36	198	0
Windows - U=0.43, SHGC=0.39	45,866	156	36	192	6
Windows - U=0.26, SHGC=0.37	45,105	154	36	190	8
Windows - U=0.22, SHGC=0.22	42,996	147	36	183	15

Table 55. SHIRT Alternatives Impact on Energy Consumption

Prototype #8 Small Hotel - Internal Retail Tenant					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	2,752	331	14	346	-
Package - Optimum EE	2,752	290	10	300	46
DHW - EF=0.640	2,752	331	13	345	1
DHW - EF=0.823	2,752	331	10	342	4
HVAC - EER 12.19, COP 3.52	2,752	321	14	336	10
HVAC - EER 12.06, COP 3.48	2,752	322	14	337	9
HVAC - EER 12.80, COP 3.66	2,752	318	14	332	14
Walls - R19 batt	2,752	331	14	346	0
Walls - R21 batt	2,752	331	14	346	0
Walls - R21 batt + R5 rigid	2,752	332	14	346	0
Windows - U=0.43, SHGC=0.39	2,752	319	14	334	12
Windows - U=0.26, SHGC=0.37	2,752	314	14	329	17
Windows - U=0.22, SHGC=0.22	2,752	300	14	314	32

Table 56. SHIRT Alternatives Impact on TDV

2.15 Retail/Commercial Mixed-Use Building – Office Space

Type II construction, approximately 105,000 sf three-story slab on 35,000 sf grade, mixed use building with street level retail shops and two floor levels of service commercial or office space above. Interior floor space demised to accommodate 24 individual retail tenants at street level averaging 1,400 sf each. The floor-to-floor height is 13'-6" and 50% of the roof area is available for solar cells.

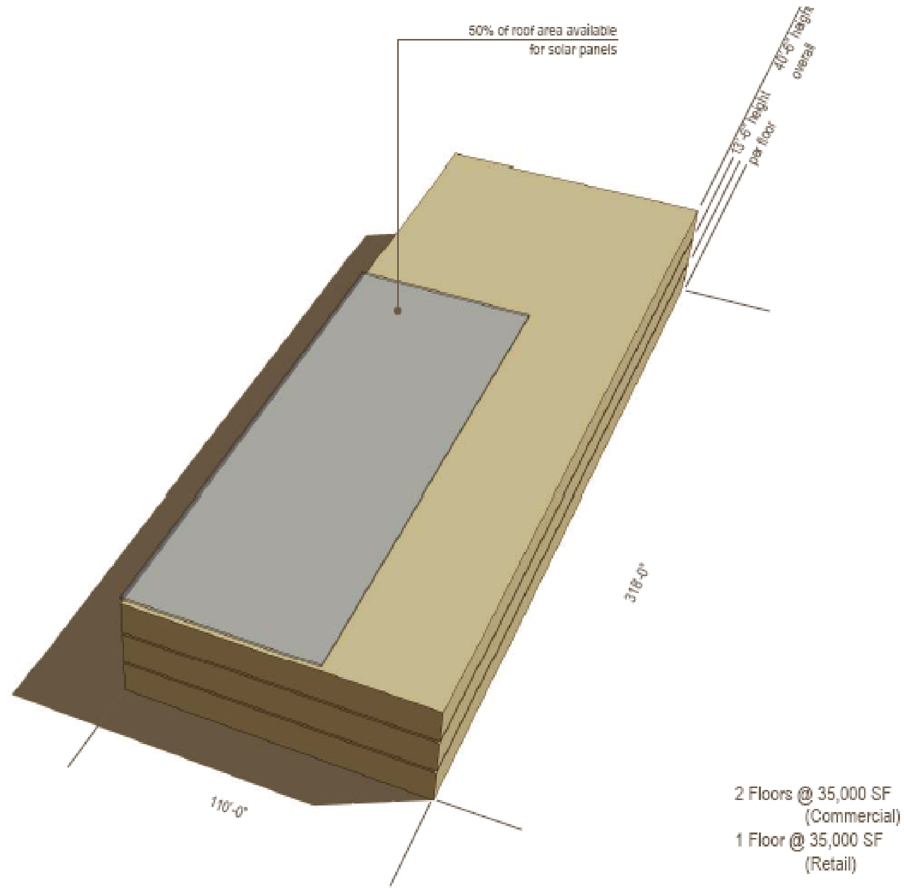

Figure 9. Retail/Commercial Mixed-Use Building

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=75%	Heating - AFUE=85%	None	None	No Alternative
Space Cooling	HVAC - COP 4.90	HVAC - COP 6.13	None	None	Alternative 1
Lighting	Lighting - 1.10 watts/sf	Lighting - 0.90 watts/sf	None	None	Alternative 1
Photovoltaics	No PV	PV - 8424 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 rigid	Roof - U=R15 rigid	Roof - U=R20 rigid	None	Alternative 2
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 3
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 57. Retail/Commercial Mixed Use: Office Space (R/CMUOS) Alternatives

Prototype #9 Retail/Commercial Mixed Use - Office Space					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$147,134	$9,468	$156,602	-	-
Package - Optimum EE	$120,197	$8,204	$128,402	$102,694	3.6
Package - Optimum EE + PV	$101,180	$8,196	$109,376	$510,388	10.8
CoolRoof - Abs=0.25	$144,836	$9,487	$154,323	$11,120	4.9
DHW - EF=0.640	$147,134	$9,194	$156,328	$620	2.3
DHW - EF=0.823	$147,134	$8,406	$155,540	$741	0.7
Heating - AFUE=85%	$147,134	$9,430	$156,564	$2,199	57.9
HVAC - COP 6.13	$139,279	$9,468	$148,747	$3,865	0.5
Lighting - 0.90 watts/sf	$137,272	$9,542	$146,814	$0	0.0
PV - 8424 sqft	$109,766	$9,468	$119,234	$418,814	10.2
Roof - U=R15 rigid	$146,145	$9,352	$155,496	$8,424	7.6
Roof - U=R20 rigid	$145,462	$9,316	$154,778	$15,163	8.3
Walls - R19 batt	$146,999	$9,434	$156,433	$1,497	8.9
Walls - R21 batt	$146,975	$9,430	$156,406	$2,041	10.4
Walls - R21 batt + R5 rigid	$146,804	$9,394	$156,197	$3,946	9.7
Windows - U=0.43, SHGC=0.39	$146,994	$9,397	$156,392	$7,439	35.4
Windows - U=0.26, SHGC=0.37	$146,510	$9,320	$155,830	$22,226	28.8
Windows - U=0.22, SHGC=0.22	$139,316	$9,387	$148,703	$67,859	8.6

Table 58. R/CMUOS Alternatives Impact on Utility Costs & Paybacks

Prototype #9 Retail/Commercial Mixed Use - Office Space					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	836,700	2,855	585	3,440	-
Package - Optimum EE	694,112	2,368	493	2,861	579
Package - Optimum EE + PV	570,561	1,947	492	2,439	1,001
CoolRoof - Abs=0.25	823,975	2,811	587	3,398	42
DHW - EF=0.640	836,700	2,855	566	3,420	20
DHW - EF=0.823	836,700	2,855	508	3,363	77
Heating - AFUE=85%	836,700	2,855	583	3,437	3
HVAC - COP 6.13	797,070	2,720	585	3,305	135
Lighting - 0.90 watts/sf	779,800	2,661	591	3,252	188
PV - 8424 sqft	593,592	2,025	585	2,611	829
Roof - U=R15 rigid	832,565	2,841	577	3,417	23
Roof - U=R20 rigid	829,782	2,831	574	3,405	35
Walls - R19 batt	836,285	2,853	583	3,436	4
Walls - R21 batt	836,207	2,853	583	3,436	4
Walls - R21 batt + R5 rigid	835,462	2,851	580	3,430	10
Windows - U=0.43, SHGC=0.39	836,818	2,855	580	3,435	5
Windows - U=0.26, SHGC=0.37	835,553	2,851	574	3,425	15
Windows - U=0.22, SHGC=0.22	795,397	2,714	579	3,293	147

Table 59. R/CMUOS Alternatives Impact on Energy Consumption

Prototype #9 Retail/Commercial Mixed Use - Office Space					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	67,392	241	10	251	-
Package - Optimum EE	67,392	198	8	206	45
Package - Optimum EE + PV	67,392	158	8	166	85
CoolRoof - Abs=0.25	67,392	237	10	247	4
DHW - EF=0.640	67,392	241	9	250	1
DHW - EF=0.823	67,392	241	8	249	2
Heating - AFUE=85%	67,392	241	10	251	0
HVAC - COP 6.13	67,392	229	10	238	13
Lighting - 0.90 watts/sf	67,392	225	10	234	17
PV - 8424 sqft	67,392	158	10	168	83
Roof - U=R15 rigid	67,392	240	9	249	2
Roof - U=R20 rigid	67,392	239	9	248	3
Walls - R19 batt	67,392	241	10	250	1
Walls - R21 batt	67,392	241	10	250	1
Walls - R21 batt + R5 rigid	67,392	241	9	250	1
Windows - U=0.43, SHGC=0.39	67,392	241	9	250	1
Windows - U=0.26, SHGC=0.37	67,392	240	9	250	1
Windows - U=0.22, SHGC=0.22	67,392	228	9	238	13

Table 60. R/CMUOS Alternatives Impact on TDVI

2.16 Retail/Commercial Mixed-Use Building – Corner Retail Tenant

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.57, SHGC=0.61	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 61. Retail/Commercial Mixed Use - Corner Retail Tenant (R/CMUCRT) Alternatives

Prototype #9 Retail/Commercial Mixed Use - Corner Retail Tenant					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$4,514	$1,698	$6,212	-	-
Package - Optimum EE	$3,971	$1,629	$5,600	$5,745	9.4
DHW - EF=0.640	$4,514	$1,678	$6,192	$310	15.5
DHW - EF=0.823	$4,514	$1,629	$6,143	$371	5.4
HVAC - EER 12.19, COP 3.52	$4,394	$1,698	$6,092	$557	4.6
HVAC - EER 12.06, COP 3.48	$4,401	$1,698	$6,099	$1,672	14.8
HVAC - EER 12.80, COP 3.66	$4,326	$1,698	$6,024	$2,786	14.8
Walls - R19 batt	$4,525	$1,698	$6,223	$200	Never
Walls - R21 batt	$4,524	$1,698	$6,222	$272	Never
Walls - R21 batt + R5 rigid	$4,531	$1,698	$6,229	$526	Never
Windows - U=0.43, SHGC=0.39	$4,298	$1,698	$5,996	$284	1.3
Windows - U=0.26, SHGC=0.37	$4,279	$1,698	$5,977	$848	3.6
Windows - U=0.22, SHGC=0.22	$4,072	$1,698	$5,770	$2,588	5.9

Table 62. R/CMUCRT Alternatives Impact on Utility Costs & Paybacks

Prototype #9 Retail/Commercial Mixed Use - Corner Retail Tenant					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	25,640	87	18	106	-
Package - Optimum EE	22,908	78	13	91	15
DHW - EF=0.640	25,640	87	17	104	2
DHW - EF=0.823	25,640	87	13	101	5
HVAC - EER 12.19, COP 3.52	24,968	85	18	103	3
HVAC - EER 12.06, COP 3.48	25,045	85	18	104	2
HVAC - EER 12.80, COP 3.66	24,477	84	18	102	4
Walls - R19 batt	25,694	88	18	106	0
Walls - R21 batt	25,708	88	18	106	0
Walls - R21 batt + R5 rigid	25,750	88	18	106	0
Windows - U=0.43, SHGC=0.39	24,172	82	18	101	5
Windows - U=0.26, SHGC=0.37	24,221	83	18	101	5
Windows - U=0.22, SHGC=0.22	23,417	80	18	98	8

Table 63. R/CMUCRT Alternatives Impact on Energy Consumption

Prototype #9 Retail/Commercial Mixed Use - Corner Retail Tenant					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	1,404	350	14	364	-
Package - Optimum EE	1,404	308	10	318	46
DHW - EF=0.640	1,404	350	13	363	1
DHW - EF=0.823	1,404	350	10	361	3
HVAC - EER 12.19, COP 3.52	1,404	339	14	354	10
HVAC - EER 12.06, COP 3.48	1,404	341	14	355	9
HVAC - EER 12.80, COP 3.66	1,404	332	14	346	18
Walls - R19 batt	1,404	351	14	365	-1
Walls - R21 batt	1,404	351	14	365	-1
Walls - R21 batt + R5 rigid	1,404	351	14	366	-2
Windows - U=0.43, SHGC=0.39	1,404	329	14	343	21
Windows - U=0.26, SHGC=0.37	1,404	329	14	343	21
Windows - U=0.22, SHGC=0.22	1,404	317	14	331	33

Table 64. R/CMUCRT Alternatives Impact on TDVI

2.17 Retail/Commercial Mixed-Use Building – Internal Retail Tenant

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.57, SHGC=0.61	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 65. Retail/Commercial Mixed Use - Internal Retail Tenant (R/CMUCRT) Alternatives

Prototype #9 Retail/Commercial Mixed Use - Internal Retail Tenant					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$4,293	$1,698	$5,991	-	-
Package - Optimum EE	$3,837	$1,629	$5,466	$4,200	8.0
DHW - EF=0.640	$4,293	$1,678	$5,971	$310	15.5
DHW - EF=0.823	$4,293	$1,629	$5,922	$371	5.4
HVAC - EER 12.19, COP 3.52	$4,178	$1,698	$5,876	$443	3.8
HVAC - EER 12.06, COP 3.48	$4,184	$1,698	$5,882	$1,328	12.2
HVAC - EER 12.80, COP 3.66	$4,088	$1,698	$5,786	$2,213	10.8
Walls - R19 batt	$4,292	$1,698	$5,990	$214	Never
Walls - R21 batt	$4,290	$1,698	$5,988	$292	Never
Walls - R21 batt + R5 rigid	$4,291	$1,698	$5,989	$564	Never
Windows - U=0.43, SHGC=0.39	$4,105	$1,698	$5,803	$177	0.9
Windows - U=0.26, SHGC=0.37	$4,099	$1,698	$5,797	$529	2.7
Windows - U=0.22, SHGC=0.22	$3,997	$1,698	$5,695	$1,616	5.5

Table 66. R/CMUCRT Alternatives Impact on Utility Costs & Paybacks

Prototype #9 Retail/Commercial Mixed Use - Internal Retail Tenant					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	24,373	83	18	101	-
Package - Optimum EE	21,837	75	13	88	13
DHW - EF=0.640	24,373	83	17	100	1
DHW - EF=0.823	24,373	83	13	96	5
HVAC - EER 12.19, COP 3.52	23,955	82	18	100	1
HVAC - EER 12.06, COP 3.48	23,996	82	18	100	1
HVAC - EER 12.80, COP 3.66	23,777	81	18	99	2
Walls - R19 batt	24,393	83	18	101	0
Walls - R21 batt	24,402	83	18	102	-1
Walls - R21 batt + R5 rigid	24,424	83	18	102	-1
Windows - U=0.43, SHGC=0.39	23,733	81	18	99	2
Windows - U=0.26, SHGC=0.37	23,679	81	18	99	2
Windows - U=0.22, SHGC=0.22	23,014	79	18	97	4

Table 67. R/CMUCRT Alternatives Impact on Energy Consumption

Prototype #9 Retail/Commercial Mixed Use - Internal Retail Tenant					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	1,404	330	14	345	-
Package - Optimum EE	1,404	293	10	304	41
DHW - EF=0.640	1,404	330	13	344	1
DHW - EF=0.823	1,404	330	10	341	4
HVAC - EER 12.19, COP 3.52	1,404	323	14	338	7
HVAC - EER 12.06, COP 3.48	1,404	324	14	338	7
HVAC - EER 12.80, COP 3.66	1,404	320	14	335	10
Walls - R19 batt	1,404	330	14	345	0
Walls - R21 batt	1,404	331	14	345	0
Walls - R21 batt + R5 rigid	1,404	331	14	345	0
Windows - U=0.43, SHGC=0.39	1,404	321	14	335	10
Windows - U=0.26, SHGC=0.37	1,404	320	14	335	10
Windows - U=0.22, SHGC=0.22	1,404	310	14	325	20

Table 68. R/CMUCRT Alternatives Impact on TDVI

2.18 Retail/Residential Mixed-Use Mid-Rise Building: Residential Space

Type III construction, approximately 136,000 sf six-story mixed use slab on 33,000 sf grade. Interior floor space demised to accommodate 24 individual retail tenants at street level averaging 1,400 sf each. Five floor levels of residential apartments above the first floor totaling approximately 103,300 sf. Residential floor space demised to accommodate 110 individual units; 47 Studios, 34 2BR and 29 3BR units ranging from approximately 600 to 1,300 sf each. The floor-to-floor height for the first floor retail is 14'-0" and 10'-0" for the residential levels above. 50% of the roof area is available for solar cells.

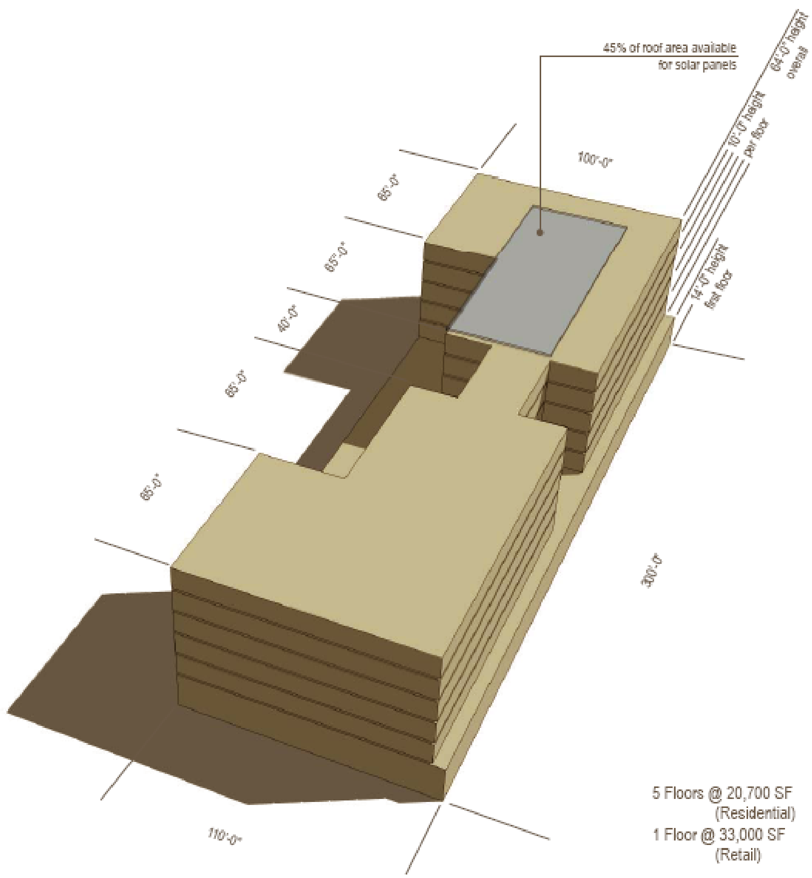

Figure 10. Retail/Residential Mixed-Use Mid-Rise Building

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliance	Dish EF=.46, Clothes MMEF=1.26	Dish EF=.64, Clothes MMEF=2.0	Dish EF=.64, Clothes MMEF=2.2	None	Alternative 1
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=75%	Heating - AFUE=85%	None	None	No Alternative
Space Cooling	HVAC - COP 6.10	HVAC - COP 7.63	None	None	Alternative 1
Lighting	Lighting - 0.713 watts/sf	Lighting - 0.674 watts/sf	None	None	No Alternative
Photovoltaics	No PV	PV - 9301 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 rigid	Roof - U=R15 rigid	Roof - U=R20 rigid	None	No Alternative
Wall Insulation	Walls - R13 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 3
Windows	Windows - U=0.48, SHGC=0.47	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 69. Retail/Residential Mixed Use Mid-Rise - Residential Space (R/RMUMRRS) Alternatives

Prototype #10 Retail/Residential Mixed Use Mid-Rise - Residential Space					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$166,804	$25,058	$191,862	-	-
Package - Optimum EE	$154,484	$21,093	$175,577	$112,688	6.9
Package - Optimum EE + PV	$119,468	$21,091	$140,559	$568,264	11.2
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	$164,271	$25,057	$189,328	$29,110	11.5
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	$164,116	$25,057	$189,173	$39,450	14.7
CoolRoof - Abs=0.25	$165,107	$25,057	$190,164	$6,820	4.0
DHW - EF=0.640	$166,804	$24,037	$190,841	$34,075	33.4
DHW - EF=0.823	$166,804	$21,104	$187,908	$40,770	10.3
Heating - AFUE=85%	$166,804	$25,048	$191,852	$1,000	100.0
HVAC - COP 7.63	$162,643	$25,058	$187,701	$4,809	1.2
Lighting - 0.674 watts/sf	$162,857	$25,058	$187,915	$99,000	25.1
PV - 9301 sqft	$129,686	$25,058	$154,744	$462,396	12.2
Roof - U=R15 rigid	$166,778	$25,053	$191,831	$5,167	166.7
Roof - U=R20 rigid	$166,616	$25,048	$191,664	$9,301	47.0
Walls - R19 batt	$166,673	$25,056	$191,729	$2,723	20.5
Walls - R21 batt	$166,610	$25,053	$191,663	$3,934	19.8
Walls - R21 batt + R5 rigid	$166,181	$25,052	$191,233	$11,498	18.3
Windows - U=0.43, SHGC=0.39	$165,786	$25,058	$190,844	$2,157	2.1
Windows - U=0.26, SHGC=0.37	$165,866	$25,054	$190,920	$6,446	6.8
Windows - U=0.22, SHGC=0.22	$163,042	$25,056	$188,098	$19,680	5.2

Table 70. R/RMUMRRS Alternatives Impact on Utility Costs & Paybacks

Prototype #10 Retail/Residential Mixed Use Mid-Rise - Residential Space					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	683,630	2,333	1,912	4,244	-
Package - Optimum EE	633,886	2,163	1,610	3,773	471
Package - Optimum EE + PV	491,935	1,678	1,610	3,289	955
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	673,315	2,297	1,912	4,209	35
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	672,685	2,295	1,912	4,207	37
CoolRoof - Abs=0.25	676,752	2,309	1,912	4,221	23
DHW - EF=0.640	683,630	2,333	1,834	4,167	77
DHW - EF=0.823	683,630	2,333	1,611	3,944	300
Heating - AFUE=85%	683,630	2,333	1,911	4,244	0
HVAC - COP 7.63	666,931	2,276	1,912	4,187	57
Lighting - 0.674 watts/sf	667,562	2,278	1,912	4,190	54
PV - 9301 sqft	533,163	1,819	1,912	3,731	513
Roof - U=R15 rigid	683,580	2,332	1,911	4,244	0
Roof - U=R20 rigid	682,951	2,330	1,911	4,241	3
Walls - R19 batt	683,133	2,331	1,912	4,243	1
Walls - R21 batt	682,892	2,330	1,911	4,241	3
Walls - R21 batt + R5 rigid	681,185	2,324	1,911	4,235	9
Windows - U=0.43, SHGC=0.39	679,505	2,318	1,912	4,230	14
Windows - U=0.26, SHGC=0.37	679,850	2,320	1,912	4,231	13
Windows - U=0.22, SHGC=0.22	668,390	2,281	1,912	4,192	52

Table 71. R/RMUMRRS Alternatives Impact on Energy Consumption

Prototype #10 Retail/Residential Mixed Use Mid-Rise - Residential Space					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	103,339	98	20	117	-
Package - Optimum EE	103,339	90	17	107	10
Package - Optimum EE + PV	103,339	67	17	84	33
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	103,339	96	20	116	1
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	103,339	96	20	116	1
CoolRoof - Abs=0.25	103,339	97	20	116	1
DHW - EF=0.640	103,339	98	19	116	1
DHW - EF=0.823	103,339	98	17	114	3
Heating - AFUE=85%	103,339	98	20	117	0
HVAC - COP 7.63	103,339	95	20	115	2
Lighting - 0.674 watts/sf	103,339	95	20	115	2
PV - 9301 sqft	103,339	74	20	93	24
Roof - U=R15 rigid	103,339	98	20	117	0
Roof - U=R20 rigid	103,339	97	20	117	0
Walls - R19 batt	103,339	98	20	117	0
Walls - R21 batt	103,339	97	20	117	0
Walls - R21 batt + R5 rigid	103,339	97	20	117	0
Windows - U=0.43, SHGC=0.39	103,339	97	20	117	0
Windows - U=0.26, SHGC=0.37	103,339	97	20	117	0
Windows - U=0.22, SHGC=0.22	103,339	95	20	115	2

Table 72. R/RMUMRRS Alternatives Impact on TDVI

2.19 Retail/Residential Mixed-Use Mid-Rise Building: Corner Retail Tenant

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.57, SHGC=0.61	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 73. Retail/Residential Mixed Use Mid-Rise - Corner Retail Tenant (R/RMUMRCRT) Alternatives

Prototype #10 Retail/Residential Mixed Use Mid-Rise - Corner Retail Tenant					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$4,514	$1,698	$6,212	-	-
Package - Optimum EE	$3,946	$1,629	$5,575	$5,482	8.6
DHW - EF=0.640	$4,514	$1,678	$6,192	$310	15.5
DHW - EF=0.823	$4,514	$1,629	$6,143	$371	5.4
HVAC - EER 12.19, COP 3.52	$4,391	$1,698	$6,089	$487	4.0
HVAC - EER 12.06, COP 3.48	$4,414	$1,698	$6,112	$1,460	14.6
HVAC - EER 12.80, COP 3.66	$4,318	$1,698	$6,016	$2,434	12.4
Walls - R19 batt	$4,517	$1,698	$6,215	$207	Never
Walls - R21 batt	$4,516	$1,698	$6,214	$282	-141.2
Walls - R21 batt + R5 rigid	$4,520	$1,698	$6,218	$753	-125.5
Windows - U=0.43, SHGC=0.39	$4,298	$1,698	$5,996	$294	1.4
Windows - U=0.26, SHGC=0.37	$4,299	$1,698	$5,997	$877	4.1
Windows - U=0.22, SHGC=0.22	$4,093	$1,698	$5,791	$2,678	6.4

Table 74. R/RMUMRCRT Alternatives Impact on Utility Costs & Paybacks

Prototype #10 Retail/Residential Mixed Use Mid-Rise - Corner Retail Tenant					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	25,609	87	18	106	-
Package - Optimum EE	22,730	78	13	91	15
DHW - EF=0.640	25,609	87	17	104	2
DHW - EF=0.823	25,609	87	13	101	5
HVAC - EER 12.19, COP 3.52	24,861	85	18	103	3
HVAC - EER 12.06, COP 3.48	24,949	85	18	103	3
HVAC - EER 12.80, COP 3.66	24,570	84	18	102	4
Walls - R19 batt	25,655	88	18	106	0
Walls - R21 batt	25,643	87	18	106	0
Walls - R21 batt + R5 rigid	25,691	88	18	106	0
Windows - U=0.43, SHGC=0.39	24,254	83	18	101	5
Windows - U=0.26, SHGC=0.37	24,289	83	18	101	5
Windows - U=0.22, SHGC=0.22	23,387	80	18	98	8

Table 75. R/RMUMRCRT Alternatives Impact on Energy Consumption

Prototype #10 Retail/Residential Mixed Use Mid-Rise - Corner Retail Tenant					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	1,404	350	14	364	-
Package - Optimum EE	1,404	306	10	316	48
DHW - EF=0.640	1,404	350	13	363	1
DHW - EF=0.823	1,404	350	10	360	4
HVAC - EER 12.19, COP 3.52	1,404	338	14	352	12
HVAC - EER 12.06, COP 3.48	1,404	339	14	354	10
HVAC - EER 12.80, COP 3.66	1,404	333	14	348	16
Walls - R19 batt	1,404	350	14	365	-1
Walls - R21 batt	1,404	350	14	364	0
Walls - R21 batt + R5 rigid	1,404	350	14	365	-1
Windows - U=0.43, SHGC=0.39	1,404	330	14	345	19
Windows - U=0.26, SHGC=0.37	1,404	330	14	344	20
Windows - U=0.22, SHGC=0.22	1,404	317	14	331	33

Table 76. R/RMUMRCRT Alternatives Impact on TDVI

2.20 Retail/Residential Mixed-Use Mid-Rise Building: Internal Retail Tenant

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.57, SHGC=0.61	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 77. Retail/Residential Mixed Use Mid-Rise - Internal Retail Tenant (R/RMUMRIRT) Alternatives

Prototype #10 Retail/Residential Mixed Use Mid-Rise - Internal Retail Tenant					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$4,274	$1,698	$5,972	-	-
Package - Optimum EE	$3,832	$1,629	$5,461	$4,020	7.9
DHW - EF=0.640	$4,274	$1,678	$5,952	$310	15.5
DHW - EF=0.823	$4,274	$1,629	$5,903	$371	5.4
HVAC - EER 12.19, COP 3.52	$4,133	$1,698	$5,831	$395	2.8
HVAC - EER 12.06, COP 3.48	$4,156	$1,698	$5,854	$1,184	10.0
HVAC - EER 12.80, COP 3.66	$4,077	$1,698	$5,775	$1,973	10.0
Walls - R19 batt	$4,273	$1,698	$5,971	$90	Never
Walls - R21 batt	$4,273	$1,698	$5,971	$122	122.4
Walls - R21 batt + R5 rigid	$4,274	$1,698	$5,972	$326	Never
Windows - U=0.43, SHGC=0.39	$4,100	$1,698	$5,798	$184	1.1
Windows - U=0.26, SHGC=0.37	$4,106	$1,698	$5,804	$549	3.3
Windows - U=0.22, SHGC=0.22	$3,994	$1,698	$5,692	$1,676	6.0

Table 78. R/RMUMRIRT Alternatives Impact on Utility Costs & Paybacks

Prototype #10 Retail/Residential Mixed Use Mid-Rise - Internal Retail Tenant					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	24,434	83	18	102	-
Package - Optimum EE	21,803	74	13	88	14
DHW - EF=0.640	24,434	83	17	100	2
DHW - EF=0.823	24,434	83	13	97	5
HVAC - EER 12.19, COP 3.52	23,854	81	18	100	2
HVAC - EER 12.06, COP 3.48	23,903	82	18	100	2
HVAC - EER 12.80, COP 3.66	23,552	80	18	99	3
Walls - R19 batt	24,445	83	18	102	0
Walls - R21 batt	24,445	83	18	102	0
Walls - R21 batt + R5 rigid	24,456	83	18	102	0
Windows - U=0.43, SHGC=0.39	23,517	80	18	98	4
Windows - U=0.26, SHGC=0.37	23,571	80	18	99	3
Windows - U=0.22, SHGC=0.22	23,002	78	18	97	5

Table 79. R/RMUMRIRT Alternatives Impact on Energy Consumption

Prototype #10 Retail/Residential Mixed Use Mid-Rise - Internal Retail Tenant					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	1,404	331	14	345	-
Package - Optimum EE	1,404	293	10	303	42
DHW - EF=0.640	1,404	331	13	344	1
DHW - EF=0.823	1,404	331	10	341	4
HVAC - EER 12.19, COP 3.52	1,404	322	14	337	8
HVAC - EER 12.06, COP 3.48	1,404	323	14	338	7
HVAC - EER 12.80, COP 3.66	1,404	318	14	332	13
Walls - R19 batt	1,404	331	14	345	0
Walls - R21 batt	1,404	331	14	345	0
Walls - R21 batt + R5 rigid	1,404	331	14	345	0
Windows - U=0.43, SHGC=0.39	1,404	318	14	333	12
Windows - U=0.26, SHGC=0.37	1,404	319	14	333	12
Windows - U=0.22, SHGC=0.22	1,404	310	14	324	21

Table 80. R/RMUMRIRT Alternatives Impact on TDVI

2.21 Retail/Residential Mixed-Use Low-Rise: Residential Space

Type II construction at ground level and type V construction above, approximately 76,000 sf three-story mixed use slab on 33,000 sf grade. Interior floor space demised to accommodate 24 individual retail tenants at street level averaging 1,400 sf each. Two floor levels of residential apartments above the first floor totaling approximately 44,000 sf. Residential floor space demised to accommodate 46 individual units; 18 Studios, 16 2BR and 12 3BR units ranging from approximately 600 to 1,300 sf each. The floor-to-floor height for the first floor retail is 14’-0” and 10’-0” for the residential levels above. 45% of the roof area is available for solar cells.

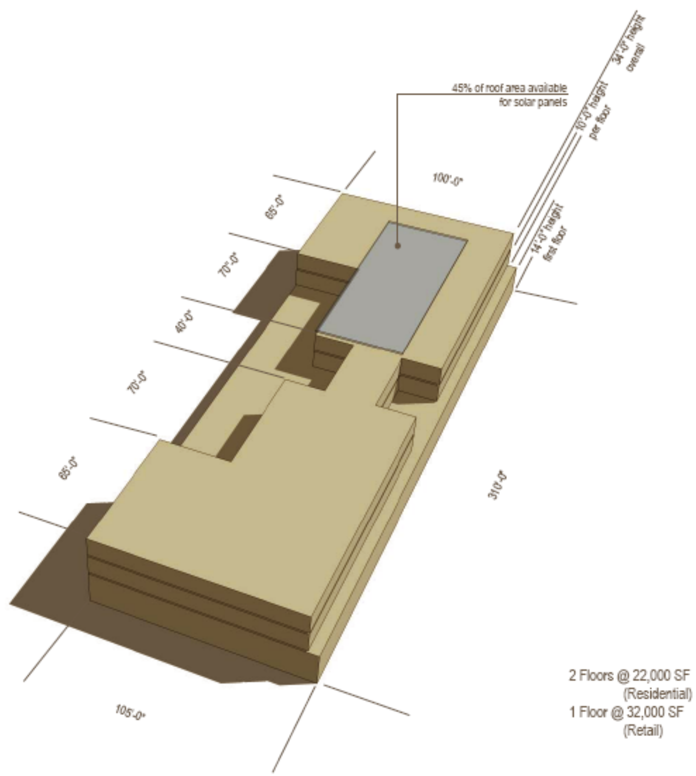

Figure 11. Retail/Residential Mixed-Use Low-Rise Building

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliance	Dish EF=.46, Clothes MMEF=1.26	Dish EF=.64, Clothes MMEF=2.0	Dish EF=.64, Clothes MMEF=2.2	None	Alternative 1
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Lighting	Lighting - 0.713 watts/sf	Lighting - 0.667 watts/sf	None	None	No Alternative
Photovoltaics	No PV	PV - 9904 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R30 batt	Roof - R38 batt	Roof - R49 batt	None	No Alternative
Wall Insulation	Walls - R13 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 81. Retail/Residential Mixed-Use Low-Rise: Residential Space (R/RMULRRS) Alternatives

Prototype #11 Retail/Residential Mixed Use Low-Rise - Residential Space					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$58,486	$10,460	$68,946	-	-
Package - Optimum EE	$55,127	$8,808	$63,935	$53,550	10.7
Package - Optimum EE + PV	$15,750	$8,808	$24,558	$580,062	11.8
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	$57,392	$10,460	$67,852	$12,173	11.1
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	$57,319	$10,460	$67,779	$16,497	14.1
CoolRoof - Abs=0.25	$57,901	$10,460	$68,361	$7,263	12.4
DHW - EF=0.640	$58,486	$10,034	$68,520	$14,249	33.4
DHW - EF=0.823	$58,486	$8,808	$67,294	$17,049	10.3
HVAC - EER 12.19, COP 3.52	$57,535	$10,460	$67,995	$2,844	3.0
HVAC - EER 12.06, COP 3.48	$57,643	$10,460	$68,103	$8,532	10.1
HVAC - EER 12.80, COP 3.66	$57,251	$10,460	$67,711	$14,220	11.5
Lighting - 0.667 watts/sf	$56,821	$10,460	$67,281	$41,400	24.9
PV - 9904 sqft	$18,684	$10,460	$29,144	$492,375	10.2
Roof - R38 batt	$58,516	$10,460	$68,976	$4,182	Never
Roof - R49 batt	$58,662	$10,460	$69,122	$14,525	Never
Walls - R19 batt	$58,535	$10,460	$68,995	$1,112	Never
Walls - R21 batt	$58,584	$10,460	$69,044	$1,606	Never
Walls - R21 batt + R5 rigid	$58,542	$10,460	$69,002	$4,695	Never
Windows - U=0.43, SHGC=0.39	$58,577	$10,460	$69,037	$1,002	Never
Windows - U=0.26, SHGC=0.37	$58,710	$10,460	$69,170	$2,994	Never
Windows - U=0.22, SHGC=0.22	$57,559	$10,460	$68,019	$2,844	3.1

Table 82. R/RMULRRS Alternatives Impacts on Utility Costs & Paybacks

Prototype #11 Retail/Residential Mixed Use Low-Rise - Residential Space					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	240,792	822	803	1,624	-
Package - Optimum EE	227,239	775	677	1,452	172
Package - Optimum EE + PV	67,612	231	677	908	716
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	236,341	806	803	1,609	15
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	236,045	805	803	1,608	16
CoolRoof - Abs=0.25	238,416	813	803	1,616	8
DHW - EF=0.640	240,792	822	770	1,592	32
DHW - EF=0.823	240,792	822	677	1,499	125
HVAC - EER 12.19, COP 3.52	236,996	809	803	1,611	13
HVAC - EER 12.06, COP 3.48	237,417	810	803	1,613	11
HVAC - EER 12.80, COP 3.66	235,856	805	803	1,607	17
Lighting - 0.667 watts/sf	234,028	799	803	1,601	23
PV - 9904 sqft	79,448	271	803	1,074	550
Roof - R38 batt	240,932	822	803	1,625	-1
Roof - R49 batt	241,550	824	803	1,627	-3
Walls - R19 batt	241,003	822	803	1,625	-1
Walls - R21 batt	241,212	823	803	1,626	-2
Walls - R21 batt + R5 rigid	241,080	823	803	1,625	-1
Windows - U=0.43, SHGC=0.39	241,171	823	803	1,625	-1
Windows - U=0.26, SHGC=0.37	241,722	825	803	1,627	-3
Windows - U=0.22, SHGC=0.22	237,054	809	803	1,611	13

Table 83. R/RMULRRS Alternatives Impacts on Energy Consumption

Prototype #11 Retail/Residential Mixed Use Low-Rise - Residential Space					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	44,017	81	19	100	-
Package - Optimum EE	44,017	76	16	92	11
Package - Optimum EE + PV	44,017	17	16	33	12
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	44,017	79	19	99	11
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	44,017	79	19	99	14
CoolRoof - Abs=0.25	44,017	80	19	99	12
DHW - EF=0.640	44,017	81	19	99	33
DHW - EF=0.823	44,017	81	16	97	10
HVAC - EER 12.19, COP 3.52	44,017	80	19	99	3
HVAC - EER 12.06, COP 3.48	44,017	80	19	99	10
HVAC - EER 12.80, COP 3.66	44,017	79	19	98	12
Lighting - 0.667 watts/sf	44,017	79	19	98	25
PV - 9904 sqft	44,017	21	19	41	10
Roof - R38 batt	44,017	81	19	100	-139
Roof - R49 batt	44,017	81	19	100	-83
Walls - R19 batt	44,017	81	19	100	-23
Walls - R21 batt	44,017	81	19	100	-16
Walls - R21 batt + R5 rigid	44,017	81	19	100	-84
Windows - U=0.43, SHGC=0.39	44,017	81	19	100	-11
Windows - U=0.26, SHGC=0.37	44,017	81	19	100	-13
Windows - U=0.22, SHGC=0.22	44,017	80	19	99	3

Table 84. R/RMULRRS Alternatives Impacts on TDVI

2.22 Retail/Residential Mixed-Use Low-Rise: Corner Retail Tenant

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.57, SHGC=0.61	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 85. Retail/Residential Mixed Use Low -Rise - Corner Retail Tenant (R/RMULRCRT) Alternatives

Prototype #11 Retail/Residential Mixed Use Low-Rise - Corner Retail Tenant					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$4,514	$1,698	$6,212	-	-
Package - Optimum EE	$3,948	$1,629	$5,577	$5,629	9
DHW - EF=0.640	$4,514	$1,678	$6,192	$310	15
DHW - EF=0.823	$4,514	$1,629	$6,143	$371	5
HVAC - EER 12.19, COP 3.52	$4,381	$1,698	$6,079	$516	4
HVAC - EER 12.06, COP 3.48	$4,390	$1,698	$6,088	$1,548	12
HVAC - EER 12.80, COP 3.66	$4,326	$1,698	$6,024	$2,581	14
Walls - R19 batt	$4,523	$1,698	$6,221	$207	Never
Walls - R21 batt	$4,522	$1,698	$6,220	$282	Never
Walls - R21 batt + R5 rigid	$4,512	$1,698	$6,210	$546	Never
Windows - U=0.43, SHGC=0.39	$4,301	$1,698	$5,999	$294	1
Windows - U=0.26, SHGC=0.37	$4,301	$1,698	$5,999	$877	4
Windows - U=0.22, SHGC=0.22	$4,085	$1,698	$5,783	$2,678	6

Table 86. R/RMULRCRT Alternatives Impact on Utility Costs & Paybacks

Prototype #11 Retail/Residential Mixed Use Low-Rise - Corner Retail Tenant					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	25,696	88	18	106	-
Package - Optimum EE	22,746	78	13	91	15
DHW - EF=0.640	25,696	88	17	105	1
DHW - EF=0.823	25,696	88	13	101	5
HVAC - EER 12.19, COP 3.52	24,857	85	18	103	3
HVAC - EER 12.06, COP 3.48	24,923	85	18	103	3
HVAC - EER 12.80, COP 3.66	24,516	84	18	102	4
Walls - R19 batt	25,761	88	18	106	0
Walls - R21 batt	25,782	88	18	106	0
Walls - R21 batt + R5 rigid	25,722	88	18	106	0
Windows - U=0.43, SHGC=0.39	24,224	83	18	101	5
Windows - U=0.26, SHGC=0.37	24,265	83	18	101	5
Windows - U=0.22, SHGC=0.22	23,434	80	18	98	8

Table 87. R/RMULRCRT Alternatives Impact on Energy Consumption

Prototype #11 Retail/Residential Mixed Use Low-Rise - Corner Retail Tenant					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	1,404	351	14	365	-
Package - Optimum EE	1,404	306	10	317	48
DHW - EF=0.640	1,404	351	13	364	1
DHW - EF=0.823	1,404	351	10	361	4
HVAC - EER 12.19, COP 3.52	1,404	338	14	353	12
HVAC - EER 12.06, COP 3.48	1,404	339	14	354	11
HVAC - EER 12.80, COP 3.66	1,404	333	14	347	18
Walls - R19 batt	1,404	352	14	366	-1
Walls - R21 batt	1,404	352	14	366	-1
Walls - R21 batt + R5 rigid	1,404	351	14	365	0
Windows - U=0.43, SHGC=0.39	1,404	330	14	344	21
Windows - U=0.26, SHGC=0.37	1,404	330	14	344	21
Windows - U=0.22, SHGC=0.22	1,404	317	14	332	33

Table 88. R/RMULRCRT Alternatives Impact on TDVI

2.23 Retail/Residential Mixed-Use Low-Rise Building: Internal Retail Tenant

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.57, SHGC=0.61	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 89. Retail/Residential Mixed Use Low -Rise - Internal Retail Tenant (R/RMULRIRT) Alternatives

Prototype #11 Retail/Residential Mixed Use Low-Rise - Internal Retail Tenant					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$4,293	$1,698	$5,991	-	-
Package - Optimum EE	$3,834	$1,629	$5,463	$5,125	9.7
DHW - EF=0.640	$4,293	$1,678	$5,971	$310	15
DHW - EF=0.823	$4,293	$1,629	$5,922	$371	5
HVAC - EER 12.19, COP 3.52	$4,151	$1,698	$5,849	$415	3
HVAC - EER 12.06, COP 3.48	$4,169	$1,698	$5,867	$1,246	10
HVAC - EER 12.80, COP 3.66	$4,084	$1,698	$5,782	$2,076	10
Walls - R19 batt	$4,296	$1,698	$5,994	$222	Never
Walls - R21 batt	$4,285	$1,698	$5,983	$302	Never
Walls - R21 batt + R5 rigid	$4,300	$1,698	$5,998	$585	Never
Windows - U=0.43, SHGC=0.39	$4,119	$1,698	$5,817	$294	2
Windows - U=0.26, SHGC=0.37	$4,126	$1,698	$5,824	$877	5
Windows - U=0.22, SHGC=0.22	$3,999	$1,698	$5,697	$2,678	9

Table 90. R/RMULRIRT Alternatives Impact on Utility Costs & Paybacks

Prototype #11 Retail/Residential Mixed Use Low-Rise - Internal Retail Tenant					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$4,293	$1,698	$5,991	-	-
Package - Optimum EE	$3,834	$1,629	$5,463	$5,125	9.7
DHW - EF=0.640	$4,293	$1,678	$5,971	$310	15
DHW - EF=0.823	$4,293	$1,629	$5,922	$371	5
HVAC - EER 12.19, COP 3.52	$4,151	$1,698	$5,849	$415	3
HVAC - EER 12.06, COP 3.48	$4,169	$1,698	$5,867	$1,246	10
HVAC - EER 12.80, COP 3.66	$4,084	$1,698	$5,782	$2,076	10
Walls - R19 batt	$4,296	$1,698	$5,994	$222	Never
Walls - R21 batt	$4,285	$1,698	$5,983	$302	Never
Walls - R21 batt + R5 rigid	$4,300	$1,698	$5,998	$585	Never
Windows - U=0.43, SHGC=0.39	$4,119	$1,698	$5,817	$294	2
Windows - U=0.26, SHGC=0.37	$4,126	$1,698	$5,824	$877	5
Windows - U=0.22, SHGC=0.22	$3,999	$1,698	$5,697	$2,678	9

Table 91. R/RMULRIRT Alternatives Impact on Energy Consumption

Prototype #11 Retail/Residential Mixed Use Low-Rise - Internal Retail Tenant					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	1,404	331	14	345	-
Package - Optimum EE	1,404	293	10	303	42
DHW - EF=0.640	1,404	331	13	344	1
DHW - EF=0.823	1,404	331	10	341	4
HVAC - EER 12.19, COP 3.52	1,404	322	14	337	8
HVAC - EER 12.06, COP 3.48	1,404	324	14	339	6
HVAC - EER 12.80, COP 3.66	1,404	319	14	334	11
Walls - R19 batt	1,404	331	14	345	0
Walls - R21 batt	1,404	331	14	345	0
Walls - R21 batt + R5 rigid	1,404	331	14	346	-1
Windows - U=0.43, SHGC=0.39	1,404	320	14	335	10
Windows - U=0.26, SHGC=0.37	1,404	321	14	335	10
Windows - U=0.22, SHGC=0.22	1,404	310	14	325	20

Table 92. R/RMULRIRT Alternatives Impact on TDVI

2.24 Civic/Commercial Mixed-Use Building: Library Space

Type II construction, approximately 110,000 sf five-story slab on 27,000 sf grade, mixed use building with 1.5 levels of civic (library) space and 3.5 levels of office space above. Interior floor space demised to accommodate 43,500 sf of library and 66,600 sf of office space. The ground level floor-to-floor height is 18'-0" and 14'0" for the four levels above. 45% of the roof area is available for solar cells.

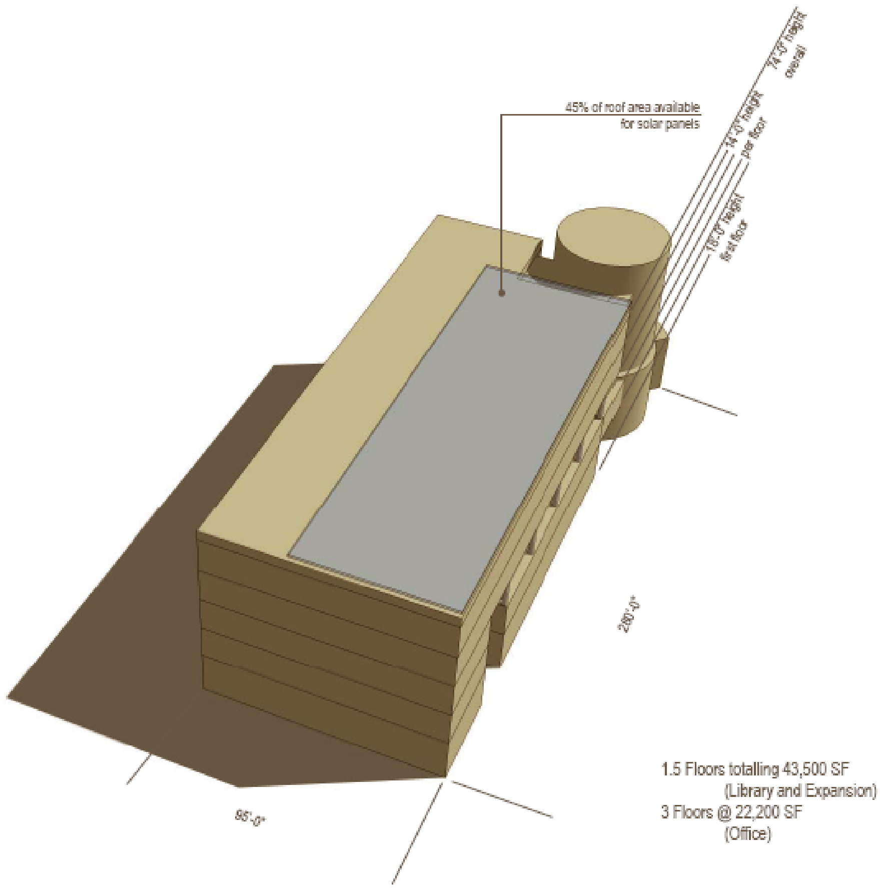

Figure 12. Civic/Commercial Mixed-Use Building

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=75%	Heating - AFUE=85%	None	None	No Alternative
Space Cooling	HVAC - COP 4.90	HVAC - COP 6.13	None	None	Alternative 1
Lighting	Lighting - 1.10 watts/sf	Lighting - 1.02 watts/sf	None	None	Alternative 1
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 2
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 93. Civic/Commercial Mixed Use: Library (C/CMUL) Alternatives

Prototype #12 Civic/Commercial Mixed Use - Library					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$69,637	$5,333	$74,970	-	-
Package - Optimum EE	$54,935	$4,669	$59,604	$45,404	3.0
DHW - EF=0.640	$69,637	$5,169	$74,806	$310	1.9
DHW - EF=0.823	$69,637	$4,701	$74,338	$371	0.6
Heating - AFUE=85%	$69,637	$5,322	$74,959	$889	80.8
HVAC - COP 6.13	$65,721	$5,333	$71,054	$3,426	0.9
Lighting - 1.02 watts/sf	$61,752	$5,370	$67,122	$0	0.0
Walls - R19 batt	$69,557	$5,320	$74,877	$891	9.6
Walls - R21 batt	$69,542	$5,320	$74,862	$1,215	11.3
Walls - R21 batt + R5 rigid	$69,469	$5,310	$74,778	$40,392	210.4
Windows - U=0.43, SHGC=0.39	$69,540	$5,311	$74,851	$4,428	37.2
Windows - U=0.26, SHGC=0.37	$69,247	$5,281	$74,527	$13,230	29.9
Windows - U=0.22, SHGC=0.22	$64,893	$5,304	$70,198	$40,392	8.5

Table 94. C/CMUL Alternatives Impact on Utility Costs & Paybacks

Prototype #12 Civic/Commercial Mixed Use - Library					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	393,633	1,343	283	1,626	-
Package - Optimum EE	314,390	1,073	235	1,308	318
DHW - EF=0.640	393,633	1,343	272	1,615	11
DHW - EF=0.823	393,633	1,343	237	1,580	46
Heating - AFUE=85%	393,633	1,343	283	1,626	0
HVAC - COP 6.13	373,678	1,275	283	1,558	68
Lighting - 1.02 watts/sf	348,339	1,189	286	1,475	151
Walls - R19 batt	393,261	1,342	282	1,624	2
Walls - R21 batt	393,175	1,342	282	1,624	2
Walls - R21 batt + R5 rigid	392,909	1,341	282	1,622	4
Windows - U=0.43, SHGC=0.39	393,623	1,343	282	1,625	1
Windows - U=0.26, SHGC=0.37	392,768	1,340	279	1,619	7
Windows - U=0.22, SHGC=0.22	368,113	1,256	281	1,537	89

Table 95. C/CMUL Alternatives Impact on Energy Consumption

Prototype #12 Civic/Commercial Mixed Use - Library					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	26,600	288	12	300	-
Package - Optimum EE	26,600	228	10	238	62
DHW - EF=0.640	26,600	288	11	299	1
DHW - EF=0.823	26,600	288	10	298	2
Heating - AFUE=85%	26,600	288	12	300	0
HVAC - COP 6.13	26,600	273	12	284	16
Lighting - 1.02 watts/sf	26,600	255	12	267	33
Walls - R19 batt	26,600	288	12	299	1
Walls - R21 batt	26,600	288	12	299	1
Walls - R21 batt + R5 rigid	26,600	287	12	299	1
Windows - U=0.43, SHGC=0.39	26,600	288	12	299	1
Windows - U=0.26, SHGC=0.37	26,600	287	12	298	2
Windows - U=0.22, SHGC=0.22	26,600	268	12	280	20

Table 96. C/CMUL Alternatives Impact on TDVI

2.25 Civic/Commercial Mixed-Use Building: Office Space

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=75%	Heating - AFUE=85%	None	None	No Alternative
Space Cooling	HVAC - COP 4.90	HVAC - COP 6.13	None	None	Alternative 1
Lighting	Lighting - 1.10 watts/sf	Lighting - 0.90 watts/sf	None	None	Alternative 1
Photovoltaics	No PV	PV - 11970 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 rigid	Roof - R15 rigid	Roof - R20 rigid	None	Alternative 2
Wall Insulation	Walls - R11 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 2
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 97. Civic/Commercial Mixed Use - Office Space (C/CMUOS) Alternatives

Prototype #12 Civic/Commercial Mixed Use - Office Space					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility**	**Alt Cost $**	**Payback yrs**
Baseline	$237,414	$13,894	$251,308	-	-
Package - Optimum EE	$194,821	$12,062	$206,883	$157,498	3.5
Package - Optimum EE + PV	$166,552	$12,058	$178,609	$743,829	10.2
CoolRoof - Abs=0.25	$235,610	$13,897	$249,506	$8,778	4.9
DHW - EF=0.640	$237,414	$13,456	$250,870	$929	2.1
DHW - EF=0.823	$237,414	$12,209	$249,623	$1,112	0.7
Heating - AFUE=85%	$237,414	$13,858	$251,272	$3,424	95.1
HVAC - COP 6.13	$224,331	$13,894	$238,225	$6,194	0.5
Lighting - 0.90 watts/sf	$221,850	$13,940	$235,790	$0	0.0
PV - 11970 sqft	$207,332	$13,894	$221,226	$595,110	19.2
Roof - R15 rigid	$236,782	$13,849	$250,631	$6,650	9.8
Roof - R20 rigid	$236,319	$13,816	$250,135	$11,970	10.2
Walls - R19 batt	$237,236	$13,865	$251,101	$2,772	13.4
Walls - R21 batt	$237,212	$13,863	$251,075	$3,780	16.2
Walls - R21 batt + R5 rigid	$236,956	$13,841	$250,798	$7,308	14.3
Windows - U=0.43, SHGC=0.39	$237,266	$13,840	$251,106	$13,776	68.2
Windows - U=0.26, SHGC=0.37	$236,700	$13,736	$250,436	$41,160	47.2
Windows - U=0.22, SHGC=0.22	$223,378	$13,810	$237,188	$125,664	8.9

Table 98. C/CMUOS Alternatives Impact on Utility Costs & Paybacks

Prototype #12 Civic/Commercial Mixed Use - Office Space					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	1,355,741	4,626	908	5,533	-
Package - Optimum EE	1,125,886	3,842	774	4,616	917
Package - Optimum EE + PV	945,252	3,225	774	3,999	1,534
CoolRoof - Abs=0.25	1,345,463	4,591	908	5,499	34
DHW - EF=0.640	1,355,741	4,626	876	5,502	31
DHW - EF=0.823	1,355,741	4,626	785	5,411	122
Heating - AFUE=85%	1,355,741	4,626	905	5,531	2
HVAC - COP 6.13	1,288,801	4,397	908	5,305	228
Lighting - 0.90 watts/sf	1,266,044	4,320	911	5,231	302
PV - 11970 sqft	1,168,899	3,988	908	4,896	637
Roof - R15 rigid	1,353,171	4,617	904	5,521	12
Roof - R20 rigid	1,351,279	4,611	902	5,512	21
Walls - R19 batt	1,354,931	4,623	906	5,529	4
Walls - R21 batt	1,354,817	4,623	905	5,528	5
Walls - R21 batt + R5 rigid	1,353,640	4,619	904	5,522	11
Windows - U=0.43, SHGC=0.39	1,356,307	4,628	904	5,531	2
Windows - U=0.26, SHGC=0.37	1,355,163	4,624	896	5,520	13
Windows - U=0.22, SHGC=0.22	1,280,186	4,368	901	5,269	264

Table 99. C/CMUOS Alternatives Impact on Energy Consumption

Prototype #12 Civic/Commercial Mixed Use - Office Space					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	106,400	248	9	257	-
Package - Optimum EE	106,400	204	8	212	45
Package - Optimum EE + PV	106,400	167	8	175	82
CoolRoof - Abs=0.25	106,400	246	9	255	2
DHW - EF=0.640	106,400	248	9	257	0
DHW - EF=0.823	106,400	248	8	256	1
Heating - AFUE=85%	106,400	248	9	257	0
HVAC - COP 6.13	106,400	235	9	244	13
Lighting - 0.90 watts/sf	106,400	231	9	241	16
PV - 11970 sqft	106,400	210	9	220	37
Roof - R15 rigid	106,400	247	9	256	1
Roof - R20 rigid	106,400	247	9	256	1
Walls - R19 batt	106,400	247	9	257	0
Walls - R21 batt	106,400	247	9	257	0
Walls - R21 batt + R5 rigid	106,400	247	9	256	1
Windows - U=0.43, SHGC=0.39	106,400	247	9	257	0
Windows - U=0.26, SHGC=0.37	106,400	247	9	256	1
Windows - U=0.22, SHGC=0.22	106,400	233	9	242	15

Table 100. C/CMUOS Alternatives Impact on TDVI

2.26 Residential Multi-Family/Town Home (20-dua)

Type V construction, two parallel town home buildings approximately 9,800 sf each. Three-story structure with tuck-under parking. Interior floor space demised to accommodate 7 individual units; three 2BR, three 3BR, and one 4 BR units ranging from approximately 1300 sf to 1,600 sf each. The floor-to-floor height is 10'-0" and 45% of the roof area is available for solar cells.

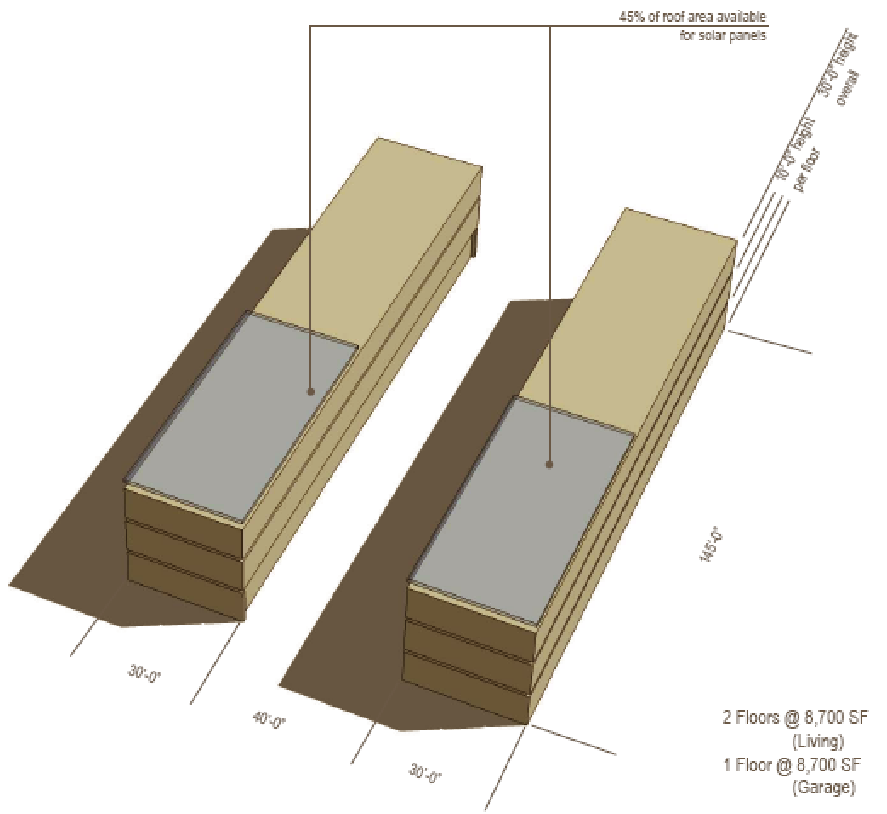

Figure 13. Residential Multi-Family/Town Home

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliance	Dish EF=.46, Clothes MMEF=1.26	Dish EF=.64, Clothes MMEF=2.0	Dish EF=.64, Clothes MMEF=2.2	None	No Alternative
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Lighting	Lighting - 0.706 watts/sf	Lighting - 0.657 watts/sf	None	None	No Alternative
Photovoltaics	No PV	PV - 2205 watts/sf	None	None	Alternative 1
Roof Insulation	Roof - U=R30 batt	Roof - R38 batt	Roof - R49 batt	None	No Alternative
Wall Insulation	Walls - R13 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3
Solar Thermal	No Solar Thermal	ST - 441 sqft, 840 gal	None	None	No Alternative

Table 101. Residential Multi-Family/Town Home (RMF/TH) Alternatives

Prototype #13 Residential Multi-Family/Town Home					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$11,384	$2,117	$13,501	-	-
Package - Optimum EE	$10,929	$1,698	$12,627	$13,644	15.6
Package - Optimum EE + PV	$2,291	$1,698	$3,989	$132,089	11.6
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	$11,305	$2,117	$13,422	$1,852	23.4
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	$11,305	$2,117	$13,422	$2,510	31.8
DHW - EF=0.640	$11,384	$2,007	$13,391	$4,337	39.4
DHW - EF=0.823	$11,384	$1,698	$13,082	$5,189	12.4
HVAC - EER 12.19, COP 3.52	$11,237	$2,117	$13,354	$736	5.0
HVAC - EER 12.06, COP 3.48	$11,254	$2,117	$13,371	$2,209	17.0
HVAC - EER 12.80, COP 3.66	$11,149	$2,117	$13,266	$3,682	15.7
Lighting - 0.657 watts/sf	$11,078	$2,117	$13,195	$8,820	28.8
PV - 2205 sqft	$2,692	$2,117	$4,809	$109,625	10.3
Roof - R38 batt	$11,366	$2,117	$13,483	$931	51.7
Roof - R49 batt	$11,325	$2,117	$13,442	$3,234	54.8
Walls - R19 batt	$11,384	$2,117	$13,501	$464	Never
Walls - R21 batt	$11,386	$2,117	$13,503	$671	Never
Walls - R21 batt + R5 rigid	$11,374	$2,117	$13,491	$1,961	196.1
Windows - U=0.43, SHGC=0.39	$11,393	$2,117	$13,510	$523	Never
Windows - U=0.26, SHGC=0.37	$11,421	$2,117	$13,538	$1,563	Never
Windows - U=0.22, SHGC=0.22	$11,092	$2,117	$13,209	$4,772	16.3
ST - 441 sqft, 840 gal	Not Reported				

Table 102. RMF/TH Alternatives Impact on Utility Costs & Paybacks

Prototype #13 Residential Multi-Family/Town Home					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	49,337	168	169	337	-
Package - Optimum EE	47,521	162	137	299	38
Package - Optimum EE + PV	11,820	40	137	177	160
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	49,028	167	169	336	1
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	49,018	167	169	336	1
DHW - EF=0.640	49,337	168	160	329	8
DHW - EF=0.823	49,337	168	137	305	32
HVAC - EER 12.19, COP 3.52	48,750	166	169	335	2
HVAC - EER 12.06, COP 3.48	48,816	167	169	335	2
HVAC - EER 12.80, COP 3.66	48,392	165	169	334	3
Lighting - 0.657 watts/sf	48,103	164	169	333	4
PV - 2205 watts/sf	13,639	47	169	215	122
Roof - R38 batt	49,268	168	169	337	0
Roof - R49 batt	49,101	168	169	336	1
Walls - R19 batt	49,335	168	169	337	0
Walls - R21 batt	49,344	168	169	337	0
Walls - R21 batt + R5 rigid	49,299	168	169	337	0
Windows - U=0.43, SHGC=0.39	49,373	168	169	337	0
Windows - U=0.26, SHGC=0.37	49,486	169	169	337	0
Windows - U=0.22, SHGC=0.22	48,179	164	169	333	4
ST - 441 sqft, 840 gal	Not Reported				

Table 103. RMF/TH Alternatives Impact on Energy Consumption

Prototype #13 Residential Multi-Family/Town Home					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	9,800	75	18	93	-
Package - Optimum EE	9,800	72	15	87	6
Package - Optimum EE + PV	9,800	13	15	27	66
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	9,800	75	18	93	0
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	9,800	75	18	93	0
DHW - EF=0.640	9,800	75	17	92	1
DHW - EF=0.823	9,800	75	15	90	3
HVAC - EER 12.19, COP 3.52	9,800	74	18	92	1
HVAC - EER 12.06, COP 3.48	9,800	74	18	92	1
HVAC - EER 12.80, COP 3.66	9,800	73	18	92	1
Lighting - 0.657 watts/sf	9,800	73	18	91	2
PV - 2205 watts/sf	9,800	16	18	34	59
Roof - R38 batt	9,800	75	18	93	0
Roof - R49 batt	9,800	75	18	93	0
Walls - R19 batt	9,800	75	18	93	0
Walls - R21 batt	9,800	75	18	93	0
Walls - R21 batt + R5 rigid	9,800	75	18	93	0
Windows - U=0.43, SHGC=0.39	9,800	75	18	93	0
Windows - U=0.26, SHGC=0.37	9,800	75	18	93	0
Windows - U=0.22, SHGC=0.22	9,800	73	18	91	2
ST - 441 sqft, 840 gal	9,800	0	0	0	0

Table 104. RMF/TH Alternatives Impact on TDVI

2.27 Residential Low-Rise (30-40+ dua)

Type II construction at ground level parking and type V construction above, approximately 63,000 sf three-story residential above 44,000 sf parking structure. Residential floor space demised to accommodate 62 individual units; 19 Studios, 24 2BR and 19 3BR units ranging from approximately 600 to 1,300 sf each. The floor-to-floor height is 10'-0" for the residential levels. 45% of the roof area is available for solar cells.

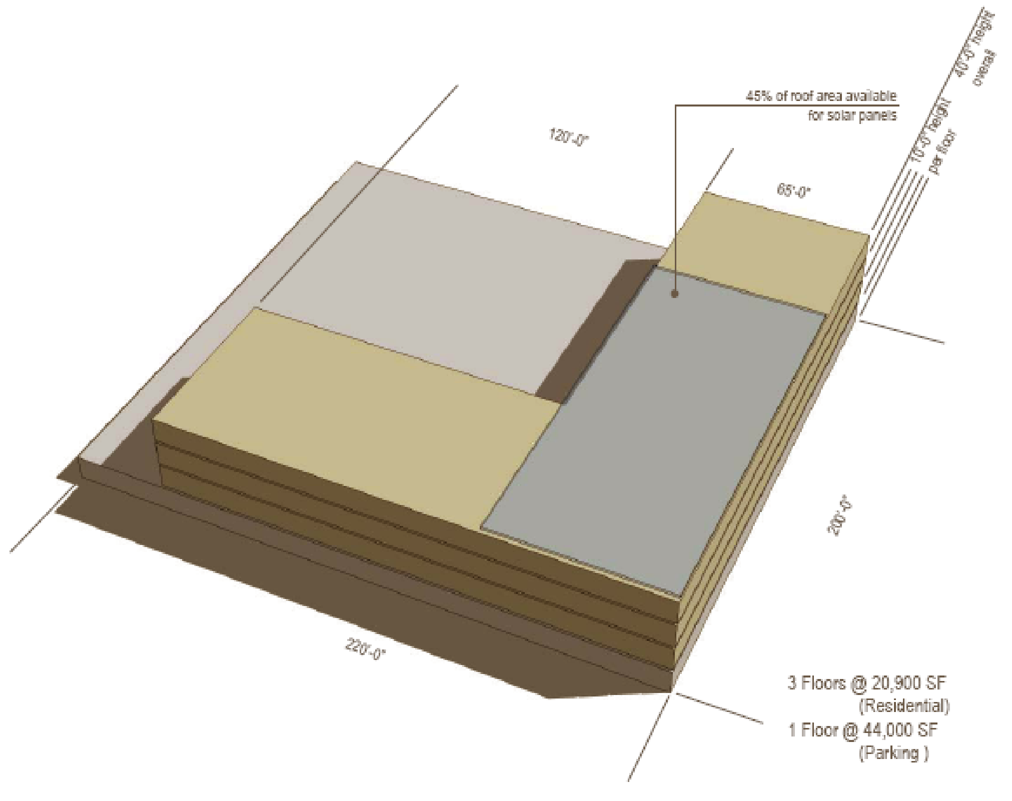

Figure 14. Residential Low-Rise

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliance	Dish EF=.46, Clothes MMEF=1.26	Dish EF=.64, Clothes MMEF=2.0	Dish EF=.64, Clothes MMEF=2.2	None	Alternative 1
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Htg/Clg	HVAC - EER 11.07, COP 3.28	HVAC - EER 12.19, COP 3.52	HVAC - EER 12.06, COP 3.48	HVAC - EER 12.80, COP 3.66	Alternative 3
Lighting	Lighting - 0.711 watts/sf	Lighting - 0.648 watts/sf	None	None	No Alternative
Photovoltaics	No PV	PV - 9375 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R30 batt	Roof - R38 batt	Roof - R49 batt	None	No Alternative
Wall Insulation	Walls - R13 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	No Alternative
Windows	Windows - U=0.56, SHGC=0.42	Windows - U=0.43, SHGC=0.39	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	Alternative 3

Table 105. Residential Low-Rise (RLR) Alternatives

Prototype #14 Residential Low-Rise					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$84,776	$14,469	$99,245	-	-
Package - Optimum EE	$80,010	$12,243	$92,253	$62,740	9.0
Package - Optimum EE + PV	$42,669	$12,243	$54,912	$584,627	12.0
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	$83,400	$14,469	$97,869	$16,408	11.9
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	$83,346	$14,469	$97,815	$22,236	15.5
CoolRoof - Abs=0.25	$84,432	$14,469	$98,901	$6,875	20.0
DHW - EF=0.640	$84,776	$13,894	$98,670	$19,206	33.4
DHW - EF=0.823	$84,776	$12,243	$97,019	$22,980	10.3
HVAC - EER 12.19, COP 3.52	$83,337	$14,469	$97,806	$3,925	2.7
HVAC - EER 12.06, COP 3.48	$83,559	$14,469	$98,028	$11,776	9.7
HVAC - EER 12.80, COP 3.66	$82,601	$14,469	$97,070	$11,676	5.4
Lighting - 0.648 watts/sf	$82,566	$14,469	$97,035	$55,800	25.2
PV - 9375 sqft	$47,153	$14,469	$61,622	$466,087	11.0
Roof - R38 batt	$84,850	$14,469	$99,319	$3,958	Never
Roof - R49 batt	$85,046	$14,469	$99,515	$13,750	Never
Walls - R19 batt	$84,900	$14,469	$99,369	$1,420	Never
Walls - R21 batt	$85,016	$14,469	$99,485	$2,051	Never
Walls - R21 batt + R5 rigid	$85,103	$14,469	$99,572	$5,996	Never
Windows - U=0.43, SHGC=0.39	$84,861	$14,469	$99,330	$1,280	Never
Windows - U=0.26, SHGC=0.37	$85,135	$14,469	$99,604	$3,824	Never
Windows - U=0.22, SHGC=0.22	$83,835	$14,469	$98,304	$11,676	12.4

Table 106. RLR Alternatives Impact on Utility Costs & Paybacks

Prototype #14 Residential Low-Rise					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	347,832	1,187	1,107	2,294	-
Package - Optimum EE	328,556	1,121	938	2,059	235
Package - Optimum EE + PV	177,176	605	938	1,543	751
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	342,215	1,168	1,107	2,275	19
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	341,995	1,167	1,107	2,274	20
CoolRoof - Abs=0.25	346,445	1,182	1,107	2,289	5
DHW - EF=0.640	347,832	1,187	1,064	2,250	44
DHW - EF=0.823	347,832	1,187	938	2,125	169
HVAC - EER 12.19, COP 3.52	342,034	1,167	1,107	2,274	20
HVAC - EER 12.06, COP 3.48	342,942	1,170	1,107	2,277	17
HVAC - EER 12.80, COP 3.66	339,075	1,157	1,107	2,264	30
Lighting - 0.648 watts/sf	338,826	1,156	1,107	2,263	31
PV - 9375 sqft	195,328	666	1,107	1,774	520
Roof - R38 batt	348,148	1,188	1,107	2,295	-1
Roof - R49 batt	348,972	1,191	1,107	2,298	-4
Walls - R19 batt	348,371	1,189	1,107	2,296	-2
Walls - R21 batt	348,857	1,190	1,107	2,297	-3
Walls - R21 batt + R5 rigid	349,239	1,192	1,107	2,299	-5
Windows - U=0.43, SHGC=0.39	348,197	1,188	1,107	2,295	-1
Windows - U=0.26, SHGC=0.37	349,335	1,192	1,107	2,299	-5
Windows - U=0.22, SHGC=0.22	344,037	1,174	1,107	2,281	13

Table 107. RLR Alternatives Impact on Energy Consumption

Prototype #14 Residential Low-Rise					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	62,498	82	19	101	-
Package - Optimum EE	62,498	77	16	93	8
Package - Optimum EE + PV	62,498	38	16	54	47
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	62,498	81	19	100	1
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	62,498	81	19	99	2
CoolRoof - Abs=0.25	62,498	82	19	100	1
DHW - EF=0.640	62,498	82	18	100	1
DHW - EF=0.823	62,498	82	16	98	3
HVAC - EER 12.19, COP 3.52	62,498	81	19	99	2
HVAC - EER 12.06, COP 3.48	62,498	81	19	100	1
HVAC - EER 12.80, COP 3.66	62,498	80	19	99	2
Lighting - 0.648 watts/sf	62,498	80	19	99	2
PV - 9375 sqft	62,498	42	19	61	40
Roof - R38 batt	62,498	82	19	101	0
Roof - R49 batt	62,498	82	19	101	0
Walls - R19 batt	62,498	82	19	101	0
Walls - R21 batt	62,498	82	19	101	0
Walls - R21 batt + R5 rigid	62,498	82	19	101	0
Windows - U=0.43, SHGC=0.39	62,498	82	19	101	0
Windows - U=0.26, SHGC=0.37	62,498	82	19	101	0
Windows - U=0.22, SHGC=0.22	62,498	81	19	100	1

Table 108. RLR Alternatives Impact on TDVI

2.28 Residential Mid-Rise (60-75+ dua)

Type III construction, approximately 130,000 sf six-story residential above parking structure. Residential floor space demised to accommodate 135 individual units; 19 Studios, 48 2BR and 36 3BR units ranging from approximately 600 to 1,300 sf each. The floor-to-floor height is 10'-0" for the residential levels. 45% of the roof area is available for solar cells.

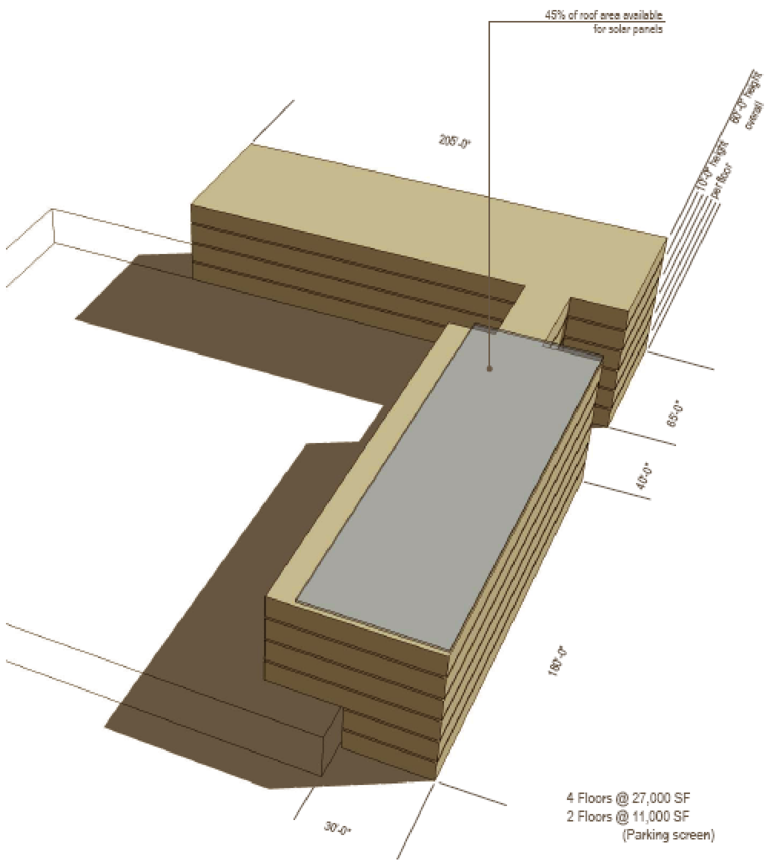

Figure 15. Residential Mid-Rise

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliance	Dish EF=.46, Clothes MMEF=1.26	Dish EF=.64, Clothes MMEF=2.0	Dish EF=.64, Clothes MMEF=2.2	None	No Alternative
Roof Material	CoolRoof - Abs=0.40	CoolRoof - Abs=0.25	None	None	Alternative 1
Water Heating	DHW - EF=0.594	DHW - EF=0.640	DHW - EF=0.823	None	Alternative 2
Space Heating	Heating - AFUE=75%	Heating - AFUE=85%	None	None	No Alternative
Space Cooling	HVAC - COP 6.10	HVAC - COP 7.63	None	None	Alternative 1
Lighting	Lighting - 0.703 watts/sf	Lighting - 0.664 watts/sqft	None	None	No Alternative
Photovoltaics	No PV	PV - 9763 sqft	None	None	Alternative 1
Roof Insulation	Roof - U=R10 batt	Roof - U=R15 rigid	Roof - U=R20 rigid	None	Alternative 2
Wall Insulation	Walls - R13 batt	Walls - R19 batt	Walls - R21 batt	Walls - R21 batt + R5 rigid	Alternative 3
Windows	Windows - U=0.48, SHGC=0.47	Windows - U=0.26, SHGC=0.37	Windows - U=0.22, SHGC=0.22	None	Alternative 2

Table 109. Residential Mid-Rise (RMR) Alternatives

Prototype #15 Residential Mid-Rise					
Alternative	Elec Utility $	Gas Utility $	Total Utility	Alt Cost $	Payback yrs
Baseline	$181,789	$48,919	$230,709	-	-
Package - Optimum EE	$168,877	$44,007	$212,885	$106,601	6.0
Package - Optimum EE + PV	$131,077	$44,004	$175,081	$584,814	10.6
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	$179,739	$48,922	$228,661	$35,726	17.4
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	$179,616	$48,922	$228,538	$48,416	22.3
CoolRoof - Abs=0.25	$180,046	$48,922	$228,968	$7,159	4.1
DHW - EF=0.640	$182,651	$47,563	$230,214	$41,819	84.5
DHW - EF=0.823	$181,789	$44,064	$225,853	$50,036	10.3
Heating - AFUE=85%	$181,789	$48,909	$230,698	$1,000	90.9
HVAC - COP 7.63	$176,440	$48,919	$225,360	$5,671	1.1
Lighting - 0.664 watts/sqft	$176,990	$48,925	$225,915	$121,500	25.3
PV - 9763 sqft	$142,691	$48,919	$191,611	$485,372	12.4
Roof - U=R15 rigid	$181,671	$48,909	$230,580	$5,424	42.0
Roof - U=R20 rigid	$181,467	$48,894	$230,362	$9,763	28.1
Walls - R19 batt	$181,659	$48,914	$230,573	$2,967	21.8
Walls - R21 batt	$181,580	$48,913	$230,493	$4,285	19.8
Walls - R21 batt + R5 rigid	$181,117	$48,900	$230,017	$12,527	18.1
Windows - U=0.26, SHGC=0.37	$178,474	$48,914	$227,388	$7,024	2.1
Windows - U=0.22, SHGC=0.22	$175,595	$48,918	$224,513	$21,445	3.5

Table 110. RMR Alternatives Impact on Utility Costs & Paybacks

Prototype #15 Residential Mid-Rise					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	744,371	2,540	3,725	6,264	-
Package - Optimum EE	692,345	2,362	3,351	5,714	550
Package - Optimum EE + PV	539,100	1,839	3,351	5,191	1,073
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	736,021	2,511	3,725	6,236	28
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	735,522	2,510	3,725	6,234	30
CoolRoof - Abs=0.25	737,301	2,516	3,725	6,240	24
DHW - EF=0.640	745,095	2,542	3,622	6,164	100
DHW - EF=0.823	744,371	2,540	3,356	5,896	368
Heating - AFUE=85%	744,371	2,540	3,724	6,263	1
HVAC - COP 7.63	722,879	2,466	3,725	6,191	73
Lighting - 0.664 watts/sqft	724,843	2,473	3,725	6,198	66
PV - 9763 sqft	585,882	1,999	3,725	5,724	540
Roof - U=R15 rigid	743,934	2,538	3,724	6,262	2
Roof - U=R20 rigid	743,132	2,536	3,723	6,258	6
Walls - R19 batt	743,872	2,538	3,724	6,262	2
Walls - R21 batt	743,558	2,537	3,724	6,261	3
Walls - R21 batt + R5 rigid	741,716	2,531	3,723	6,254	10
Windows - U=0.26, SHGC=0.37	730,946	2,494	3,724	6,218	46
Windows - U=0.22, SHGC=0.22	719,268	2,454	3,724	6,179	85

Table 111. RMR Alternatives Impact on Energy Consumption

Prototype #15 Residential Mid-Rise					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	130,171	85	30	115	-
Package - Optimum EE	130,171	78	27	106	9
Package - Optimum EE + PV	130,171	59	27	86	29
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 1.26	130,171	84	30	114	1
Appliance - Dishwasher EF=0.64, Clothes Washer MMEF = 2.00	130,171	84	30	114	1
CoolRoof - Abs=0.25	130,171	84	30	114	1
DHW - EF=0.640	130,171	85	29	114	1
DHW - EF=0.823	130,171	85	27	112	3
Heating - AFUE=85%	130,171	85	30	115	0
HVAC - COP 7.63	130,171	82	30	112	3
Lighting - 0.664 watts/sqft	130,171	82	30	113	2
PV - 9763 sqft	130,171	65	30	95	20
Roof - U=R15 rigid	130,171	84	30	115	0
Roof - U=R20 rigid	130,171	84	30	115	0
Walls - R19 batt	130,171	85	30	115	0
Walls - R21 batt	130,171	84	30	115	0
Walls - R21 batt + R5 rigid	130,171	84	30	115	0
Windows - U=0.26, SHGC=0.37	130,171	83	30	113	2
Windows - U=0.22, SHGC=0.22	130,171	82	30	112	3

Table 112. RMR Alternatives Impact on TDVI

Chapter 3. Alternatives for 12 Building Types & Spaces: Residential-Sites

3.1 Residential Single-Family Detached Home (6 -dua)

Type V construction, Colonial style approximately 2,540 sf. 2-story structure with 2-car attached direct-access garage parking. Interior floor space demised to accommodate 4 BR and 3 BA. The floor-to-floor height is 11'-0" and 45% of the roof area is available for solar cells.

Figure 16. Residential Single-Family Detached Home

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	0.35193 w/sqft, 0.54043 Btu/hr/sqft	0.34694 w/sqft, 0.54043 Btu/hr/sqft	0.34663 w/sqft, 0.54043 Btu/hr/sqft	None	No Alternative
CHP	None	None	None	None	No Alternative
Roof Material	100% of roof at Abs=0.70	None	None	None	No Alternative
Water Heating	EF=0.594	EF=0.823	None	None	Alternative 1
Windows	U=0.56, SHGC=0.42	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	Alternative 2
Space Heating	Heat Pump (See Space Cooling)	AFUE=94%	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	SEER 14, EER 11.99	SEER 15, EER 12.72	SEER 18, EER 13.37	Alternative 2
Lighting	0.554 watts/sqft	0.508 watts/sqft	None	None	No Alternative
Photovoltaics	None	None	None	None	No Alternative
Roof Insulation	R30 batt	R38 batt	R49 batt	None	Alternative 1
Solar Thermal	None	42 Sqft of panels, 84 Gal tank	None	None	No Alternative
Thermal Storage	None	None	None	None	No Alternative
Wall Insulation	R13 batt	R19 batt	R21 batt	R21 batt + R5 rigid	Alternative 2

Table 113. Residential Single-Family Detached Home (RSFDH) Alternatives

Prototype #1 Luminara Residential					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility $**	**Alt Cost $**	**Payback yrs**
Baseline	$1,689	$363	$2,052	$0	NA
Baseline + EE Package	$1,464	$315	$1,779	$3,406	12.5
Baseline + High Efficiency Appliances, 0.34694 w/sqft, 0.54043 Btu/hr/sqft	$1,672	$363	$2,035	$265	15.6
Baseline + High Efficiency Appliances, 0.34663 w/sqft, 0.54043 Btu/hr/sqft	$1,671	$363	$2,034	$359	19.9
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$1,689	$304	$1,993	$371	6.3
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$1,692	$342	$2,034	$476	26.4
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$1,501	$392	$1,893	$1,421	8.9
Baseline + High Efficiency Heating, AFUE=94%	$1,689	$353	$2,042	$1,000	100.0
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	$1,665	$363	$2,028	$329	13.7
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	$1,647	$363	$2,010	$658	15.7
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	$1,633	$363	$1,996	$1,645	29.4
Baseline + High Efficiency Lighting, 0.508 watts/sqft	$1,645	$364	$2,009	$2,070	48.1
Baseline + Envelope Insulation - Roof, R38 batt	$1,683	$360	$2,043	$213	23.7
Baseline + Envelope Insulation - Roof, R49 batt	$1,676	$359	$2,035	$978	57.5
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	$1,689	$238	$1,927	$9,112	89.1
Baseline + Envelope Insulation - Walls, R19 batt	$1,682	$354	$2,036	$403	25.2
Baseline + Envelope Insulation - Walls, R21 batt	$1,681	$353	$2,034	$743	41.3
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$1,673	$342	$2,015	$4,707	127.2

Table 114. RSFDH Alternatives Impact on Utility Costs and Paybacks

Prototype #1 Luminara Residential					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	11,091	38	33	71	0
Baseline + EE Package	10,078	34	29	63	8
Baseline + High Efficiency Appliances, 0.34694 w/sqft, 0.54043 Btu/hr/sqft	11,009	38	33	70	1
Baseline + High Efficiency Appliances, 0.34663 w/sqft, 0.54043 Btu/hr/sqft	11,004	38	33	70	1
Baseline + High Efficiency Domestic Hot Water, EF=0.823	11,091	38	28	65	6
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	11,100	38	31	69	2
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	10,242	35	36	70	1
Baseline + High Efficiency Heating, AFUE=94%	11,091	38	32	70	1
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	10,986	37	33	70	1
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	10,912	37	33	70	1
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	10,853	37	33	70	1
Baseline + High Efficiency Lighting, 0.508 watts/sqft	10,891	37	33	70	1
Baseline + Envelope Insulation - Roof, R38 batt	11,071	38	33	70	1
Baseline + Envelope Insulation - Roof, R49 batt	11,044	38	33	70	1
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	11,091	38	22	60	11
Baseline + Envelope Insulation - Walls, R19 batt	11,060	38	32	70	1
Baseline + Envelope Insulation - Walls, R21 batt	11,048	38	32	69	2
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	11,012	38	31	68	3

Table 115. RSFDH Alternatives Impact on Energy Consumption

Prototype #1 Luminara Residential					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	2,540	66	14	80	0
Baseline + EE Package	2,540	59	12	71	9
Baseline + High Efficiency Appliances, 0.34694 w/sqft, 0.54043 Btu/hr/sqft	2,540	66	14	80	0
Baseline + High Efficiency Appliances, 0.34663 w/sqft, 0.54043 Btu/hr/sqft	2,540	66	14	79	1
Baseline + High Efficiency Domestic Hot Water, EF=0.823	2,540	66	11	78	2
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	2,540	66	13	79	1
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	2,540	61	15	75	5
Baseline + High Efficiency Heating, AFUE=94%	2,540	66	13	80	0
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	2,540	66	14	79	1
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	2,540	65	14	78	2
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	2,540	64	14	78	2
Baseline + High Efficiency Lighting, 0.508 watts/sqft	2,540	65	14	79	1
Baseline + Envelope Insulation - Roof, R38 batt	2,540	66	14	80	0
Baseline + Envelope Insulation - Roof, R49 batt	2,540	66	13	80	0
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	2,540	66	9	75	5
Baseline + Envelope Insulation - Walls, R19 batt	2,540	66	13	79	1
Baseline + Envelope Insulation - Walls, R21 batt	2,540	66	13	79	1
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	2,540	66	13	78	2

Table 116. RSFDH Alternatives Impact on TDVI

3.2 Residential Multi-Family Town Home (15+ dua)

Type V construction, approximately 2,980 sf total. 2-story structure with 2-car attached direct-access garage parking per unit. Interior floor space demised to accommodate 2 individual units at approximately 1490 sf each, 3 BR and 2.5 BA. The floor-to-floor height is 11'-0" and 45% of the roof area is available for solar cells.

Figure 17. Residential Multi-Family Town Home

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	0.39347 w/sqft, 0.93 Btu/hr/sqft	0.38497 w/sqft, 0.93 Btu/hr/sqft	0.38444 w/sqft, 0.93 Btu/hr/sqft	None	No Alternative
CHP	None	None	None	None	No Alternative
Roof Material	100% of roof at Abs=0.70	None	None	None	No Alternative
Water Heating	EF=0.594	EF=0.823	None	None	Alternative 1
Windows	U=0.56, SHGC=0.42	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	Alternative 2
Space Heating	Heat Pump (See Space Cooling)	AFUE=94%	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	SEER 14, EER 11.99	SEER 15, EER 12.72	SEER 18, EER 13.37	Alternative 1
Lighting	0.592 watts/sqft	0.542 watts/sqft	None	None	No Alternative
Photovoltaics	None	None	None	None	No Alternative
Roof Insulation	R30 batt	R38 batt	R49 batt	None	Alternative 1
Solar Thermal	None	42 Sqft of panels, 84 Gal tank	None	None	No Alternative
Thermal Storage	None	None	None	None	No Alternative
Wall Insulation	R13 batt	R19 batt	R21 batt	R21 batt + R5 rigid	Alternative 2

Table 117 - Residential Multi-Family Town Home (RMFTH) Alternatives

Prototype #2 Chambray Residential					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility $**	**Alt Cost $**	**Payback yrs**
Baseline	$2,238	$601	$2,839	$0	NA
Baseline + EE Package	$2,036	$484	$2,520	$3,213	10.1
Baseline + High Efficiency Appliances, 0.38497 w/sqft, 0.93 Btu/hr/sqft	$2,204	$602	$2,806	$529	16.0
Baseline + High Efficiency Appliances, 0.38444 w/sqft, 0.93 Btu/hr/sqft	$2,201	$602	$2,803	$717	19.9
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$2,238	$493	$2,731	$741	6.9
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$2,244	$586	$2,830	$331	36.8
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$2,091	$625	$2,716	$990	8.0
Baseline + High Efficiency Heating, AFUE=94%	$2,238	$590	$2,828	$2,000	181.8
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	$2,215	$601	$2,816	$400	17.4
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	$2,197	$601	$2,798	$800	19.5
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	$2,185	$601	$2,786	$2,001	37.7
Baseline + High Efficiency Lighting, 0.542 watts/sqft	$2,182	$602	$2,784	$2,700	49.1
Baseline + Envelope Insulation - Roof, R38 batt	$2,231	$598	$2,829	$250	25.0
Baseline + Envelope Insulation - Roof, R49 batt	$2,225	$598	$2,823	$1,148	71.8
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	$2,238	$371	$2,609	$18,224	98.8
Baseline + Envelope Insulation - Walls, R19 batt	$2,233	$592	$2,825	$450	32.2
Baseline + Envelope Insulation - Walls, R21 batt	$2,231	$588	$2,819	$831	41.6
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$2,223	$577	$2,800	$5,266	135.0

Table 118. RMFTH Alternatives Impact on Utility Costs and Paybacks

Prototype #2 Chambray Residential					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	13,612	46	53	99	0
Baseline + EE Package	12,710	43	43	86	13
Baseline + High Efficiency Appliances, 0.38497 w/sqft, 0.93 Btu/hr/sqft	13,450	46	53	99	0
Baseline + High Efficiency Appliances, 0.38444 w/sqft, 0.93 Btu/hr/sqft	13,440	46	53	99	0
Baseline + High Efficiency Domestic Hot Water, EF=0.823	13,612	46	44	90	9
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	13,634	47	52	98	1
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	12,954	44	55	99	0
Baseline + High Efficiency Heating, AFUE=94%	13,612	46	52	99	0
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	13,511	46	53	99	0
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	13,439	46	53	99	0
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	13,381	46	53	98	1
Baseline + High Efficiency Lighting, 0.542 watts/sqft	13,359	46	53	99	0
Baseline + Envelope Insulation - Roof, R38 batt	13,587	46	53	99	0
Baseline + Envelope Insulation - Roof, R49 batt	13,553	46	52	99	0
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	13,612	46	33	80	19
Baseline + Envelope Insulation - Walls, R19 batt	13,584	46	52	98	1
Baseline + Envelope Insulation - Walls, R21 batt	13,576	46	52	98	1
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	13,539	46	51	97	2

Table 119. RMFTH Alternatives Impact on Energy Consumption

Prototype #2 Chambray Residential					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	2,982	69	19	87	0
Baseline + EE Package	2,982	63	15	79	8
Baseline + High Efficiency Appliances, 0.38497 w/sqft, 0.93 Btu/hr/sqft	2,982	68	19	87	0
Baseline + High Efficiency Appliances, 0.38444 w/sqft, 0.93 Btu/hr/sqft	2,982	68	19	87	0
Baseline + High Efficiency Domestic Hot Water, EF=0.823	2,982	69	16	84	3
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	2,982	69	18	87	0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	2,982	65	19	84	3
Baseline + High Efficiency Heating, AFUE=94%	2,982	69	19	87	0
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	2,982	68	19	87	0
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	2,982	68	19	86	1
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	2,982	67	19	86	1
Baseline + High Efficiency Lighting, 0.542 watts/sqft	2,982	67	19	86	1
Baseline + Envelope Insulation - Roof, R38 batt	2,982	69	19	87	0
Baseline + Envelope Insulation - Roof, R49 batt	2,982	68	19	87	0
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	2,982	69	12	80	7
Baseline + Envelope Insulation - Walls, R19 batt	2,982	68	18	87	0
Baseline + Envelope Insulation - Walls, R21 batt	2,982	68	18	87	0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	2,982	68	18	86	1

Table 120. RMFTH Alternatives Impact on TDVI

3.3 Retail/Residential Mixed-Use Low-Rise Building Residential Space (20-dua)

Type V construction for retail and residential space, approximately 10,110 sf three-story mixed use slab on grade building. Interior floor space demised to accommodate 2 individual retail tenants at street level averaging 510 sf each. Two and a half floor levels of residential apartments on or above the first floor totaling approximately 9,090 sf. Residential floor space demised to accommodate 5 individual 2BR, 2BA units ranging from approximately 1220 to 1,970 sf each. The floor-to-floor height for the first floor retail is 14'-0" and 11'-0" for the residential levels above. 45% of the roof area is available for solar cells.

Figure 18. Residential Multi-Family Town Home

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	0.37556 w/sqft, 0.75563 Btu/hr/sqft	0.36858 w/sqft, 0.75563 Btu/hr/sqft	0.36815 w/sqft, 0.75563 Btu/hr/sqft	None	Alternative 1
CHP	None	None	None	None	No Alternative
Roof Material	75% of roof at Abs=0.70	75% of roof at Abs=0.25	None	None	Alternative 1
Water Heating	EF=0.594	EF=0.823	None	None	Alternative 1
Windows	U=0.56, SHGC=0.42	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	Alternative 2
Space Heating	Heat Pump (See Space Cooling)	AFUE=94%	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	SEER 14, EER 11.99	SEER 15, EER 12.72	SEER 18, EER 13.37	Alternative 2
Lighting	0.643 watts/sqft	0.587 watts/sqft	None	None	No Alternative
Photovoltaics	None	1640 Sqft @ 0 deg pitch	None	None	Alternative 1
Roof Insulation	R30 batt	R38 batt	R49 batt	None	Alternative 2
Solar Thermal	None	42 Sqft of panels, 84 Gal tank	None	None	No Alternative
Thermal Storage	None	None	None	None	No Alternative
Wall Insulation	R13 batt	R19 batt	R21 batt	R21 batt + R5 rigid	No Alternative

Table 121. Retail/Residential Mixed-Use Low-Rise Building – Residential Space (R/RMULRB-RS) Alternatives

Prototype #3 Artisan Residential					
Alternative	Elec Utility $	Gas Utility $	Total Utility $	Alt Cost $	Payback yrs
Baseline	$8,712	$1,556	$10,268	$0	NA
Baseline + EE Package	$8,127	$1,273	$9,400	$8,144	9.4
Baseline + EE Package + Photovoltaics	$4,701	$1,273	$5,974	$89,680	16.2
Baseline + High Efficiency Appliances, 0.36858 w/sqft, 0.75563 Btu/hr/sqft	$8,609	$1,558	$10,167	$1,323	13.1
Baseline + High Efficiency Appliances, 0.36815 w/sqft, 0.75563 Btu/hr/sqft	$8,604	$1,558	$10,162	$1,793	16.9
Baseline + Cool Roof, 75% of roof at Abs=0.25	$8,574	$1,563	$10,137	$900	6.9
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$8,712	$1,269	$9,981	$1,853	6.5
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$8,724	$1,550	$10,274	$400	never
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$8,486	$1,563	$10,049	$1,196	5.5
Baseline + High Efficiency Heating, AFUE=94%	$8,712	$1,541	$10,253	$5,000	333.3
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	$8,631	$1,556	$10,187	$891	11.0
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	$8,574	$1,556	$10,130	$1,781	12.9
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	$8,527	$1,556	$10,083	$4,453	24.1
Baseline + High Efficiency Lighting, 0.587 watts/sqft	$8,478	$1,559	$10,037	$8,910	38.6
Baseline + Photovoltaics, 1640 Sqft @ 0 deg pitch	$5,028	$1,556	$6,584	$81,535	16.9
Baseline + Envelope Insulation - Roof, R38 batt	$8,677	$1,550	$10,227	$655	16.0
Baseline + Envelope Insulation - Roof, R49 batt	$8,670	$1,547	$10,217	$1,091	21.4
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	$8,712	$917	$9,629	$45,560	86.8
Baseline + Envelope Insulation - Walls, R19 batt	$8,708	$1,550	$10,258	$754	75.4
Baseline + Envelope Insulation - Walls, R21 batt	$8,709	$1,547	$10,256	$1,392	116.0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$8,704	$1,543	$10,247	$8,819	419.9

Table 122. R/RMULRB-RS Alternatives Impact on Utility Costs and Paybacks

Prototype #3 Artisan Residential					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	41,274	141	126	267	0
Baseline + EE Package	38,948	133	104	237	30
Baseline + EE Package + Photovoltaics	24,612	84	104	188	79
Baseline + High Efficiency Appliances, 0.36858 w/sqft, 0.75563 Btu/hr/sqft	40,865	139	126	265	2
Baseline + High Efficiency Appliances, 0.36815 w/sqft, 0.75563 Btu/hr/sqft	40,840	139	126	265	2
Baseline + Cool Roof, 75% of roof at Abs=0.25	40,730	139	126	265	2
Baseline + High Efficiency Domestic Hot Water, EF=0.823	41,274	141	104	245	22
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	41,335	141	125	267	0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	40,383	138	127	264	3
Baseline + High Efficiency Heating, AFUE=94%	41,274	141	125	266	1
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	40,955	140	126	266	1
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	40,729	139	126	265	2
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	40,548	138	126	264	3
Baseline + High Efficiency Lighting, 0.587 watts/sqft	40,332	138	126	264	3
Baseline + Photovoltaics, 1640 Sqft @ 0 deg pitch	26,021	89	126	215	52
Baseline + Envelope Insulation - Roof, R38 batt	41,148	140	125	266	1
Baseline + Envelope Insulation - Roof, R49 batt	41,112	140	125	266	1
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	41,274	141	77	218	49
Baseline + Envelope Insulation - Walls, R19 batt	41,258	141	126	266	1
Baseline + Envelope Insulation - Walls, R21 batt	41,272	141	125	266	1
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	41,258	141	125	266	1

Table 123. R/RMULRB-RS Alternatives Impact on Energy Consumption

Prototype #3 Artisan Residential					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	9,091	68	15	83	0
Baseline + EE Package	9,091	64	12	76	7
Baseline + EE Package + Photovoltaics	9,091	16	12	28	55
Baseline + High Efficiency Appliances, 0.36858 w/sqft, 0.75563 Btu/hr/sqft	9,091	67	15	82	1
Baseline + High Efficiency Appliances, 0.36815 w/sqft, 0.75563 Btu/hr/sqft	9,091	67	15	82	1
Baseline + Cool Roof, 75% of roof at Abs=0.25	9,091	67	15	82	1
Baseline + High Efficiency Domestic Hot Water, EF=0.823	9,091	68	12	80	3
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	9,091	68	15	83	0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	9,091	66	15	81	2
Baseline + High Efficiency Heating, AFUE=94%	9,091	68	15	82	1
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	9,091	67	15	82	1
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	9,091	67	15	81	2
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	9,091	66	15	81	2
Baseline + High Efficiency Lighting, 0.587 watts/sqft	9,091	66	15	81	2
Baseline + Photovoltaics, 1640 Sqft @ 0 deg pitch	9,091	20	15	35	48
Baseline + Envelope Insulation - Roof, R38 batt	9,091	68	15	82	1
Baseline + Envelope Insulation - Roof, R49 batt	9,091	68	15	82	1
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	9,091	68	9	77	6
Baseline + Envelope Insulation - Walls, R19 batt	9,091	68	15	83	0
Baseline + Envelope Insulation - Walls, R21 batt	9,091	68	15	82	1
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	9,091	68	15	82	1

Table 124. R/RMULRB-RS Alternatives Impact on TDVI

3.4 Retail/Residential Mixed-Use Low-Rise Building – Small Corner Retail Shop

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	Not Applicable	None	None	None	No Alternative
CHP	Not Applicable	None	None	None	No Alternative
Roof Material	Not Applicable	None	None	None	No Alternative
Water Heating	EF=0.594	EF=0.823	None	None	No Alternative
Windows	U=0.57, SHGC=0.61	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	Alternative 2
Space Heating	Heat Pump (See Space Cooling)	None	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	HSPF 8.6, EER 12.19, COP 3.52	HSPF 8.8 ,EER 12.70, COP 3.74	HSPF 9.2 ,EER 12.88, COP 3.66	Alternative 3
Lighting	1.5 watts/sqft	None	None	None	No Alternative
Photovoltaics	Not Applicable	None	None	None	No Alternative
Roof Insulation	Not Applicable	None	None	None	No Alternative
Solar Thermal	Not Applicable	None	None	None	No Alternative
Thermal Storage	Not Applicable	None	None	None	No Alternative
Wall Insulation	R11 batt	R19 batt	R21 batt	R21 batt + R5 rigid	Alternative 3

Table 125. R/RMULRB – Small Corner Retail Shop (R/RMULRB – SCRS) Alternatives

Prototype #3 Artisan Retail Corner Small Shop					
Alternative	Elec Utility $	Gas Utility $	Total Utility $	Alt Cost $	Payback yrs
Baseline	$1,812	$1,536	$3,348	$0	NA
Baseline + EE Package	$1,593	$1,536	$3,129	$2,525	11.5
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$1,812	$1,512	$3,324	$371	15.4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$1,769	$1,536	$3,305	$168	3.9
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$1,700	$1,536	$3,236	$503	4.5
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	$1,766	$1,536	$3,302	$209	4.6
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	$1,743	$1,536	$3,279	$419	6.1
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	$1,732	$1,536	$3,268	$1,047	13.1
Baseline + Envelope Insulation - Walls, R19 batt	$1,790	$1,536	$3,326	$83	3.8
Baseline + Envelope Insulation - Walls, R21 batt	$1,789	$1,536	$3,325	$154	6.7
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$1,776	$1,536	$3,312	$975	27.1

Table 126. R/RMULRB – SCRS Alternatives Impact on Utility Costs and Paybacks

Prototype #3 Artisan Retail Corner Small Shop					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	7,044	24	7	31	0
Baseline + EE Package	5,927	20	7	27	4
Baseline + High Efficiency Domestic Hot Water, EF=0.823	7,044	24	5	29	2
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	6,929	24	7	30	1
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	6,379	22	7	28	3
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	6,815	23	7	30	1
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	6,698	23	7	29	2
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	6,633	23	7	29	2
Baseline + Envelope Insulation - Walls, R19 batt	7,008	24	7	31	0
Baseline + Envelope Insulation - Walls, R21 batt	7,000	24	7	30	1
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	6,927	24	7	30	1

Table 127. R/RMULRB – SCRS Alternatives Impact on Energy Consumption

Prototype #3 Artisan Retail Corner Small Shop					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	510	275	14	289	0
Baseline + EE Package	510	227	14	241	48
Baseline + High Efficiency Domestic Hot Water, EF=0.823	510	275	11	285	4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	510	271	14	285	4
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	510	250	14	264	25
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	510	264	14	279	10
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	510	259	14	273	16
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	510	256	14	270	19
Baseline + Envelope Insulation - Walls, R19 batt	510	273	14	287	2
Baseline + Envelope Insulation - Walls, R21 batt	510	273	14	287	2
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	510	270	14	284	5

Table 128. R/RMULRB – SCRS Alternatives Impact on TDVI

3.5 Retail/Residential Mixed-Use Low-Rise Building – Residential Space (30-dua)

Type II construction for the ground floor and Type V construction for the residential space above. Approximately 19,800 sf three-story mixed use slab on grade building. Interior floor space demised to accommodate 5 individual retail tenants at street level averaging 510 sf each. Two floor levels of residential apartments above the first floor totaling approximately 17,250 sf. Residential floor space demised to accommodate five 3BR, 3BA and five 4BR, 3BA units ranging from approximately 1600 to 1,850 sf each. The floor-to-floor height for the first floor retail is 14'-0" and 11'-0" for the residential levels above. 45% of the roof area is available for solar cells.

Figure 19. Retail/Residential Mixed-Use Low-Rise Building

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	0.3801 w/sqft, 0.79647 Btu/hr/sqft	0.37273 w/sqft, 0.79647 Btu/hr/sqft	0.37228 w/sqft, 0.79647 Btu/hr/sqft	None	Alternative 1
CHP	None	30 kW, 0 Tons Abs	None	None	No Alternative
Roof Material	100% of roof at Abs=0.70	100% of roof at Abs=0.25	None	None	Alternative 1
Water Heating	EF=0.594	EF=0.823	None	None	Alternative 1
Windows	U=0.56, SHGC=0.42	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	Alternative 2
Space Heating	Heat Pump (See Space Cooling)	AFUE=94%	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	SEER 14, EER 11.99	SEER 15, EER 12.72	SEER 18, EER 13.37	Alternative 2
Lighting	0.576 watts/sqft	0.532 watts/sqft	None	None	No Alternative
Photovoltaics	None	3870 Sqft @ 0 deg pitch	None	None	Alternative 1
Roof Insulation	R30 batt	R38 batt	R49 batt	None	Alternative 2
Solar Thermal	None	42 Sqft of panels, 84 Gal tank	None	None	No Alternative
Thermal Storage	None	None	None	None	No Alternative
Wall Insulation	R13 batt	R19 batt	R21 batt	R21 batt + R5 rigid	No Alternative

Table 129. Retail/Residential Mixed-Use Low-Rise Building – Residential Space (R/RMULRB-RS)

Prototype #4 Studio Walk Residential					
Alternative	Elec Utility $	Gas Utility $	Total Utility $	Alt Cost $	Payback yrs
Baseline	$17,693	$3,185	$20,878	$0	NA
Baseline + EE Package	$16,256	$2,623	$18,879	$18,225	9.1
Baseline + EE Package + Photovoltaics	$9,215	$2,623	$11,838	$210,629	16.7
Baseline + High Efficiency Appliances, 0.37273 w/sqft, 0.79647 Btu/hr/sqft	$17,484	$3,186	$20,670	$2,646	12.7
Baseline + High Efficiency Appliances, 0.37228 w/sqft, 0.79647 Btu/hr/sqft	$17,470	$3,186	$20,656	$3,586	16.2
Baseline + Combined Heat and Power, 30 kW, 0 Tons Abs	$8,191	$11,066	$19,257	$88,693	97.4
Baseline + Cool Roof, 100% of roof at Abs=0.25	$17,156	$3,210	$20,366	$2,840	5.5
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$17,693	$2,615	$20,308	$3,706	6.5
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$17,744	$3,171	$20,915	$882	never
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$17,080	$3,203	$20,283	$2,634	4.4
Baseline + High Efficiency Heating, AFUE=94%	$17,693	$3,153	$20,846	$10,000	312.5
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	$17,502	$3,185	$20,687	$1,908	10.0
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	$17,370	$3,185	$20,555	$3,815	11.8
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	$17,261	$3,185	$20,446	$9,537	22.1
Baseline + High Efficiency Lighting, 0.532 watts/sqft	$17,339	$3,187	$20,526	$17,100	48.6
Baseline + Photovoltaics, 3870 Sqft @ 0 deg pitch	$10,029	$3,185	$13,214	$192,404	17.6
Baseline + Envelope Insulation - Roof, R38 batt	$17,626	$3,171	$20,797	$1,549	19.1
Baseline + Envelope Insulation - Roof, R49 batt	$17,596	$3,167	$20,763	$2,582	22.5
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	$17,693	$1,917	$19,610	$91,120	87.6
Baseline + Envelope Insulation - Walls, R19 batt	$17,695	$3,173	$20,868	$1,220	122.0
Baseline + Envelope Insulation - Walls, R21 batt	$17,692	$3,171	$20,863	$2,252	150.1
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$17,682	$3,161	$20,843	$14,263	407.5

Table 130. R/RMULRB-RS Alternatives Impact on Utility Costs and Paybacks

Prototype #4 Studio Walk Residential					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	77,738	265	250	515	0
Baseline + EE Package	71,984	246	207	453	62
Baseline + EE Package + Photovoltaics	43,454	148	207	355	160
Baseline + High Efficiency Appliances, 0.37273 w/sqft, 0.79647 Btu/hr/sqft	76,885	262	250	512	3
Baseline + High Efficiency Appliances, 0.37228 w/sqft, 0.79647 Btu/hr/sqft	76,831	262	250	512	3
Baseline + Combined Heat and Power, 30 kW, 0 Tons Abs	33,414	114	849	963	-448
Baseline + Cool Roof, 100% of roof at Abs=0.25	75,592	258	252	510	5
Baseline + High Efficiency Domestic Hot Water, EF=0.823	77,738	265	207	472	43
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	77,941	266	249	515	0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	75,282	257	251	508	7
Baseline + High Efficiency Heating, AFUE=94%	77,738	265	247	513	2
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	76,983	263	250	513	2
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	76,449	261	250	511	4
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	76,023	259	250	509	6
Baseline + High Efficiency Lighting, 0.532 watts/sqft	76,302	260	250	510	5
Baseline + Photovoltaics, 3870 Sqft @ 0 deg pitch	46,727	159	250	409	106
Baseline + Envelope Insulation - Roof, R38 batt	77,468	264	249	513	2
Baseline + Envelope Insulation - Roof, R49 batt	77,352	264	249	513	2
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	77,738	265	154	419	96
Baseline + Envelope Insulation - Walls, R19 batt	77,742	265	249	514	1
Baseline + Envelope Insulation - Walls, R21 batt	77,726	265	249	514	1
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	77,693	265	248	513	2

Table 131. R/RMULRB-RS Alternatives Impact on Energy Consumption

Prototype #4 Studio Walk Residential					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	17,215	68	15	83	0
Baseline + EE Package	17,215	62	13	75	8
Baseline + EE Package + Photovoltaics	17,215	3	13	15	68
Baseline + High Efficiency Appliances, 0.37273 w/sqft, 0.79647 Btu/hr/sqft	17,215	67	15	82	1
Baseline + High Efficiency Appliances, 0.37228 w/sqft, 0.79647 Btu/hr/sqft	17,215	67	15	82	1
Baseline + Combined Heat and Power, 30 kW, 0 Tons Abs	17,215	28	52	81	2
Baseline + Cool Roof, 100% of roof at Abs=0.25	17,215	66	15	81	2
Baseline + High Efficiency Domestic Hot Water, EF=0.823	17,215	68	13	80	3
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	17,215	68	15	83	0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	17,215	65	15	81	2
Baseline + High Efficiency Heating, AFUE=94%	17,215	68	15	83	0
Baseline + High Efficiency Cooling, SEER 14, EER 11.99	17,215	67	15	82	1
Baseline + High Efficiency Cooling, SEER 15, EER 12.72	17,215	66	15	82	1
Baseline + High Efficiency Cooling, SEER 18, EER 13.37	17,215	66	15	81	2
Baseline + High Efficiency Lighting, 0.532 watts/sqft	17,215	66	15	82	1
Baseline + Photovoltaics, 3870 Sqft @ 0 deg pitch	17,215	8	15	24	59
Baseline + Envelope Insulation - Roof, R38 batt	17,215	67	15	83	0
Baseline + Envelope Insulation - Roof, R49 batt	17,215	67	15	82	1
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	17,215	68	9	77	6
Baseline + Envelope Insulation - Walls, R19 batt	17,215	68	15	83	0
Baseline + Envelope Insulation - Walls, R21 batt	17,215	68	15	83	0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	17,215	67	15	83	0

Table 132. R/RMULRB-RS Alternatives Impact on TDVI

3.6 Retail/Residential Mixed-Use Low-Rise Building – Retail Small Corner Shop

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	Not Applicable	None	None	None	No Alternative
CHP	Not Applicable	None	None	None	No Alternative
Roof Material	Not Applicable	None	None	None	No Alternative
Water Heating	EF=0.594	EF=0.823	None	None	No Alternative
Windows	U=0.57, SHGC=0.61	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	Alternative 2
Space Heating	Heat Pump (See Space Cooling)	None	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	HSPF 8.6, EER 12.19, COP 3.52	HSPF 8.8 ,EER 12.70, COP 3.74	HSPF 9.2 ,EER 12.88, COP 3.66	Alternative 3
Lighting	1.5 watts/sqft	None	None	None	No Alternative
Photovoltaics	Not Applicable	None	None	None	No Alternative
Roof Insulation	Not Applicable	None	None	None	No Alternative
Solar Thermal	Not Applicable	None	None	None	No Alternative
Thermal Storage	Not Applicable	None	None	None	No Alternative
Wall Insulation	R11 batt	R19 batt	R21 batt	R21 batt + R5 rigid	Alternative 3

Table 133. R/RMULRB – Retail Small Corner Shop (RSCS) Alternatives

Prototype #4 Studio Walk Retail Small Corner Shop					
Alternative	Elec Utility $	Gas Utility $	Total Utility $	Alt Cost $	Payback yrs
Baseline	$1,792	$1,536	$3,328	$0	NA
Baseline + EE Package	$1,595	$1,536	$3,131	$2,493	12.7
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$1,792	$1,512	$3,304	$371	15.4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$1,764	$1,536	$3,300	$168	6.0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$1,697	$1,536	$3,233	$503	5.3
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	$1,757	$1,536	$3,293	$203	5.8
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	$1,738	$1,536	$3,274	$406	7.5
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	$1,729	$1,536	$3,265	$1,015	16.1
Baseline + Envelope Insulation - Walls, R19 batt	$1,784	$1,536	$3,320	$83	10.4
Baseline + Envelope Insulation - Walls, R21 batt	$1,784	$1,536	$3,320	$154	19.2
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$1,773	$1,536	$3,309	$975	51.3

Table 134. R/RMULRB- RSCS Impacts on Utility Costs and Paybacks

Prototype #4 Studio Walk Retail Small Corner Shop					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	6,996	24	7	30	0
Baseline + EE Package	5,922	20	7	27	3
Baseline + High Efficiency Domestic Hot Water, EF=0.823	6,996	24	5	29	1
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	6,878	23	7	30	0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	6,352	22	7	28	2
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	6,774	23	7	30	0
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	6,654	23	7	29	1
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	6,589	22	7	29	1
Baseline + Envelope Insulation - Walls, R19 batt	6,960	24	7	30	0
Baseline + Envelope Insulation - Walls, R21 batt	6,955	24	7	30	0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	6,883	23	7	30	0

Table 135. R/RMULRB- RSCS Alternatives Impact on Energy Consumption

Prototype #4 Studio Walk Retail Small Corner Shop					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	510	273	14	287	0
Baseline + EE Package	510	226	14	241	46
Baseline + High Efficiency Domestic Hot Water, EF=0.823	510	273	11	283	4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	510	269	14	283	4
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	510	248	14	263	24
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	510	262	14	277	10
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	510	257	14	271	16
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	510	254	14	268	19
Baseline + Envelope Insulation - Walls, R19 batt	510	271	14	285	2
Baseline + Envelope Insulation - Walls, R21 batt	510	271	14	285	2
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	510	268	14	282	5

Table 136. R/RMULRB-RSCS Alternatives Impact on TDVI

3.7 Retail/Residential Mixed-Use Low-Rise Building – Retail Internal Small Shop

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	Not Applicable	None	None	None	No Alternative
CHP	Not Applicable	None	None	None	No Alternative
Roof Material	Not Applicable	None	None	None	No Alternative
Water Heating	EF=0.594	EF=0.823	None	None	No Alternative
Windows	U=0.57, SHGC=0.61	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	Alternative 2
Space Heating	Heat Pump (See Space Cooling)	None	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	HSPF 8.6, EER 12.19, COP 3.52	HSPF 8.8 ,EER 12.70, COP 3.74	HSPF 9.2 ,EER 12.88, COP 3.66	Alternative 3
Lighting	1.5 watts/sqft	None	None	None	No Alternative
Photovoltaics	Not Applicable	None	None	None	No Alternative
Roof Insulation	Not Applicable	None	None	None	No Alternative
Solar Thermal	Not Applicable	None	None	None	No Alternative
Thermal Storage	Not Applicable	None	None	None	No Alternative
Wall Insulation	R11 batt	R19 batt	R21 batt	R21 batt + R5 rigid	Alternative 3

Table 137. R/RMULRB - Retail Internal Small Shop (RISS)

Prototype #4 Studio Walk Retail Internal Small Shop					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility $**	**Alt Cost $**	**Payback yrs**
Baseline	$1,667	$1,536	$3,203	$0	NA
Baseline + EE Package	$1,564	$1,536	$3,100	$1,524	14.8
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$1,667	$1,512	$3,179	$371	15.4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$1,653	$1,536	$3,189	$105	7.5
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$1,603	$1,536	$3,139	$314	4.9
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	$1,623	$1,536	$3,159	$161	3.6
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	$1,595	$1,536	$3,131	$321	4.5
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	$1,588	$1,536	$3,124	$803	10.2
Baseline + Envelope Insulation - Walls, R19 batt	$1,661	$1,536	$3,197	$35	5.8
Baseline + Envelope Insulation - Walls, R21 batt	$1,660	$1,536	$3,196	$64	9.2
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$1,655	$1,536	$3,191	$406	33.9

Table 138. R/RMULRB-RISS Alternatives Impact on Utility Costs and Paybacks

Prototype #4 Studio Walk Retail Internal Small Shop					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	6,233	21	7	28	0
Baseline + EE Package	5,794	20	7	26	2
Baseline + High Efficiency Domestic Hot Water, EF=0.823	6,233	21	5	26	2
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	6,178	21	7	28	0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	6,024	21	7	27	1
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	6,017	21	7	27	1
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	5,942	20	7	27	1
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	5,912	20	7	27	1
Baseline + Envelope Insulation - Walls, R19 batt	6,213	21	7	28	0
Baseline + Envelope Insulation - Walls, R21 batt	6,203	21	7	28	0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	6,175	21	7	28	0

Table 139. R/RMULRB-RISS Alternatives Impact on Energy Consumption

Prototype #4 Studio Walk Retail Internal Small Shop					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	510	244	14	258	0
Baseline + EE Package	510	219	14	234	24
Baseline + High Efficiency Domestic Hot Water, EF=0.823	510	244	11	254	4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	510	242	14	256	2
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	510	233	14	247	11
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	510	232	14	246	12
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	510	228	14	242	16
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	510	226	14	240	18
Baseline + Envelope Insulation - Walls, R19 batt	510	243	14	257	1
Baseline + Envelope Insulation - Walls, R21 batt	510	242	14	257	1
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	510	241	14	256	2

Table 140. R/RMULRB-RISS Alternatives Impact on Impacts on TDVI

3.8 Retail/Residential Mixed-Use Mid-Rise Building – Residential Space (85 dua)

Type III construction, approximately 134,000 sf five-story mixed use slab on grade building. Interior floor space demised to accommodate 12 individual retail tenants at street level averaging 1,050 sf each. Four floor levels of residential apartments above the first floor totaling approximately 121,300 sf. Residential floor space demised to accommodate 84 individual units; 12 @ 850 sqft, 8 @ 1,115 sqft, 14 @ 1450 sqft, 4 @ 1,580 sqft, 16 @ 1,545, 20 @ 1,645, and 10 @ 1,795. The floor-to-floor height for the first floor retail is 14'-0" and 11'-0" for the residential levels above. 50% of the roof area is available for solar cells.

Figure 20. Retail/Residential Mixed-Use Mid-Rise Building

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	0.39693 w/sqft, 0.94594 Btu/hr/sqft	0.38815 w/sqft, 0.94594 Btu/hr/sqft	0.3876 w/sqft, 0.94594 Btu/hr/sqft	None	Alternative 1
CHP	None	120 kW, 0 Tons Abs	None	None	Alternative 1
Roof Material	100% of roof at Abs=0.70	100% of roof at Abs=0.25	None	None	Alternative 1
Water Heating	EF=0.594	EF=0.823	None	None	Alternative 1
Windows	U=0.56, SHGC=0.42	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	Alternative 2
Space Heating	AFUE=75%	None	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	HSPF 8.6, EER 12.19, COP 3.52	HSPF 8.8 ,EER 12.70, COP 3.74	HSPF 9.2 ,EER 12.88, COP 3.66	Alternative 3
Lighting	0.623 watts/sqft	0.573 watts/sqft	None	None	No Alternative
Photovoltaics	None	13650 Sqft @ 0 deg pitch	None	None	Alternative 1
Roof Insulation	R30 batt	R38 batt	R49 batt	None	No Alternative
Solar Thermal	None	42 Sqft of panels, 84 Gal tank	None	None	No Alternative
Thermal Storage	None	None	None	None	No Alternative
Wall Insulation	R11 batt	R19 batt	R21 batt	R21 batt + R5 rigid	No Alternative

Table 141. Retail/Residential Mixed-Use Mid-Rise Building – Residential Space (R/RMUMRB-RS) Alternatives

Prototype #5 Gateway Residential					
Alternative	Elec Utility $	Gas Utility $	Total Utility $	Alt Cost $	Payback yrs
Baseline	$146,255	$24,397	$170,652	$0	NA
Baseline + EE Package	$138,714	$19,977	$158,691	$112,274	9.4
Baseline + EE Package + Distributed Generation	$42,303	$68,927	$111,230	$350,098	6.2
Baseline + EE Package + Photovoltaics	$83,874	$19,977	$103,851	$790,908	11.1
Baseline + High Efficiency Appliances, 0.38815 w/sqft, 0.94594 Btu/hr/sqft	$144,509	$24,397	$168,906	$22,230	12.7
Baseline + High Efficiency Appliances, 0.3876 w/sqft, 0.94594 Btu/hr/sqft	$144,354	$24,397	$168,751	$30,126	15.8
Baseline + Combined Heat and Power, 120 kW, 0 Tons Abs	$45,289	$72,634	$117,923	$237,824	4.8
Baseline + Cool Roof, 100% of roof at Abs=0.25	$145,522	$24,397	$169,919	$10,008	13.7
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$146,255	$19,977	$166,232	$31,134	7.0
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$146,678	$24,397	$171,075	$2,027	never
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$144,724	$24,397	$169,121	$6,056	4.0
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	$143,871	$24,397	$168,268	$8,570	3.6
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	$143,052	$24,397	$167,449	$17,139	5.4
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	$142,604	$24,397	$167,001	$42,847	11.7
Baseline + High Efficiency Lighting, 0.573 watts/sqft	$143,217	$24,397	$167,614	$111,420	36.7
Baseline + Photovoltaics, 13650 Sqft @ 0 deg pitch	$91,451	$24,397	$115,848	$678,634	11.7
Baseline + Envelope Insulation - Roof, R38 batt	$147,006	$24,397	$171,403	$5,459	never
Baseline + Envelope Insulation - Roof, R49 batt	$147,246	$24,397	$171,643	$9,098	never
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	$146,255	$14,313	$160,568	$765,408	93.7
Baseline + Envelope Insulation - Walls, R19 batt	$146,514	$24,397	$170,911	$3,856	never
Baseline + Envelope Insulation - Walls, R21 batt	$146,672	$24,397	$171,069	$7,118	never
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$146,665	$24,397	$171,062	$45,083	never

Table 142. R/RMUMRB-RS Alternatives Impact on Utility Costs and Paybacks

Prototype #5 Gateway Residential					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	597,864	2,040	1,861	3,901	0
Baseline + EE Package	567,363	1,936	1,526	3,461	440
Baseline + EE Package + Distributed Generation	256,594	875	5,245	6,120	-2,219
Baseline + EE Package + Photovoltaics	345,055	1,177	1,526	2,703	1,198
Baseline + High Efficiency Appliances, 0.38815 w/sqft, 0.94594 Btu/hr/sqft	590,752	2,016	1,861	3,877	24
Baseline + High Efficiency Appliances, 0.3876 w/sqft, 0.94594 Btu/hr/sqft	590,121	2,013	1,861	3,875	26
Baseline + Combined Heat and Power, 120 kW, 0 Tons Abs	275,030	938	5,527	6,465	-2,564
Baseline + Cool Roof, 100% of roof at Abs=0.25	594,892	2,030	1,861	3,891	10
Baseline + High Efficiency Domestic Hot Water, EF=0.823	597,864	2,040	1,526	3,566	335
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	599,637	2,046	1,861	3,907	-6
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	591,661	2,019	1,861	3,880	21
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	588,273	2,007	1,861	3,869	32
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	584,977	1,996	1,861	3,857	44
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	583,152	1,990	1,861	3,851	50
Baseline + High Efficiency Lighting, 0.573 watts/sqft	585,493	1,998	1,861	3,859	42
Baseline + Photovoltaics, 13650 Sqft @ 0 deg pitch	375,715	1,282	1,861	3,143	758
Baseline + Envelope Insulation - Roof, R38 batt	601,009	2,051	1,861	3,912	-11
Baseline + Envelope Insulation - Roof, R49 batt	602,017	2,054	1,861	3,915	-14
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	597,864	2,040	1,095	3,135	766
Baseline + Envelope Insulation - Walls, R19 batt	598,956	2,044	1,861	3,905	-4
Baseline + Envelope Insulation - Walls, R21 batt	599,618	2,046	1,861	3,907	-6
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	599,629	2,046	1,861	3,907	-6

Table 143. R/RMUMRB-RS Alternatives Impact on Energy Consumption

Prototype #5 Gateway Residential					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	30,327	73	16	89	0
Baseline + EE Package	30,327	69	13	82	7
Baseline + EE Package + Distributed Generation	30,327	29	46	75	14
Baseline + EE Package + Photovoltaics	30,327	39	13	52	37
Baseline + High Efficiency Appliances, 0.38815 w/sqft, 0.94594 Btu/hr/sqft	30,327	72	16	88	1
Baseline + High Efficiency Appliances, 0.3876 w/sqft, 0.94594 Btu/hr/sqft	30,327	72	16	88	1
Baseline + Combined Heat and Power, 120 kW, 0 Tons Abs	30,327	31	48	80	9
Baseline + Cool Roof, 100% of roof at Abs=0.25	30,327	72	16	88	1
Baseline + High Efficiency Domestic Hot Water, EF=0.823	30,327	73	13	86	3
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	30,327	73	16	89	0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	30,327	72	16	88	1
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	30,327	71	16	88	1
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	30,327	71	16	87	2
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	30,327	71	16	87	2
Baseline + High Efficiency Lighting, 0.573 watts/sqft	30,327	71	16	87	2
Baseline + Photovoltaics, 13650 Sqft @ 0 deg pitch	30,327	43	16	59	30
Baseline + Envelope Insulation - Roof, R38 batt	30,327	73	16	89	0
Baseline + Envelope Insulation - Roof, R49 batt	30,327	73	16	89	0
Baseline + Solar Thermal, 42 Sqft of panels, 84 Gal tank	30,327	73	10	82	7
Baseline + Envelope Insulation - Walls, R19 batt	30,327	73	16	89	0
Baseline + Envelope Insulation - Walls, R21 batt	30,327	73	16	89	0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	30,327	73	16	89	0

Table 144. R/RMUMRB-RS Alternatives Impact on TDVI

3.9 Retail/Residential Mixed-Use Mid-Rise Building – Retail Corner Large Shop

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	Not Applicable	None	None	None	No Alternative
CHP	Not Applicable	None	None	None	No Alternative
Roof Material	Not Applicable	None	None	None	No Alternative
Water Heating	EF=0.594	EF=0.823	None	None	Alternative 1
Windows	U=0.57, SHGC=0.61	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	Alternative 2
Space Heating	Heat Pump (See Space Cooling)	None	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	HSPF 8.6, EER 12.19, COP 3.52	HSPF 8.8 ,EER 12.70, COP 3.74	HSPF 9.2 ,EER 12.88, COP 3.66	Alternative 3
Lighting	1.5 watts/sqft	None	None	None	No Alternative
Photovoltaics	Not Applicable	None	None	None	No Alternative
Roof Insulation	Not Applicable	None	None	None	No Alternative
Solar Thermal	Not Applicable	None	None	None	No Alternative
Thermal Storage	Not Applicable	None	None	None	No Alternative
Wall Insulation	R11 batt	R19 batt	R21 batt	R21 batt + R5 rigid	No Alternative

Table 145. R/RMUMRB – Retail Corner Larger Shop (RCLS) Alternatives

Prototype #5 Gateway Retail Corner Large Shop					
Alternative	Elec Utility $	Gas Utility $	Total Utility $	Alt Cost $	Payback yrs
Baseline	$6,518	$1,898	$8,416	$0	NA
Baseline + EE Package	$6,120	$1,774	$7,894	$3,982	7.6
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$6,518	$1,774	$8,292	$371	3.0
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$6,540	$1,898	$8,438	$373	never
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$6,357	$1,898	$8,255	$1,115	6.9
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	$6,276	$1,898	$8,174	$499	2.1
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	$6,214	$1,898	$8,112	$998	3.3
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	$6,201	$1,898	$8,099	$2,496	7.9
Baseline + Envelope Insulation - Walls, R19 batt	$6,519	$1,898	$8,417	$185	never
Baseline + Envelope Insulation - Walls, R21 batt	$6,521	$1,898	$8,419	$341	never
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$6,529	$1,898	$8,427	$2,162	never

Table 146. R/RMUMRB-RCLS Alternatives Impact on Utility Costs and Paybacks

Prototype #5 Gateway Retail Corner Large Shop					
Alternative	**Elec kWh**	**Elec MMBtu**	**Gas MMBtu**	**Total MMBtu**	**MMBtu Saved**
Baseline	39,644	135	33	168	0
Baseline + EE Package	36,884	126	24	150	18
Baseline + High Efficiency Domestic Hot Water, EF=0.823	39,644	135	24	159	9
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	39,865	136	33	169	-1
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	38,223	130	33	163	5
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	37,871	129	33	162	6
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	37,541	128	33	161	7
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	37,420	128	33	161	7
Baseline + Envelope Insulation - Walls, R19 batt	39,672	135	33	168	0
Baseline + Envelope Insulation - Walls, R21 batt	39,679	135	33	168	0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	39,735	136	33	168	0

Table 147. R/RMUMRB-RCLS Alternatives Impact on Energy Consumption

Prototype #5 Gateway Retail Corner Large Shop					
Alternative	**Space Sqft**	**Elec TDVI**	**Gas TDVI**	**Total TDVI**	**TDVI Saved**
Baseline	2,528	300	14	314	0
Baseline + EE Package	2,528	279	10	289	25
Baseline + High Efficiency Domestic Hot Water, EF=0.823	2,528	300	10	310	4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	2,528	301	14	316	-2
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	2,528	290	14	304	10
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	2,528	287	14	301	13
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	2,528	284	14	298	16
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	2,528	283	14	297	17
Baseline + Envelope Insulation - Walls, R19 batt	2,528	300	14	314	0
Baseline + Envelope Insulation - Walls, R21 batt	2,528	300	14	314	0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	2,528	300	14	315	-1

Table 148. R/RMUMRB-RCLS Alternatives Impact on TDVI

3.10 Retail/Residential Mixed-Use Mid-Rise Building – Retail Corner Small Shop

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	Not Applicable	None	None	None	No Alternative
CHP	Not Applicable	None	None	None	No Alternative
Roof Material	Not Applicable	None	None	None	No Alternative
Water Heating	EF=0.594	EF=0.823	None	None	Alternative 1
Windows	U=0.57, SHGC=0.61	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	Alternative 2
Space Heating	Heat Pump (See Space Cooling)	None	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	HSPF 8.6, EER 12.19, COP 3.52	HSPF 8.8 ,EER 12.70, COP 3.74	HSPF 9.2 ,EER 12.88, COP 3.66	Alternative 1
Lighting	1.5 watts/sqft	None	None	None	No Alternative
Photovoltaics	Not Applicable	None	None	None	No Alternative
Roof Insulation	Not Applicable	None	None	None	No Alternative
Solar Thermal	Not Applicable	None	None	None	No Alternative
Thermal Storage	Not Applicable	None	None	None	No Alternative
Wall Insulation	R11 batt	R19 batt	R21 batt	R21 batt + R5 rigid	No Alternative

Table 149. R/RMUMRB - Retail Corner Small Shop (RCSS) Alternatives

Prototype #5 Gateway Retail Corner Small Shop					
Alternative	**Elec Utility $**	**Gas Utility $**	**Total Utility $**	**Alt Cost $**	**Payback yrs**
Baseline	$2,897	$1,625	$4,522	$0	NA
Baseline + EE Package	$2,749	$1,575	$4,324	$1,148	5.8
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$2,897	$1,575	$4,472	$371	7.4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$2,891	$1,625	$4,516	$148	24.7
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$2,874	$1,625	$4,499	$443	19.3
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	$2,869	$1,625	$4,494	$334	11.9
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	$2,865	$1,625	$4,490	$668	20.9
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	$2,864	$1,625	$4,489	$1,670	50.6
Baseline + Envelope Insulation - Walls, R19 batt	$2,900	$1,625	$4,525	$118	never
Baseline + Envelope Insulation - Walls, R21 batt	$2,899	$1,625	$4,524	$217	never
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$2,893	$1,625	$4,518	$1,374	never

Table 150. R/RMUMRB-RCSS Alternatives Impact on Utility Costs and Paybacks

Prototype #5 Gateway Retail Corner Small Shop					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	14,831	51	13	64	0
Baseline + EE Package	13,733	47	9	56	8
Baseline + High Efficiency Domestic Hot Water, EF=0.823	14,831	51	9	60	4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	14,929	51	13	64	0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	14,768	50	13	63	1
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	14,731	50	13	63	1
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	14,706	50	13	63	1
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	14,688	50	13	63	1
Baseline + Envelope Insulation - Walls, R19 batt	14,863	51	13	64	0
Baseline + Envelope Insulation - Walls, R21 batt	14,869	51	13	64	0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	14,957	51	13	64	0

Table 151. R/RMUMRB-RCSS Alternatives Impact on Energy Consumption

Prototype #5 Gateway Retail Corner Small Shop					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	1,003	285	14	299	0
Baseline + EE Package	1,003	266	10	276	23
Baseline + High Efficiency Domestic Hot Water, EF=0.823	1,003	285	10	295	4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	1,003	286	14	301	-2
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	1,003	283	14	298	1
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	1,003	282	14	297	2
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	1,003	282	14	296	3
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	1,003	282	14	296	3
Baseline + Envelope Insulation - Walls, R19 batt	1,003	285	14	299	0
Baseline + Envelope Insulation - Walls, R21 batt	1,003	285	14	300	-1
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	1,003	287	14	301	-2

Table 152. R/RMUMRB-RCSS Alternatives Impact on TDVI

3.11 Retail/Residential Mixed-Use Mid-Rise Building – Retail Internal Large Shop

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	Not Applicable	None	None	None	No Alternative
CHP	Not Applicable	None	None	None	No Alternative
Roof Material	Not Applicable	None	None	None	No Alternative
Water Heating	EF=0.594	EF=0.823	None	None	Alternative 1
Windows	U=0.57, SHGC=0.61	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	No Alternative
Space Heating	Heat Pump (See Space Cooling)	None	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	HSPF 8.6, EER 12.19, COP 3.52	HSPF 8.8 ,EER 12.70, COP 3.74	HSPF 9.2 ,EER 12.88, COP 3.66	No Alternative
Lighting	1.5 watts/sqft	None	None	None	No Alternative
Photovoltaics	Not Applicable	None	None	None	No Alternative
Roof Insulation	Not Applicable	None	None	None	No Alternative
Solar Thermal	Not Applicable	None	None	None	No Alternative
Thermal Storage	Not Applicable	None	None	None	No Alternative
Wall Insulation	R11 batt	R19 batt	R21 batt	R21 batt + R5 rigid	No Alternative

Table 153. R/RMUMRB - Retail Internal Large Shop (RILS) Alternatives

Prototype #5 Gateway Retail Internal Large Shop					
Alternative	Elec Utility $	Gas Utility $	Total Utility $	Alt Cost $	Payback yrs
Baseline	$2,891	$1,625	$4,516	$0	NA
Baseline + EE Package	$2,891	$1,575	$4,466	$371	7.4
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$2,891	$1,575	$4,466	$371	7.4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$2,900	$1,625	$4,525	$166	never
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$2,886	$1,625	$4,511	$494	98.9
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	$2,882	$1,625	$4,507	$319	35.4
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	$2,877	$1,625	$4,502	$637	45.5
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	$2,875	$1,625	$4,500	$1,593	99.6
Baseline + Envelope Insulation - Walls, R19 batt	$2,894	$1,625	$4,519	$79	never
Baseline + Envelope Insulation - Walls, R21 batt	$2,895	$1,625	$4,520	$146	never
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$2,898	$1,625	$4,523	$927	never

Table 154. R/RMUMRB-RILS Alternatives Impact on Utility Costs and Paybacks

Prototype #5 Gateway Retail Internal Large Shop					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	14,944	51	13	64	0
Baseline + EE Package	14,944	51	9	60	4
Baseline + High Efficiency Domestic Hot Water, EF=0.823	14,944	51	9	60	4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	15,027	51	13	64	0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	14,898	51	13	64	0
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	14,855	51	13	64	0
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	14,833	51	13	64	0
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	14,822	51	13	64	0
Baseline + Envelope Insulation - Walls, R19 batt	14,968	51	13	64	0
Baseline + Envelope Insulation - Walls, R21 batt	14,981	51	13	64	0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	15,008	51	13	64	0

Table 155. R/RMUMRB-RILS Alternatives Impact on Energy Consumption

Prototype #5 Gateway Retail Internal Large Shop					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	1,242	286	14	301	0
Baseline + EE Package	1,242	286	10	297	4
Baseline + High Efficiency Domestic Hot Water, EF=0.823	1,242	286	10	297	4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	1,242	288	14	302	-1
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	1,242	285	14	300	1
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	1,242	284	14	299	2
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	1,242	284	14	298	3
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	1,242	284	14	298	3
Baseline + Envelope Insulation - Walls, R19 batt	1,242	287	14	301	0
Baseline + Envelope Insulation - Walls, R21 batt	1,242	287	14	301	0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	1,242	287	14	302	-1

Table 156. R/RMUMRB-RILS Alternatives Impact on TDVI

3.12 Retail/Residential Mixed-Use Mid-Rise Building – Retail Internal Small Shop

Measure	Baseline	Alternative 1	Alternative 2	Alternative 3	EE Package
Appliances	Not Applicable	None	None	None	No Alternative
CHP	Not Applicable	None	None	None	No Alternative
Roof Material	Not Applicable	None	None	None	No Alternative
Water Heating	EF=0.594	EF=0.823	None	None	Alternative 1
Windows	U=0.57, SHGC=0.61	U=0.26, SHGC=0.37	U=0.22, SHGC=0.22	None	No Alternative
Space Heating	Heat Pump (See Space Cooling)	None	None	None	No Alternative
Space Cooling	HSPF 8.1, EER 11.07, COP 3.28	HSPF 8.6, EER 12.19, COP 3.52	HSPF 8.8 ,EER 12.70, COP 3.74	HSPF 9.2 ,EER 12.88, COP 3.66	No Alternative
Lighting	1.5 watts/sqft	None	None	None	No Alternative
Photovoltaics	Not Applicable	None	None	None	No Alternative
Roof Insulation	Not Applicable	None	None	None	No Alternative
Solar Thermal	Not Applicable	None	None	None	No Alternative
Thermal Storage	Not Applicable	None	None	None	No Alternative
Wall Insulation	R11 batt	R19 batt	R21 batt	R21 batt + R5 rigid	No Alternative

Table 157. R/RMUMRB - Retail Internal Small Shop (RISS) Alternatives

Prototype #5 Gateway Retail Internal Small Shop					
Alternative	Elec Utility $	Gas Utility $	Total Utility $	Alt Cost $	Payback yrs
Baseline	$2,890	$1,625	$4,515	$0	NA
Baseline + EE Package	$2,890	$1,575	$4,465	$371	7.4
Baseline + High Efficiency Domestic Hot Water, EF=0.823	$2,890	$1,575	$4,465	$371	7.4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	$2,899	$1,625	$4,524	$148	never
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	$2,884	$1,625	$4,509	$443	73.8
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	$2,878	$1,625	$4,503	$320	26.7
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	$2,874	$1,625	$4,499	$640	40.0
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	$2,874	$1,625	$4,499	$1,599	100.0
Baseline + Envelope Insulation - Walls, R19 batt	$2,892	$1,625	$4,517	$70	never
Baseline + Envelope Insulation - Walls, R21 batt	$2,894	$1,625	$4,519	$130	never
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	$2,897	$1,625	$4,522	$821	never

Table 158. R/RMUMRB-RISS Alternatives Impact on Utility Costs and Paybacks

Prototype #5 Gateway Retail Internal Small Shop					
Alternative	Elec kWh	Elec MMBtu	Gas MMBtu	Total MMBtu	MMBtu Saved
Baseline	14,931	51	13	64	0
Baseline + EE Package	14,931	51	9	60	4
Baseline + High Efficiency Domestic Hot Water, EF=0.823	14,931	51	9	60	4
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	15,024	51	13	64	0
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	14,881	51	13	64	0
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	14,845	51	13	64	0
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	14,821	51	13	64	0
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	14,810	51	13	64	0
Baseline + Envelope Insulation - Walls, R19 batt	14,955	51	13	64	0
Baseline + Envelope Insulation - Walls, R21 batt	14,969	51	13	64	0
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	14,998	51	13	64	0

Table 159. R/RMUMRB-RISS Alternatives Impact on Energy Consumption

Prototype #5 Gateway Retail Internal Small Shop					
Alternative	Space Sqft	Elec TDVI	Gas TDVI	Total TDVI	TDVI Saved
Baseline	1,003	286	14	300	0
Baseline + EE Package	1,003	286	10	297	3
Baseline + High Efficiency Domestic Hot Water, EF=0.823	1,003	286	10	297	3
Baseline + High Efficiency Glazing, U=0.26, SHGC=0.37	1,003	288	14	302	-2
Baseline + High Efficiency Glazing, U=0.22, SHGC=0.22	1,003	285	14	299	1
Baseline + High Efficiency Cooling, HSPF 8.6, EER 12.19, COP 3.52	1,003	284	14	299	1
Baseline + High Efficiency Cooling, HSPF 8.8 ,EER 12.70, COP 3.74	1,003	284	14	298	2
Baseline + High Efficiency Cooling, HSPF 9.2 ,EER 12.88, COP 3.66	1,003	284	14	298	2
Baseline + Envelope Insulation - Walls, R19 batt	1,003	287	14	301	-1
Baseline + Envelope Insulation - Walls, R21 batt	1,003	287	14	301	-1
Baseline + Envelope Insulation - Walls, R21 batt + R5 rigid	1,003	287	14	302	-2

Table 160. R/RMUMRB-RISS Alternatives Impact on TDVI

Chapter 4. Alternatives for Community Site Development

This chapter describes the energy-efficient/low-carbon design alternatives for community site development modeled in the Chula Vista Research Project (CVRP). These alternatives include:

- Mixed-Use / Moderate-Density Development
- District Energy Systems
- Urban Runoff Mitigation Measures
- Carbon Sequestration Measures
- Urban Heat Island Reduction Measures, and
- Passive Solar Building Orientation

In addition to a description, this chapter will provide the energy efficiency performance of each alternative compared to the conventional options, and where possible, basic planning considerations for their use on large-scale development projects. The specific energy efficiency and emissions reduction performance of these alternatives will naturally vary from site to site, driven by specific energy end-uses, building types and orientations, site composition and climate. However, to provide a general sense of their performance relative to the conventional options, we cite relevant findings from the Chula Vista Research Project (CVRP) below.

4.1 Mixed-Use / Moderate Density

4.1.1 Description

Mixed-use development is characterized by the co-location of residential uses with commercial-office, commercial-retail and often public/institutional uses. Residents of mixed-use communities typically enjoy access to a variety of employment, shopping, recreational and entertainment amenities all within a quarter-mile walking distance from their homes. Mixed-use communities often include a range and mix of housing options including single-family detached homes, attached townhomes, and multifamily condominium complexes, often with commercial retail and office space at ground-level or the second floor.

Moderate-density development is characterized by approximately 11 dwelling units per-acre (dua), whereas conventional lower-density development in southern California is more typically three to four dwelling units per-acre. Moderate-density developments encourage the use of public transportation and typically place the highest density housing options closest to transit corridors, transit stations and transit stops. Moderate-density developments will include a variety of structures that generally do not exceed 10-stories in height.

4.1.2 Energy Efficiency Performance

Mixed-use/moderate-density developments have been shown to be more energy- and resource-efficient than lower density developments. This is due to the favorable spatial conditions they create that facilitate the economical use of advanced energy-efficient technologies and district energy systems, that reduce vehicular petroleum consumption and emissions, and that dramatically increase both land use efficiency and household energy savings.

Use of Advanced Energy Technologies – The CVRP researchers modeled the central power plant electricity consumption of a mixed-use/moderate-density (11-dua) development served by combined cooling, heat and power (CCHP) technologies and compared that consumption to an equivalent amount of commercial space in a lower-density (3-dua) development served by conventional building space conditioning equipment. As would be expected, the results showed a 68% reduction in central power plant electricity in the mixed-use/moderate-density development. This decrease translates into significant reductions in central power plant emissions, however use of CCHP also increases local emissions when the technology is driven by a fossil fueled (natural gas) prime mover such as an internal combustion reciprocating engine. By contrast, renewably-based CCHP systems offer the benefit of the significantly reduced central power plant energy consumption and emissions and lower or even negligible local emissions, depending on the source of energy used.

A similar analysis was conducted to examine the economic feasibility of a district energy/cooling system to serve an equivalent cooling load in a moderate-density development and a low-density development. The modeling results indicate that the costs associated with a district cooling system designed to serve the moderate-density development are 181% lower than the costs of a system designed to serve the same load in a conventional low-density development. Additionally, the research findings indicate that the additional cost of a system to serve a low-density development would render such a system economically infeasible. The next section of this chapter provides an overview of district energy technologies, additional information on their energy efficiency compared to conventional space conditioning technologies, and provides a set of planning and design guidelines for development practitioners.

Vehicular Petroleum Consumption and Emissions – The CVRP researchers modeled the vehicle-miles-traveled (VMT), petroleum consumption and vehicular emissions for a similar moderate-density / low-density comparison. They found that the moderate-density development reduced VMT by 12-15% which in turn significantly reduced petroleum consumption and vehicular emissions by approximately the same amount.

Land Use Efficiency & Household Energy Savings – Using the same density figures described above (11 and 3 dua), the CVRP researchers compared land use consumption and per-household energy savings for the same size population. The modeling results indicate that a moderate-density development could reduce land consumption by up to 80% and that its diversity in housing could produce as much as a 50% per-household energy savings.

These savings are produced as a result of smaller housing units, shared walls and heating, air conditioning and ventilation systems.

4.1.3 Planning Considerations

In order to accurately optimize the energy efficiency and emission reduction potential of mixed-use/moderate density development alternatives it is necessary to conduct detailed energy modeling of the constituent buildings on the site as well as modeling of site design features that impact energy consumption in those buildings, and in particular features affecting ambient air temperatures (discussed further below). In addition, this modeling data must be imported into a geographic information system (GIS) platform to enable planners to examine energy and emission impacts of alternative designs features and configurations. There are a number of tools that can be combined to achieve this level of analysis now on the market. In the case of the CVRP, the researchers used the following six building, district energy technology and urban design modeling tools:

- Building Energy Analyzer^tm (BEA), - a proprietary product of the Gas Technology Institute (GTI)
- Energy-10^tm - a proprietary product of the Sustainable Building Industry Council (SBIC)
- City Green^tm - a proprietary product of the American Forests organization
- Mitigation Impact Screening Tool (MIST) – a product of the U.S. Environmental Protection Agency
- CommunityViz^tm - a proprietary product of the Orton Family Foundation, and
- TERMIS – a proprietary product of 7-Technologies.

BEA was used to model energy, economic and environmental parameters for 15 types of commercial, institutional and commercial-residential mixed-use structures. Energy-10^tm was used to model five types of single and multi-family residential buildings. City Green was used to model alternative landscape design elements and to support evaluation of the urban heat island effect. MIST was used to assess the impact of increasing urban albedo (reflectance) and/or urban vegetation in reducing the urban heat island effect.

CommunityViz was used to model potable water and wastewater treatment infrastructure, urban runoff, alternative land-use configurations and transportation infrastructure, patterns and strategies. CommunityViz was also used to co-register and synthesize data inputs from the other software tools and to produce 360-degree visualizations and real-time impact simulations for stakeholder meetings in which alternative design options were evaluated.

Modeling of transportation infrastructure, patterns, and strategies for energy consumption and emission impacts entailed estimating average daily vehicle-miles traveled (VMT) using both quantitative factors such as housing density and road patterns, and qualitative factors such as the probability that residents will choose alternative modes of transportation. Based on the estimated VMT, potential savings in energy consumption and air emissions were then calculated using generally accepted averages.

Termis is a hydraulic modeling tool used for the design and analysis of the modeled district energy/cooling system.

There are now several tools on market that combine archived energy consumption and emissions data for common building types in California with transportation data and GIS land use databases. The best known tool is I-PLACE3s, developed with funding provided by the U.S. Department of Energy and California Energy Commission. The tool is useful for those conducting high-level analysis where only general estimates of building energy consumption and emissions are sufficient. For more accurate estimates, it's necessary to build customized databases derived from the geometry and construction features of the planned buildings for the development site.

Once a site's total energy (electricity and natural gas demand is known), a simple calculation is conducted to determine air emissions. The relevant conversion factors to use in this calculation are as follows:

- **CO_2**: 700.4 lbs/MWh of electric energy produced and 117.6 lbs/MMBtu of gas energy used at the building level
- **SO_x**: 0.128 lbs/MWh of electric energy produced and 0.00059 lbs/MMBtu of gas energy used at the building level
- **NO_x**: 0.352 lbs/MWh of electric energy produced and 0.092 lbs/MMBtu of gas energy used at the building level.

4.2 District Energy Systems

4.2.1 Description

District energy systems contribute to community sustainability and security by maximizing the efficient use of a variety of fuels to co-generate and deliver electricity and thermal energy, locally. Because district energy thermal networks aggregate and link the heating and cooling requirements of dozens or hundreds of buildings, they create a greater scale of thermal energy use in a community that facilitates fuel flexible solutions at a central plant or plants and allow for thermal storage applications that would not otherwise be functionally or economically feasible on an individual building basis. In addition to fossil fuels, district energy systems can utilize a combination of locally available renewable resources such as municipal solid waste, community wood waste; landfill gas, wastewater facility methane, biomass, geothermal; lake or ocean water and solar energy. District energy systems also improve local economies by increasing energy reliability, stabilizing energy costs, attracting new businesses to the district served by the system, increasing property values and ultimately, by re-circulating energy dollars in the local economy through capital investment, construction and operation and maintenance jobs.

District energy systems produce electricity, hot water, steam and/or chilled water at a central plant and then distribute the energy through underground wires and pipes to adjacent buildings connected to the system. Electricity is used to energize lights, appliances, equipment and machinery, while hot and chilled water and steam are used for space heating and cooling and a variety of commercial/industrial processing needs.

From a sustainability standpoint, the essential advantage of a district energy system over a conventional central power plant, transmission and distribution system is a far more efficient use of the input fuel relative to end-uses. Typically, only one-third of the fuel energy input to a conventional fossil-fuel power plant is delivered to the end-use consumer as electricity. The vast majority of the energy that is generated is discharged in the form of heat to adjacent rivers, lakes and to the atmosphere, resulting in significant thermal pollution.

And while this energy is discharged to the environment, consumers purchase more electricity and natural gas to meet their needs that could have been satisfied by recovering and using the wasted thermal energy. By contrast, local district energy systems capture most of the heat energy generated in electricity production and use it to produce steam and hot and chilled water. This process is known as co-generation and is made possible by combined heat and power technologies such as gas fired reciprocating engines, gas turbines, heat exchangers and absorption chillers. Figures 20 illustrates one of the common technology configurations used in the industry today.

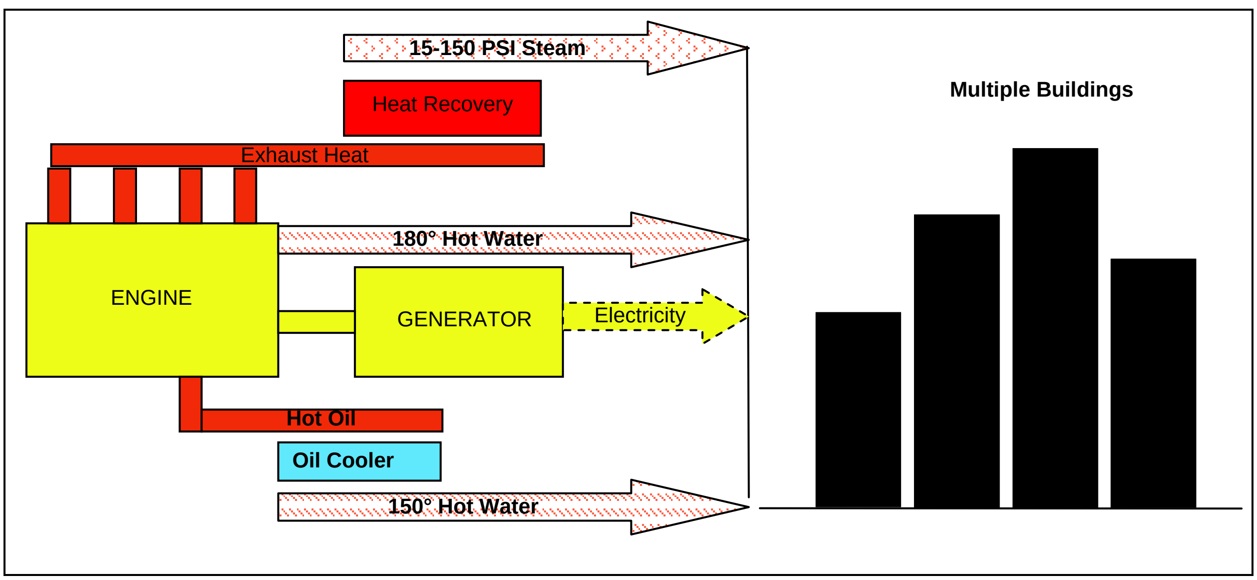

Figure 21. Reciprocating Engine-Driven CHP

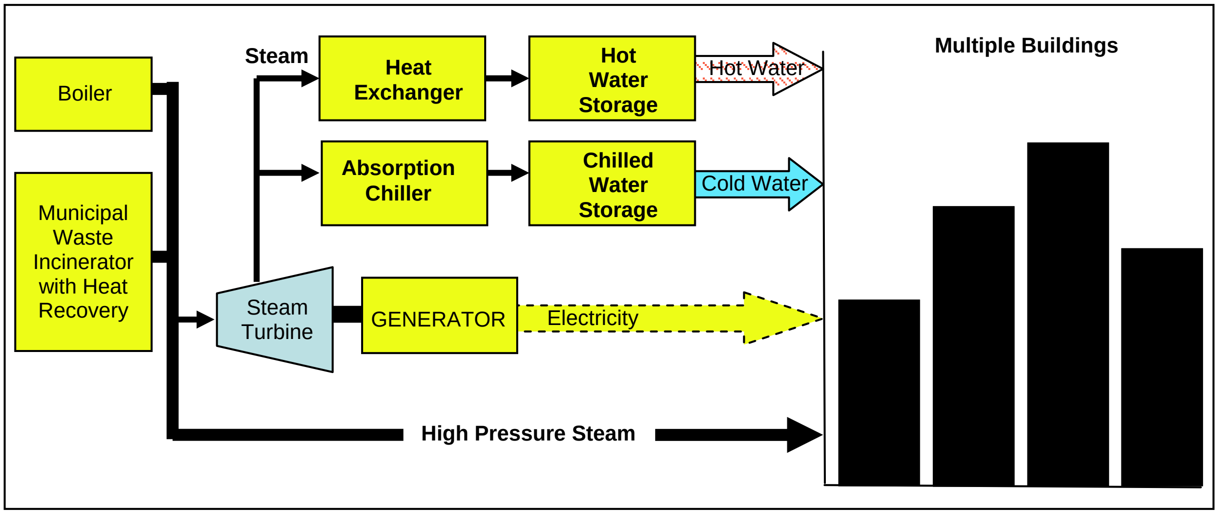

Figure 22. Turbine Driven-CCHP System

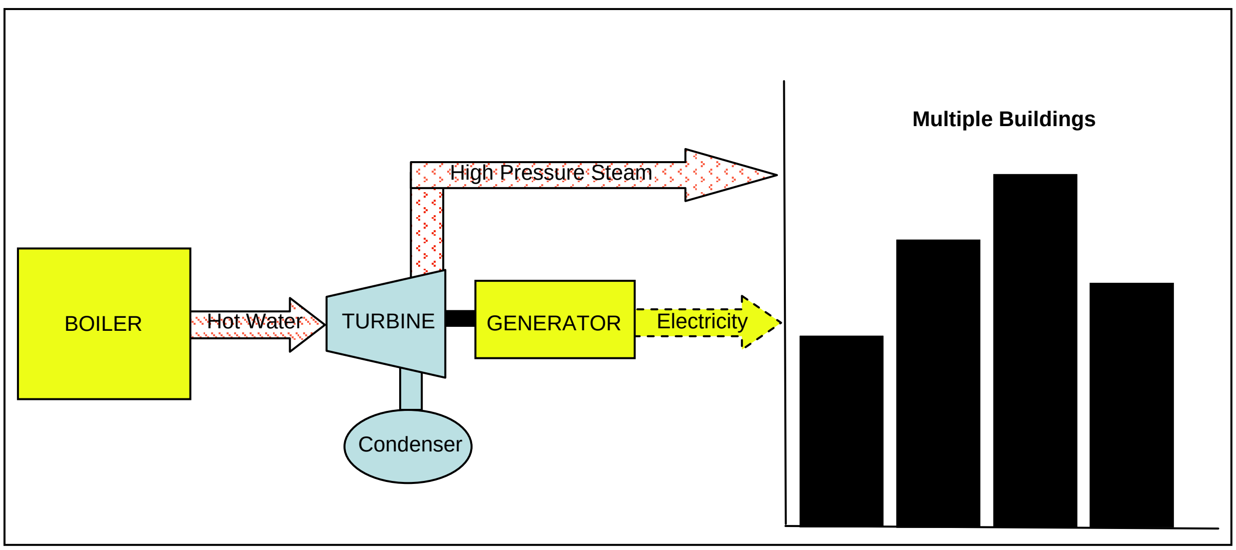

Figure 23. Turbine-Driven Steam & Electric

4.2.2 Energy Efficiency Performance

The researchers modeled the energy efficiency of a district cooling system and compared its performance to a conventional approach to building cooling for the 206-acre urban development site – stand-alone cooling equipment at individual buildings. The modeling results indicate that a district cooling system featuring thermal energy storage (TES) technology could reduce electricity consumption by over 3 million kWh and provide substantial reductions in the emission of pollutants and greenhouse gasses. Furthermore, the ability to peak shave with the TES feature significantly reduces peak power requirements, thereby reducing the amount of electrical infrastructure required to meet peak cooling loads for the development site.

4.2.3 Planning Considerations

There are four classifications of district heating and cooling (DHC) systems differentiated by the characteristics of the areas they serve. These are:

- Densely populated urban areas
- High-density building clusters
- Industrial or research campuses
- Low-density residential areas

As a rule of thumb, there are three requirements that must be met for a DHC system to operate economically:

1 There must be a high load density - determined by the thermal load per unit of building floor space, number of stories and total number of buildings in the area to be served. The capital investment in a DHC system designed for a greenfield development site must be at least partially recovered through a contribution margin of energy sales to end-users that are located within close proximity to one another. In an existing urban site, there must be a significant vertical density of customer buildings to be served to warrant the considerable cost per trench foot of constructing the underground network of piping for a DHC system;

2 There must be a large annual load factor - the ratio between the actual amounts of energy consumed annually to the amount of energy that would be consumed if the peak thermal load were to be imposed continuously for a full year. In other words, thermal energy requirements must be significant enough throughout the year that the capital cost recovery of a DHC plant and piping network is not allocated to a limited period of off-peak demand;

3 There must be a rapid rate of consumer connections to the system. This last requirement is particularly important since 50%-75% of the total district energy system investment is the cost of installing the transmission and distribution piping network. The sequence and location of "anchor users" relative to the main central plant and distribution trunk are also important factors to consider.

DHC systems have proven to be very cost-effective in densely populated urban areas where there are a variety of building types, end-uses and nearby sources of thermal energy such as power plants, industrial sites and municipal solid waste disposal facilities. DHC systems serving areas of this size typically entail a phased construction period of 20-30 years, miles of distribution piping and several thousand megawatts of electrical capacity to meet consumer demand.

These systems can ultimately cost in the hundreds of millions of dollars and typically involve extensive and complex institutional arrangements to plan, finance, build and operate. Moreover, in an urban setting, district energy systems compete openly with on-site alternatives like boilers, chillers and electric heat. The energy market can also be complex and the risks of constructing a DHC system can be significant as there are no assurances that customers will connect to and use the systems' services.

DHC systems serving high-density clusters such as suburban shopping malls, healthcare and hospitals complexes, university campuses and mixed-use complexes can be designed and installed in only 3-10 years. These systems have much smaller distribution networks and need only several hundred megawatts of generating capacity.

Typical costs for these smaller systems can range from a few million to tens of millions of dollars and typically involve institutional arrangements involving only a few decision makers in the development process. In institutional settings where the central plant is owned by the same entity as the end-user buildings, market risk for return on capital is reduced.

The economics of DHC systems designed to serve industrial complexes are driven principally by their demands for process steam and hot water. These systems are often similar in size and complexity to systems serving high-density clusters. Low-density residential areas have not proven to be a cost effective application for district heating and cooling in the United States given the high capital costs and low rates of utilization per trench foot of distribution piping investment.

Residential application of district heating has however proven to be cost effective in Europe and Scandinavia where residential densities are typically higher. These systems are designed for residential blocks with a generating capacity of 1-3 megawatts and deliver low-temperature hot water to their consumers. In fact, in many northern European cities, district heating is the predominant source of comfort and may exceed 85% market share of residential space. Given the success of these European models, residential district energy systems are now being considered for several new, large-scale residential development projects in California and across the nation.

It is important to note that there is not a universal standard for the configuration of a district energy system that will be applicable in all settings. This is due to the fact that the availability of alterative energy sources, potential for cogeneration, peak hourly loads, energy pricing, annual energy consumption patterns and market potential will vary by region and by the specific site.

Additionally, underground soil and congestion conditions, soil types, urban density and building HVAC systems can effect technical design considerations. Ambient weather trends and the ratio of customer space uses, such as commercial office, residential, retail and mixed use; event and arena space and high-volume users like hospitals, research and data centers all impact system design parameters.

There are however, a set of standard factors, minimum requirements and ranges to consider when investigating the economic and technical feasibility of a district energy system utilizing cogeneration or municipal waste incineration. These include the following:

- <u>Ambient Air Temperatures</u> - There must be a minimum of 4,000 heating degree days in a year to make a DHC system economically feasible for space heating. A degree day unit (referred to as a degree day) is a measurement of indoor heating requirements affected by outside temperatures. The number of degree day units for any given day is calculated by subtracting the mean outside temperature from 65°F, and the total degree-days for any longer period is the sum of the degree days of the individual days in that period. Degree day tables & maps are available from the National Climatic Data Center at the U.S. Department of Commerce. For district cooling systems, customers typically should consume more than 1,000 equivalent full load hours. In other words, a 200 ton peak demand building, should consume 200,000 ton hours over the course of a year.

- Area Energy Demand - Each unit of land area to be served by a district heating system must have a high hourly and annual thermal energy demand.
- Location of Thermal Plant - The energy production plant must be located close to the area to be served to reduce capital costs and thermal losses in transmission.
- Transmission Distances - Three to five miles is the maximum distance between a production plant and the end of the distribution network for an economical steam line. Fifteen miles is the maximum distance for a hot water line when thermal energy is derived from an electrical power plant. Three miles is the maximum distance for a hot water line when thermal energy is derived from a municipal solid waste incinerator.
- Land Use Zoning Threshold - All zones in which 50% or more of the land is designated for single-family detached housing, single-family attached housing, town houses, open space or other low energy intensity uses are generally not considered viable for district energy systems.
- Cooling Load Concentration - For central cooling plants to be practical, cooling load concentrations must be 150 to 250 tons per 100 lineal feet of distribution piping runs.
- Piping System Cost - If the cost of the piping system is less than one third of the cost of the total chilled water system cost, than consideration should be given to the central chilled water system.
- Substantial Anchor Load – In the phased construction of a new district energy system, it is advisable that an anchor tenant or initial user sign up for at least 20% of the initial plant capacity investment. The capital risk is further mitigated with a higher percentage pre-subscribed to the service. An important spatial consideration - the location of the anchor load should be proximate to the future market density and not an isolated node on a network.
- Plant Footprint - In urban settings, the high cost of real estate significantly impacts the economic feasibility of a DHC system as central plant space requirements can be considerable. Consequently, many cities have integrated district heating and cooling plants into the frame of urban parking garages to increase the yield of the real estate parcel and to provide incremental income for a reasonable companion use.

- Condenser Water Sources – Many DHC systems utilize contiguous rivers, lakes and bays for condenser water and/or winter cooling cycles. This minimizes air rights for locating cooling towers and provides a low cost source of winter cooling to data centers and high-rise building cores.
- Age of Buildings and Life Cycle – The opportunity to avoid the capital costs of replacement heating and cooling equipment is the most important factor in a building owner's decision to connect to a DHC system. In planning a DHC system for an existing urban site, consideration must be given to the age, type and life cycle stage for the individual buildings within the proposed service area. Sites predominantly occupied by newer buildings with existing "in-building" boiler and chiller equipment will not prove to be economical for a DHC system, as owners of these buildings will not be inclined to connect to the system.
- Utility Rates – A full understanding of the natural gas and electric utility rates in effect at a proposed development site is absolutely essential in determining the economic feasibility of a DHC system. In many urban areas where time-of-day rates, load factor ratchet penalties and high-peak electric demands exist, district cooling systems with thermal or ice storage prove to be very economically attractive. A thorough analysis of existing rate structures must be one of the first tasks engaged by planners examining the potential feasibility of a DHC system.

*FAR – The Floor Area Ratio (FAR) is a measure of development intensity. FAR is the ratio of the amount of floor area of a building to the amount of area of its site. For instance, a one-story building that covers an entire lot has an FAR of 1. Similarly, a one-story building that covers 1/2 of a lot has an FAR of 0.5. or a four story building that covers ½ of a lot has an FAR of 2.0.

Community Energy Systems			
Minimum/Maximum Standards	**District Heating System**	**District Cooling System**	**District Steam System**
Heating Degree Days	Min: 4,000	NA	Min: 4,000
Cooling Load Hours	NA	Min. 1,000 equivalent full load hours	NA
Energy Transmission Distances	Max: 15 miles when the source is a power plant Max: 5 miles when the source is a waste incinerator	Max: 5 miles when the source is a power plant Max: 5 miles when the source is a waste incinerator	Max: 7 miles when the source is a power plant Max: 5 miles when the source is a waste incinerator
High-Energy Intensity Land Uses	Min: 33% or greater	Min: 50% or greater	Min: 50% or greater
Piping System Costs	Max: 33% of total system cost	Max: 40% of total system cost	Max: 40% of total system cost
Pre-subscribed Anchor Load	Min: 25% of plant capacity	Min: 20% of plant capacity	Min: 25% of plant capacity
Building Area in SF	Min:2,000,000	Min:2,5000,000	Min: 5,000,000
Combined FAR* & Acreage	Min:3-7	Min: 3-10	Min:3-7

Table 161. Minimum/Maximum Standards

4.3 Urban Runoff Mitigation & Carbon Sequestration Measures

4.3.1 Description

Urban runoff mitigation is the process of diverting stormwater flows from collection, retention, detention and/or storm sewer processing facilities. These measures are pursued by communities interested in reducing costs associated with the construction of these facilities; and in the case of processing facilities, in reducing energy consumption and energy-related air emissions associated with their operation.

Although there are a number of different measures for diverting stormwater, the measures considered in the CVRP initiative were the use of increased tree plantings and open space. Increased tree plantings also provide another benefit to communities through carbon sequestration and pollutant removal, assisting them in meeting their carbon and pollutant reduction goals.

To quantify the stormwater diversion performance and cost savings, and the energy consumption and carbon reduction benefits of these measures, the researchers compared two scenarios for the two modeled development sites. The baseline scenario entailed minimal tree coverage on each site, while the optimized scenario introduced an additional 10% of tree coverage. The primary indicator for urban runoff mitigation is stormwater diversion for a two-year, 24-hour peak rain event. The volume diverted during such an event is measured in cubic feet and an equivalent dollar value can be calculated for costs associated with the construction of facilities to handle the diverted stormwater.

The primary indicator for carbon sequestration is the number of tons of CO_2 stored in the biomass of planted trees.

4.3.2 Energy Efficiency & Emissions Performance

The CVRP modeling results indicate that only a modest increase in tree canopy and a decrease in impervious surfaces can produce significant construction cost savings for developers and some energy and carbon emissions savings as well. In the case of the two modeled development sites, a modest 10% increase in tree canopy resulted in a 48% increase in stormwater diversion for the first site and a 64% increase in stormwater diversion for second site.

This diversion translates into a savings of approximately $122,300 for the developer of the first site, in costs associated with the construction of stormwater retention and detention pond systems. In the case of the second site, the developer could save as much as $387,440 in construction costs associated with these systems.

While communities that have these systems don’t enjoy direct energy savings as their stormwater flows aren’t processed by the sanitary sewer facilities, they derive other benefits from additional tree plantings such as enhanced air filtration, and carbon sequestration and lower levels of non-point source surface water pollutants, especially in urban areas. For those California communities that do have combined stormwater and sanitary sewer systems, these increases in stormwater diversion do translate into energy and carbon emissions savings. In the case of the first development site, a 10% increase in the tree canopy translates into an annual savings of 915.27 kWh over what would be expected given the conventional amount of plantings typical of most development sites. This in turn translates into the reduction of 614 lbs. of carbon emissions annually. In the case of the second site, a 10% increase in the tree canopy translates into an annual savings of 2,899.57 kWh over the conventional amount of plantings typical of most development sites. This in turn translates into the reduction of 2031 lbs. of carbon emissions annually.

With regard to carbon sequestration, the modeling revealed that a baseline 2.4% tree canopy in the first, more urban site would store 213 tons of CO_2 in existing trees and would sequester an additional 1.66 tons per year. [6] A 10% increase in canopy cover would result in the storage of 1,099 tons of CO_2 and the sequestration of 8.56 tons annually.

In the case of the second more residential development site, the modeling revealed that a baseline 5% tree canopy stores 725 tons of CO_2 in existing trees and sequesters an additional 5.64 tons per year. Increasing the canopy cover to 15% stores 2,174 tons of CO_2 and sequesters an additional 16.93 tons per year. Tables 162 and 163 contain the tailpipe pollutant removal data for the baseline and optimized development scenarios for each site.

4.3.3 Planning Considerations

To enable development practitioners to conduct their own analysis of this stormwater runoff and carbon sequestration mitigation alternative for proposed development projects, the text below describes the basic methodology used by the CVRP team to generate the results presented here.

The CVRP researchers used CITYgreen™ to analyze the ecological and economic benefits of tree canopies and other green/open space features for the baseline and optimized scenarios for each development site. CITYgreen™, built on the ESRI ArcGIS platform, allows users to derive assumptions from spatial datasets. The primary input to CITYgreen™ is a classified land cover dataset for each development scenario. Land cover assumptions were derived from site plan data provided by the developers and datasets derived from a variety of sources including aerial photography, satellite imagery and GIS vegetation layers. The datasets were classified into land cover features such as tree canopies, open spaces, impervious surfaces, and water surfaces, and configured into feasible landscape plans by the researchers to conduct the CITYgreen™ analysis

Stormwater runoff mitigation analysis - Stormwater runoff, concentrations and peak flow were calculated by the research team through the use of the Urban Hydrology for Small Watersheds model, also known as the Technical Release 55 (TR-55) model. This model is commonly used by civil engineers in the design of stormwater management facilities and was developed by the Natural Resource Conservation Service, a bureau of the U.S. Department of Agriculture. CITYgreen™ uses the TR-55 modeling

[6] Storage refers to the amount of carbon stored in the biomass of trees on planting. Sequestration refers to the additional amount of carbon stored for every year of growth.

results to calculate the volume of runoff from land cover based on the two-year 24-hour rain event. This calculation allows planners to examine the impact of tree planting on urban runoff and to estimate savings attributed to diverted stormwater.

CITYgreen™ produces this calculation by assigning a Curve Number to each classified land cover type. A Curve Number is a parameter used in hydrology for predicting runoff potential and varies by land cover type and soil type.[i] The number ranges from 30 to 100 and lower numbers indicate lower runoff potential. The calculation of diverted stormwater is estimated by taking a site-wide Curve Number, weighted by the percentage of each land cover type, under different scenarios and comparing them to a baseline (for example, a site with a canopy versus a site without a canopy). The difference in the Curve Number between two scenarios then drives the calculation of the stormwater volume diverted using the TR-55 methodology. The equations for calculating the stormwater savings are provided below.[7]

Site Wide Weighted Curve Number (CN):

CN (weighted) = Total product of (CN × Percent land cover area) / total percent area or 100

Potential Maximum Retention After Runoff Begins:

$S = ((1000 / CN) – 10)$

Runoff Equation:

$Q = [P - .2 ((1000 / CN) – 10)]2 / P + 0.8 ((1000 / CN) – 10)$

[7] Derived from the CITYgreen User Manual, 2000, References and Appendices, p. 84

Flow Length:

F = (total study area acres × 0.6) × 209

Lag Time:

$L = ((F×0.8) × ((S + 1.0) × 0.7) / (1900 × ((slope) × 0.5)))$

Time of Concentration:

$T_c = 1.67 × L$

Unit Peak Discharge:

$\log(q_u) = C_0 + C_1 × \log(T_c) + C_2[\log(Tc)] × 2$

Peak Flow:

$Peak = (q_u × A_m × Q × F_p)$

Storage Volume (this is the key indicator of how much stormwater savings result from tree planting):

$V_s = V_r × (C0 + (C1(q_o/q_i)) + (C2 × ((q_o/qi)^2)) + (C3 × (qo/qi)^3)) ×$ study area acres × 43560.17 / 12

Variable Definitions:

P	=	Average rainfall for a 24 hour period (inches)
A_m	=	Study area acres / 640 to determine square miles
F_p	=	Swamp pond percentage adjustment factor (based on the percentage of open water and swamp that exist on the site)
q_o	=	Existing peak flow condition with trees (cubic feet per second)

q_i	=	Peak flow without trees (cubic feet per second)
C_0, C_1, C_2	=	TR-55 coefficients in accordance with rain type[ii]

Output Values:

Peak	=	Peak flow (cubic feet per second)
V_s	=	Storage volume (cubic feet)
V_r	=	Runoff volume (inches)
CN	=	Runoff curve number (weighted)
Q	=	Runoff (inches)
F	=	Flow length (feet)
S	=	Potential maximum retention after runoff begins (inches)
L	=	Lag time (hours)
T_c	=	Time of concentration (hours)
q_u	=	Unit peak discharge (cubic feet per second per square mile per inch)

Carbon Sequestration Analysis - Using the same land cover assumptions generated for the stormwater analysis, the researchers used the CITYgreen™ tool to calculate the air pollution removal and carbon storage and sequestration potential of the tree canopies for the two development sites.

The CITYgreen™ tool incorporates the USDA's Urban Forest Effects Model (UFORE) to calculate tree canopy potential to remove five criteria pollutants from the atmosphere. In addition to calculating the annual pollutant levels reduced through the use of tree canopies, the model also calculates the associated dollars saved on negative externalities due to these pollutants such as increases in asthma and other respiratory ailments and decreases in tourism. CITYgreen™ estimates the amount of pollution in a given area based on data from the nearest city, in this case, San Diego. The pollution removal rate or flux (F) is calculated by multiplying the deposition velocity (V_d) by the concentration of the pollutant (C):

$$F\ (g/cm^2/sec) = V_d(cm/sec) \times C\ (g/cm^3)$$

Annual flux values are summed by estimating the total pollutant flux by hour over a surface in periods where pollutants are known to exist. These numbers are pre-calculated in CITYgreen™ for 55 modeled regions and are expressed as the weight of pollutant removed per square meter of canopy.

The UFORE model was also used by the researchers to calculate the amount of carbon stored in the trees represented on the land cover maps for each development site and to calculate their annual carbon sequestration. While storage and sequestration varies by tree species and maturity, the researchers assumed a weighted average of trees appropriate for urban plantings. Based on assumptions of average carbon storage and sequestration for trees used in a typical urban forestry program, CITYgreen™ calculates a carbon storage and sequestration weight per square meter of canopy. Table-164 (to be added) below provides the averages used by the researchers for this analysis.

Tables-165 and -166 below provide

additional assumptions used in the stormwater runoff, carbon sequestration and air quality analysis of both development sites.

Additional Site Modeling Assumptions:

Stormwater Runoff Assumptions:

P	=	1.75 inches
A_m	=	.32 sq mi
F_p	=	1.0
Soil Type	=	D (very impervious)[iii]
Raintype	=	I[iv]

Electricity Multiplier for Stormwater Processing:
652 kWh per acre-foot of water[v]

Air Quality Assumptions (for the San Diego region):

Weight of Pollutant Removed Per Square Meter of Canopy[vi]

Ozone	7.6 grams
Particulate Matter	5.6 grams
Nitrogen Dioxide	2.8 grams
Sulfur Dioxide	0.8 grams
Carbon Monoxide	0.7 grams
Total	**17.4 grams**

Dollar Value of Pollutants Removed Per Square Meter of Canopy

Ozone	0.006767
Particulate Matter	0.004518
Nitrogen Dioxide	0.006767
Sulfur Dioxide	0.001653
Carbon Monoxide	0.000940

Weight of Stored Carbon per Square Meter of Canopy[8]

Young Trees	72.31 grams
Mature Trees	99.15 grams
Even Mix	120.89 grams
Unknown Age	96.46 grams

Annual Rate of Carbon Sequestration per Square Meter of Canopy[9]

Young Trees	1.62 grams
Mature Trees	0.17 grams
Even Mix	0.34 grams
Unknown Age	0.75 grams

The principal cost associated with urban runoff mitigation and carbon sequestration measures is the cost of tree plantings. The average cost of planting a tree, including labor and materials, is approximately $445 in most southern California communities. Given this unit cost, Tables-167 and -168 provide details on planting costs for the

[8] Based on average for typical trees used in urban forestry. (McPherson, Nowak, Rowntree 1994, 201)

[9] ibid.

optimized scenarios at Site-A and Site-B, respectively.

For an excellent source of information on individual tree species and their carbon reduction potential please see:

Tree Guidelines for Coastal Southern California Communities. 2000. McPherson, Gregory, Klaus I. Scott, James R. Simpson, Qingfu Xiao, and Paula J. Peper. www.fs.fed.us/psw/programs/cufr/products/2/cufr_48.pdf

4.4 Urban Heat Island Effect Mitigation Measures

4.4.1 Description

According to the U.S. EPA, the "the term "heat island" describes built up areas that are hotter than nearby rural areas. The annual mean air temperature of a city with 1 million people or more can be 1.8–5.4°F (1–3°C) warmer than its surroundings. In the evening, the difference can be as high as 22°F (12°C). Heat islands can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality".[10]

The UHI effect can be mitigated through the use of lower-albedo (less reflective) materials on urban surfaces as well as through trees plantings. To quantify the impact of these measures on energy consumption for the two development sites, the researchers modeled two scenarios for each – one that included use of these measures and the other without them. Site-wide albedo was then calculated for both scenarios. Using MIST, the average temperature reduction and percent reduction in energy for residential, office and retail buildings was then calculated and applied to the energy usage assumptions calculated for each prototype.

The researchers used MIST to analyze the impact of specific urban heat island mitigation measures. These included cool-roof coatings, cool pavement, and increasing tree canopy.

4.4.2 Energy Efficiency Performance

The modeled application of urban heat island mitigation measures produced a 5-14% kWh energy savings for residential and commercial structures in both development sites. In the predominantly urban development site, the modeling indicated that a 10% increase in vegetation and a 0.09 increase in albedo (reflectance of surfaces) results in a temperature decrease ranging from 1.3 degrees F to 2.8 degrees F. This albedo change represents the overall weighted average change for the entire site.

These modeled temperature reductions translate to a 13% savings in residential kWh, a 5% savings in commercial-office kWh, and a 5% savings in commercial-retail kWh. The modeling results, however, show a small increase in gas consumption due to increased heating demand for residential, retail, and office units. Converting MMbtu's to equivalent kWh, there is a net energy savings of 3,835,803 kWh

[10] U.S.EPA Heat Island Home Page at: http://www.epa.gov/heatisland/index.htm

community-wide, as well as 3,029,248 lbs savings in CO_2 emissions, 635 lbs savings in SO_x emissions, and 1,344 lbs savings in NO_x emissions.

The modeling results for the predominantly residential development site indicated that a 10% increase in vegetation and a 0.11 increase in albedo results in a temperature decrease ranging from 1.1 to 2.4 degrees F. MIST's parametric model predicted an average savings of 14% in residential kWh, a 6% savings in commercial-office kWh, and a 6% savings in commercial-retail kWh. The modeling results again showed a small increase in gas consumption due to increased heating demand for residential, retail, and office units. Converting MMbtu's to equivalent kWh, there is a net energy savings of 9,283,511 kWh community-wide, as well as 7,248,920 lbs savings in CO_2 emissions, 1,503 lbs savings in SO_x emissions, and 3,245 lbs savings in NO_x emissions.

4.4.3 Planning Considerations

To enable development practitioners to conduct their own analysis of the potential impact of urban heat island mitigation measures on proposed development projects, the text below describes the basic methodology used by the CVRP team to generate the results presented here.

The essential tool necessary to conduct the analysis is USEPA's Mitigation Impact Screening Tool (MIST). The tool was specifically developed to analyze alternative urban heat island mitigation measures for development sites. MIST provides qualitative assessments of the likely impacts of heat island effect mitigation measures averaged at the city-scale. The CVRP researchers used the tool to investigate the impact of highly reflective construction and paving materials and urban vegetative cover. The researchers also used MIST to investigate average temperature reduction and to estimate the resulting impacts on ozone and energy consumption.

Once the research team examined a range of albedo, vegetation and combined albedo-vegetation scenarios for each site, MIST was used to extrapolate the results from a set of detailed meteorological model simulations for the San Diego region. These meteorological impacts were then combined with energy and tropospheric ozone air quality models to estimate the impact that the specified mitigation measure(s) may have on the development sites. It should be noted that the MIST results are intended only as a first-order estimate that urban planners can use to assess the viability of heat island mitigation strategies for their communities.

To establish the baseline for both development sites, the researchers applied a reflectance assumption to urban surfaces (roads, sidewalks, parks, roofs, etc.). The baseline represented the minimum requirements for roof albedo in California and typical developer paving choices for roads. The specific values are referenced later in this section.

An optimized scenario was then created for each site that included use of mitigation measures including "cool" roof coatings and road pavement. Because MIST uses a site-wide albedo differential as an input, the team developed a weighted measure of site-wide albedo for different types of surfaces. There were some challenges in estimating the different types of surface cover as these analyses were based on conceptual site plans that had no or little indication of parking, pathways, courtyards and other fine grained details. After removing roads, sidewalks, roofs, and parks that are specifically represented in the plan, there remained a large percentage of unclassified land cover in each site.

The researchers could not reasonably assume that all of the remaining land cover would be of one type. However, absent specific plans for these areas, estimating a large range of land cover types would not contribute significantly to the analysis. Instead, a general assumption was made that unclassified land would be divided into two categories: pavement and open space. Since these assumptions were applied equally to both sites, the relative differences still revealed impacts associated with the use of urban heat island effect mitigation measures.

To arrive at a reasonable mix of pavement and open space within the unclassified areas of each site, the research team assumed a total pavement area coverage of 41%. This assumption was derived from analysis conducted of the Sacramento metropolitan region characterizing the urban fabric.[11] In the report, researchers found that approximately 41% of areas characterized as downtown/city center are comprised of pavement.

While the CVRP study areas are not as dense as a typical city center, they are more closely related in character to these areas than outlying residential, office or industrial areas. Therefore, the researchers believed this was a reasonable estimate for the study areas, acknowledging that pavement cover varies widely from community to community. It is likely that the percentage of pavement would be lower in less dense areas, but these areas amount to little more than one-third of the total CVRP study area.

In each site, there was a specified amount of paved area classified as streets and sidewalks. The percent coverage of these areas was calculated and then subtracted from the target coverage of 41%. This remaining percentage represented the relative share of the unclassified land that was classified as paved. The remaining percentage of the unclassified land was classified as open space and assumed to be covered by grass and vegetation. Using these assumptions, a weighted albedo was calculated for the unclassified land and used in calculating the site's total weighted albedo.

The albedo assumptions are driven by the type of material covering each land cover type. The goal of this analysis was to illustrate how a change of materials can reflect more sunlight and lower the overall ambient air temperature in a development site. The optimized scenario featured higher albedo materials for key land cover types, and specifically roofs and streets.

The *baseline* scenario for both sites assumed the use of the following materials:

- Streets: Asphalt (Albedo .04)
- Sidewalk: Gray Portland cement concrete (Albedo .45)
- Roof: Minimum required cool roof (Albedo .7)
- Park and Open Space: Grass and vegetation (Albedo .23)
- Parking Lots: Asphalt (Albedo .04)

11 See Rose, Akbari, Taha. 2003

The *optimized* scenario for both sites assumed the following materials:

- Streets: Asphalt with 6 inch whitetopping (Albedo .45)
- Sidewalk: Gray Portland cement concrete (Albedo .45)
- Roof: Double coat of cool roof coating (Albedo .85)
- Park and Open Space: Grass and vegetation (Albedo .23)
- Parking Lots: Asphalt (Albedo .04)

Site-A: Urban Heat Island Effect Analysis Assumptions

Site-A: was divided into the five main land cover types: street, sidewalk, roof, park, and unclassified cover as indicated below. The albedos described above were applied to the same area for the baseline and the optimized scenarios and then weighted according to the percent coverage. Tables-169 and -170 indicates how the unclassified area albedo was derived according to the approach described above. The resulting difference (delta) of 0.09 is the relative increase in albedo between the baseline and optimized scenarios. MIST uses this number to arrive at the relative energy savings attributable to the increase in albedo and vegetation.

The researchers generated a set of variable assumptions for the site to be used in the MIST calculations. These included the following:

- Population:
  4,946
- Latitude:
  32.6
- Annual mean temperature:
  63.7
- Annual cooling degree days (65F Base)[12]: 862
- Annual heating degree days (65F Base): 1,321

These assumptions and the relative albedo differences were then used as input for the MIST analysis of the site that produced a range and mean reduction in ambient air temperature and a related reduction in energy requirements for buildings in three general categories: residential, office, and retail. The researchers applied these percent reductions to the building modeling data for the baseline energy profile. The result was an aggregate energy reduction and related cost reductions presented above.

The second, more residential site was also divided into the five land cover categories and weighted albedo values were calculated for the site.

The relative difference in albedo became one of the variables entered into the MIST analysis as in Site-A: along with the following assumptions:

- Population:
  9,342
- Latitude:
  32.6

[12] Cooling Degree Days (CDD) are a measure of how many degrees above the base (65F) are experienced in a year. Subtracting 65 from the average temperature in a given day results in the number of CDDs. Summing all of these over the year produces the annual CDD number used here. Similarly, Heating Degree Days are a measure of how many degrees below the base are occur per year.

- Annual mean temperature: 63.7
- Annual cooling degree days (65F Base)[13]: 862
- Annual heating degree days (65F Base): 1,321

Again, the researchers applied MIST outputs to the building energy consumption data to arrive at approximate aggregate energy and emission reductions presented above.

4.5 Passive Solar Building Orientation

4.5.1 Description

Passive solar building orientation entails the placement of buildings on a development site with the explicit intention of maximizing the sun and shade for heating and cooling to reduce energy consumption and costs. By facing the greatest length of a structure to the south and the shorter sides to the east and west and by installing overhangs or awnings over windows, the structure will capture solar heat in the winter and block solar gain in the summer. This can also be accomplished by minimizing the windows on the east and west sides of the structure and by increasing window cover on the south side. A true passive solar designed building will also make use of a thermal storage mass (thick dark walls that can absorb heat during the day and release it at night) and shading by trees to decrease heat in the summer.

A building that is oriented toward the sun with more glazing on the south side (up to 10 percent of floor area) is considered *solar tempered*. The single family-homes modeled in the CVRP project more accurately fit within this category.

4.5.2 Energy Efficiency Performance

The results of the limited analysis conducted under the CVRP on passive solar building orientation did lead the researchers to conclude that building orientation alone, without the aid of additional passive solar building design features, will produce improvements in energy efficiency and cost savings, although modest. Specifically, reductions in natural gas and electric consumption range between 2% and 3%.

4.5.3 Planning Consideration

Researchers found that east-west building orientation, where the greatest length of the structure is facing south, results in energy usage savings of about 2.8% annually for electricity and 2.2% annually for natural gas. These are modest savings, but result merely from changing the direction of the building without any additional design or mechanical features. The researchers produced this finding by modeling the energy consumption of the single-family detached home prototype #1 at thirty-degree incremental changes in building orientation. Although it is true that the east-west building orientation - 90 and 270 degrees, resulted in the best energy savings, the percent difference was not substantial from the worst performing orientation. In

[13] The same CDD and HDD assumptions are made for Site-X as were made earlier for Site-A

the case of electricity, the percent difference in energy use was 2.8% with a cost savings of just 4.1% annually. For natural gas, the difference was 2.2% in consumption and 1.8% in cost savings annually. However, similar buildings featuring solar photovoltaic panels, an east-west orientation, and other passive solar design features for heating and cooling would result in significantly higher energy savings. For this reason, planners particularly interested in increasing the energy efficiency of residential development sites should consider examining the benefits of their use.

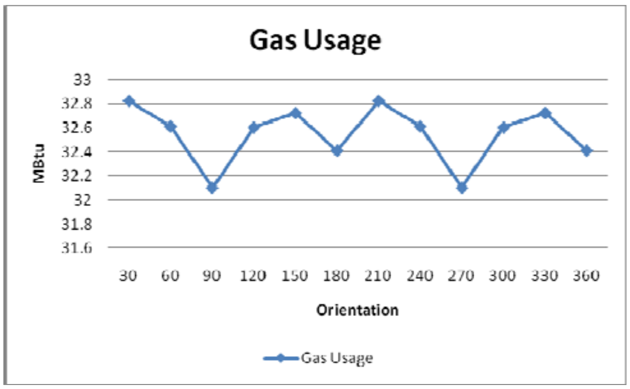

Figure 24. Site-B: Gas Usage for Prototype-1 Plotted Against Orientation

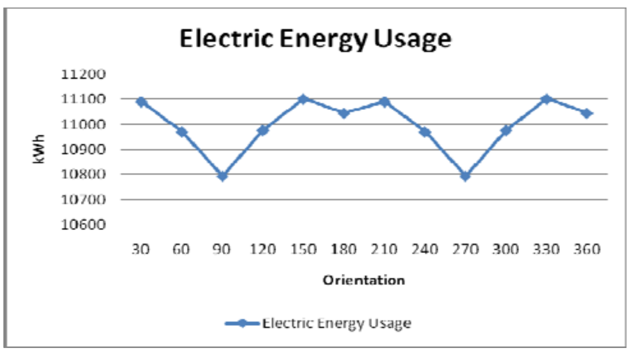

Figure 25. Site-B: Electricity Usage for Prototype-1 Plotted Against Orientation

The incremental cost of optimizing building orientation can vary dramatically from no additional costs to rotate buildings or an entire site plan, to high costs associated with changes in topography, streets and infrastructure. Given that these costs are by definition, site-specific, an estimate is not provided in this guide.

Readers are encouraged to investigate the forthcoming National Renewable Energy Laboratory's exhaustive research report on the subject of optimal solar building and subdivision orientation and planning, to be published by the California Energy Commission during calendar year - 2009.

Chapter 5.
Related Resources

Publications, Papers & Presentations

Although energy-efficient community development is only now emerging as a new field of inquiry among California state research and regulatory organizations, a number of related reference publications, papers, presentations and websites are now available that contain valuable resources on the subject. A select number of these are presented below.

Advanced Building and District Energy Technologies

Building Load Profiles and Optimal CHP Systems. 2002. Czachorski, M., W. Ryan, J. Kelly, presented at ASHRAE Summer Meeting, Honolulu, Hawaii.

Commercial Buildings Energy Consumption Survey. 1999. Energy Information

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U.S. Department of Energy

Community - District Energy Systems: Preliminary Planning & Design Standards. 2007. Newman, D., National Energy Center for Sustainable Communities and the International District Energy Association. Available at: http://www.necsc.us/docs/CommunityDistrictEnergy_Systems.pdf

Comparing Economics of Various Methods of Improving Energy Efficiency of Commercial Buildings. Czachorski, M., T. Kingston, J. Wurm. Presented at CLIMA 2007 Congress, June 10-14 2007, Helsinki, Finland.

Economics of CHP Systems. Czachorski, M., Presented at 4th Conference of International Building Performance Simulation Association - Czech Republic, IBPSA-CZ, Praha, Czech Republic November 7, 2006.

Economics of Commercial Building Cogeneration and Desiccant Technology Combinations. Czachorski, M., J. Wurm. Presented at 14th International Conference VYKUROVANIE Tatranske Matliare, Czech Republic, March 6 - 10, 2006

Economics of Installing Desiccant Dehumidifier in Commercial Buildings Application of Cooling Heating and Power Generation Systems. 2005. Czachorski, M. Presented at ASHRAE Summer Meeting, Denver, Colorado. 2005.

Evaluation of Commercial Markets for Building Cooling Heating and Power Applications in the U.S. Czachorski M., E. Ryan, J. Wurm. Paper presented at Konference Simulace Budov a Techniky Prostredí; II. Národní Konference IBPSA-CZ ; Prague, Czech Republic. 2002.

Evaluating Active Desiccant Systems for Ventilating Commercial Buildings. 2000. L. Harriman, M. Witte, M. Czachorski, D. Kosar, Published in ASHRAE Journal.

Improving the Economy of Ventilation in Commercial Buildings. 2004. Czachorski, M., J. Wurm. VVI Magazine, No. 3, Vol. 13, Published (in Czech) by the Society for Environmental Technology, Novotného Lávka 5, 11668 Prague 1, Czech Republic.

Large District Energy Systems. Contained in Sustainable Urbanism: Urban Design With Nature. Page 199. 2008. Newman, D., R. Thornton, J. Kelly - authors. D Farr – editor. John Wiley & Sons, Inc. Available at: http://www.wiley.com/WileyCDA/WileyTitle/productCd-0471475815.html

Simulation and Evaluation of Markets for Building Cooling Heating and Power Applications in the U.S. Czachorski M., J. Wurm. Paper presented at Eight International IBPSA Conference – Building Simulation 2003 for Better Design; Eindhoven, Netherlands.

Community Planning, Design and Development Policies

A Renewable Energy Community: Key Elements. 2008. N. Carlisle, J. Elling, and T. Penney, National Renewable Energy Laboratory. A reinvented community to meet untapped customer needs for shelter and transportation with minimal environmental impacts, stable energy costs, and a sense of belonging. Available at: http://www.nrel.gov/applying_technologies/pdfs/42774.pdf

Assessment of Local Models and Tools for Analyzing Smart-Growth Strategies. 2007. Loudon, William et al. Prepared for the

State of California Business, Transportation and Housing Agency, and the California Department of Transportation by DKS Associates and the University of California, Irvine

Blueprint for Urban Sustainability: Integrating Sustainable Energy Practices into Metropolitan Planning. Containing the winning entries from the U.S. Competition on Metropolitan Energy Design. 2003. Gas Technology Institute. Available at: http://www.necsc.us/docs/Blueprint_Urban_Sustainability.pdf

Characterizing the Fabric of the Urban Environment: A Case Study of Greater Houston, Texas. 2003. Rose, L.S., H. Akbari, and H. Taha. Lawrence Berkeley National Laboratory Report LBNL-51448

Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project. 1994. McPherson, Gregory, David Nowak and Rowan Rowntree. eds. Gen. Tech. Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

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Directory of Eco-villages in Europe (Book Review—Reviews the book `Directory of Eco-villages in Europe). 1999, Christensen K: Utopian Studies; Vol. 10 Issue 1, p160, 6p.

Energizing Sustainable Cities: The Power of Planning and Design. 2004. Newman, D. 2004. National Energy Center for Sustainable Communities. A 17-minute DVD, narrated by Bill Kurtis, introduces a vision for sustainable urban energy design as well as a plan and tools for how to get there. Available at: www.necsc.us/store.php

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Figures for Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks. 2005. US Environmental Protection Agency. Ann Arbor, MI

Green Building Incentives That Work: A Look at How Local Governments are Incentivizing Green Development. 2007. Yudelson and Associates, the National Association of Industrial and Office Properties. Available at: www.naiop.org/foundation/greenincentives.pdf

Heat Island Reduction Initiative Cool Pavement Report. 2005. US Environmental Protection Agency. Available at: www.epa.gov/heatisld/resources/pdf/CoolPavementReport_Former%20Guide_complete.pd

LEED for Neighborhood Development Rating System – Pilot Version. 2007. U.S. Green Building Council. U.S. Green Building Council.

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2030 Regional Growth Forecast Update. 2008. SANDAG. www.sandag.org/uploads/publicationid/publicationid_1390_8531.pdf

Federal and California State Policies

Energy Independence and Security Act of 2007. U.S. Congress. 2007. Public Law 110–140. Dec. 19, 2007. frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_public_laws&docid=f:publ140.110.pdf

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California Public Utilities Commission. 2008. *California Long Term Energy Efficiency Strategic Plan.* CPUC.

California Senate. 2008. Senate Bill 375 – Steinberg. info.sen.ca.gov/pub/07-08/bill/sen/sb_0351-0400/sb_375_bill_20080902_enrolled.pdf

Helpful Organizations & Sites

- American Council for an Energy-Efficient Economy
  www.aceee.org
- American Planning Association
  www.planning.org
- California Center for Sustainable Energy
  www.sdreo.org
- California Environmental Protection Agency – Air Resources Board
  www.arb.ca.gov/homepage.htm
- California Integrated Waste Management Board Green Building Program

www.ciwmb.ca.gov/GreenBuilding/

- City of Berkeley, Energy and Sustainable Development www.ci.berkeley.ca.us/SubUnitHome.aspx?id=15404

- City of Chula Vista – Sustainability Center http://www.chulavistaca.gov/City_Services/Development_Services/Planning_Building/SustainabilityCenter/default.asp

- City of Oakland Environmental Services Division Green Building Resource Center www.oaklandpw.com/page273.aspx

- City of San Jose, Mayor Reed's Green Vision for San Jose www.sanjoseca.gov/mayor/goals/environment/GreenVision/GreenVision.asp

- City of San Francisco Green Building Program www.sfenvironment.org/our_programs/topics.html?ssi=8&ti=19

- City of Santa Monica, Residential Green Building Program http://greenbuildings.santa-monica.org/mainpages/whatsnew.htm

- City of Santa Monica Sustainable City Plan www01.smgov.net/epd/scp/

- Congress for New Urbanism www.cnu.org

- County of Marin, Countywide Plan www.co.marin.ca.us/depts/CD/main/comdev/ADVANCE/cwp/index.cfm

- Danish Board of District Heating (DBDH) www.dbdh.dk/index.html

- Euroheat and Power Association (Euroheat) www.euroheat.org

- Global Energy Network for Sustainable Communities www.globalenergynetwork.org

- International District Energy Association (IDEA) - www.districtenergy.org

- Japan Heat Services Utility Association (JHSUA) www.jdhc.or.jp/en

- Korea District Heating Corporation (KDHC) www.kdhc.co.kr/eng

- National Energy Center for Sustainable Communities www.necsc.us

- Renewable Energy and Energy Efficiency Partnership www.reeep.org

- Santa Barbara County, Innovating Building Review Committee www.sbcountyplanning.org/projects/ibrp/index.cfm

- Smart Communities Network – National Center for Appropriate Technologies www.smartcommunities.ncat.org

- Smart Code Central www.smartcodecentral.org

- Urban Land Institute
  www.uli.org

- U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy
  www.eere.energy.gov

- U.S. Department of Housing and Urban Development – Energy Efficient Mortgage Program
  www.hud.gov/offices/hsg/sfh/eem/energy-r.cfm

- U.S. Green Building Council – LEED-ND
  www.usgbc.org/DisplayPage.aspx?CMSPageID=148

- U.S. Environmental Protection Agency – Smart Growth Website
  www.epa.gov/smartgrowth

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Glossary

Acronym	Definition
3-D	**Three dimensional visual representation of a design**
BAU	**Business-As-Usual, or a conventional approach to development**
BEA	**Building Energy Analyzer – proprietary tool of the Gas Technology Institute**
Btu	**British Thermal Unit**
BPB	**Builder’s Proposed Baseline**
CBIA	**California Building Industry Association**
CCHP	**Combined Cooling Heat and Power technology**
CEC	**California Energy Commission**
CPUC	**California Public Utility Commission**
CARB	**California Air Resources Board**
CO_2	**Carbon Dioxide**
CSI	**California Solar Initiative**
CVRP	**Chula Vista Research Project**
DG	**Distributed Generation technologies**
DR	**Demand Response**
EE	**Energy Efficiency**
EE-PB	**Energy-Efficiency and Photovoltaic technology option**
EE-DG	**Energy-Efficiency and Distributed Generation technology option**
ET&CD	**Energy Technology and Community Design options**
ETS	**Energy Transfer Stations**
GHG	**Greenhouse Gas emissions**
GTI	**Gas Technology Institute**
HVAC	**Heating, Ventilation and Air Conditioning equipment**
IC	**Internal Combustion Engine**
kWh	**Kilowatt hours**
LEED	**Leadership in Energy and Environmental Design**
MIST	**Mitigation Impact Screening Tool**
NOx	**Nitrogen Oxides**
PAC	**Project Advisory Committee**
RE	**Renewable Energy**
ROI	**Return-On-Investment**

TTP	**Transit Priority Projects**
SANDAG	**San Diego Association of Governments**
SBIC	**Sustainable Building Industry Council**
SDG&E	**San Diego Gas and Electric**
SDSU	**San Diego State University**
SOx	**Sulfur Oxide**
SPA	**Specific Planning Area Plan**
SPV	**Solar Photovoltaic**
STH	**Solar Thermal**
T-24	**California's Title-24 building energy efficiency standard, 2005**
TBD	**To-Be-Determined**
TDV	**Time Dependent Valuation**
TDVI	**Time Dependent Valuation Inclusive**
TES	**Thermal Energy Storage**
UCC-1	**Uniform Commercial Code**
UFORE	**Urban Forest Effects model**
UHI	**Urban Heat Island effect**
USDOE	**US Department of Energy**
USEPA	**US Environmental Protection Agency**
USDA	**US Department of Agriculture**
VMT	**Vehicle Miles Traveled**
ZNE	**Zero Net Energy**

Appendices

A. Site-A: Technical Modeling Assumptions and Results

B. Site-B: Technical Modeling Assumptions Manual and Results

C. Curve numbers for land use and soil types

D. Coefficients by Rainfall Type

E. Soil Types

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[i] Curve numbers for land use and soil types is contained in Appendix-R

[ii] See table of coefficients by rainfall type in Appendix-S

[iii] Used to determine the curve numbers associated with each land cover type. These values are contained in Appendix-T.

[iv] Used to determine coefficient values for the TR-55 calculations. Appendix-S contains the table of Rain Types and associated coefficient values.

[v] Multiplier derived from Hoffman, Alan R. 2004. *The Connection: Water and Energy Security.*

[vi] From air quality data associated with San Diego and packaged with CITYgreen

GTI PROJECT NUMBER: 20144/20543

Energy efficient Community Development in California: Chula Vista Research Project

APPENDIX B

Creating Energy-Efficient Communities in California: A Reference Guide to Barriers, Solutions and Resources




Prepared by the National Energy Center
for Sustainable Communities



Sponsored by the City of Chula Vista, California
And San Diego Gas and Electric

Table of Contents

Introduction

A Climate for Change

After decades of debate, a consensus now exists among the majority of scientific organizations and most national governments that global warming is occurring and that human consumption of energy resources is to blame.

Moving beyond the debate and into action, the State of California has enacted the most comprehensive set of state policies— and soon regulations—to curb energy-related greenhouse gas emissions. The *California Energy Action Plan*, the *Integrated Energy Policy Report of 2007*, the *Global Warming Solutions Act of 2006* (AB 32), *Executive Order S-3-05* and *California's Strategic Plan for Energy Efficiency* all contain goals and strategies to reduce emissions from the key industrial and transportation sectors and from individual buildings. However, if the ambitious goals contained in these documents are to be realized, State, regional, and local governments agencies must partner with utilities and the private development industry to optimize energy-efficiency at the community scale.

This document introduces these prospective partners to the existing economic, informational and procedural barriers that currently prevent the adoption of energy-efficient community development projects in California, and to some of the solutions to resolve them. The document also provides valuable resources they can use to formulate their own initiatives to contribute to the statewide challenge of reducing energy-related global greenhouse gas emissions.

The Opportunity & Challenge

It's anticipated that in the next 20 to 25 years more than half of all structures in the U.S. will be designed, constructed and remodeled. The number is staggering—equal to 213 billion square feet of built space. More than half of this work will be in new homes yet to be planned, designed and constructed.

This growth presents an unprecedented opportunity to design and build homes and offices, public facilities and whole communities to a new level of energy and resource efficiency. It's an opportunity to engage in sustainability on a broader scale than ever before and engage consumers in this goal.

The challenge is that while the design of energy-efficient and environmentally responsible "green buildings" is now well understood, and increasingly pursued by the development/building industry, there's been little engineering or social science research conducted on how to design and profitably build "green communities". This challenge is increased by the current economic decline in the real estate market, the absence of available industry incentives and the presence of significant municipal policy and procedural barriers.

What's needed is a clearer understanding of the barriers that prevent this form of development, and of the measures that State and local government personnel, utility planners and developers/builders can use to overcome them. Measures that over time, will transform California's real estate marketplace into one in which energy-efficient communities are as commonplace as green buildings are becoming today.

Recent Research on Barriers & Solutions

From 2007-2008, the U.S. Department of Energy and the California Energy Commission funded a research initiative to determine which energy technologies and strategies could be combined with advanced community design features to increase the energy efficiency and air quality of California's communities.

The initiative, known as the Chula Vista Research Project (CVRP), modeled the use of a number of building energy technologies and community design features on two large-scale development sites on the eastern side of Chula Vista, California. One site was planned as a predominantly commercial mixed-use development on 206 acres of land. The other was planned as a predominantly residential mixed-use development on 418 acres of land.
The technologies were bundled into three development options and modeled for 20 distinct building types planned for the two sites. The included:

- The EE option: advanced, highly efficient building envelope features, appliances and space conditioning equipment
- The EE-PV option: the EE option with the addition of solar photovoltaic panels
- The EE-DG option: the EE option with the addition of distributed generation technologies

Five alternative community design features were also modeled for each site and included:

- Moderate-density, mixed-use, smart-growth development
- Storm water runoff mitigation measures
- Carbon storage and sequestration measures
- Urban heat island mitigation measures
- Passive solar building orientation

Along with the engineering modeling, the researchers conducted a series of workshops, surveys and interviews to examine the market, policy and procedural barriers and investment risks preventing adoption of EECD in California and to generate potential solutions that would resolve them. Participants in the examination included developers, builders, investors, municipal development officials, utility planners, real estate market experts and members of both environmental and community advocacy organizations.

This document presents the key market and policy analysis findings of the CVRP initiative. A companion document, entitled: *A Building and Site Design Reference Guide for Energy-Efficient Community Development in California* presents the findings of the engineering and planning analysis conducted under the initiative.

The CVRP modeling findings indicated that use of these advanced building energy technologies and community design features in a large-scale development project can reduce *aggregate* electric energy consumption (kWh) by approximately 43 percent; peak demand (kW) by 45 percent; and CO_2 emissions by 35 percent, compared to a project designed for minimum compliance with California's Title-24, 2005 energy efficiency standard.

Despite these considerable benefits, the researchers found that the building industry as a whole won't integrate EECD features into large-scale projects until there is a fundamental market transformation that allows them to do so profitably.

In reaching this conclusion, the researchers adopted the California Public Utilities Commission's definition of market transformation. Specifically:

Long-lasting sustainable changes in the structure or functioning of a market achieved by reducing barriers to the adoption of energy efficiency measures to the point where further publicly-funded intervention is no longer appropriate in that specific market.

The CVRP analyses suggest that two fundamental changes are necessary in the structure of the market. These are that:

- The value of energy-efficient building technologies and community design features is recognized by all entities in the real estate development transaction chain (lenders, investors, developers, builders, design professionals, appraisers and brokers); and that
- This recognition results in market transactions that enable developers to capture capital investments in energy-efficient design features through real estate sale prices that are acceptable to consumers.

The results further suggest that there are seven economic, information, policy and procedural barriers that must be addressed in order for these changes to occur. These include the:

1. Split Incentive Dilemma: a misalignment between investment costs and benefits
2. Lack of consumer willingness to pay for the value of energy efficient features
3. Investment risks that inhibit capital market entities from financing EECD projects
4. Lack of financial incentives for developers and builders
5. Lack of municipal investments in enabling green infrastructure
6. Lack of knowledge among municipal officials inhibiting approval of EECD projects
7. Lack of uniform municipal policies, procedures and incentives for EECD projects

The researchers further concluded that State and local government- and utility-funded intervention will be necessary to address these barriers and to produce these changes over the near- to mid-term (5-10 years). This intervention should include at least the following seven components:

- **Research to further estimate the economic and environmental costs and benefits of alternative energy technologies and community design features in large-scale development projects**

  This research should advance our understanding of the dynamics of community-scale energy consumption and improve the tools and methodologies for assessing the efficacy of different technology and design options.

  Additionally, this research should include performance verification to quantify actual energy-efficiency and emission reduction gains of these options in built projects that later can be communicated to the development/building industry through case studies

- **A set of California-specific site development standards for energy-efficiency and carbon emissions reduction**

  These should be performance-based standards to allow developers and builders flexibility in achieving compliance and they should be based on verified performance of the alternative technologies and design options

- **A uniform set of direct and indirect economic and procedural incentives for developers and builders**

  Incentives that recognize and reward, on a graduated scale, performance above minimum compliance. These should include as many of the incentives described in this document as possible, and information about these incentives should be centralized in one database accessible to all practitioners

- **Uniform product labeling**

  Labeling of all residential, commercial, industrial and institutional structures and whole planned community development sites that communicate the energy, water and resource efficiency of each to consumers, at the point-of-sale

- **An education effort mounted to inform the lending, investment, and real estate appraisal and brokerage industries about the value of energy- and resource-efficient structures and community development projects**

  This should be conducted along with a companion initiative to revise real estate appraisal practices and to generate new financial instruments and mortgage products that reflect that value

- **Further development of real-time resource monitoring technologies**

  Technologies that inform consumers about their real-time use of electricity, natural gas and water

- **A workforce training initiative for municipal authorities**

  Training on the use of tools and methods to evaluate energy-efficient development projects and an awareness-building initiative to communicate the value of these projects/properties to the consumer

Essentially, the CVRP researchers found that it would take a combination of market push and market pull mechanisms to transform the market to the point where energy-efficient community development in California could be sustained without public and utility intervention. Because these barriers and proposed solutions are so critical to reaching this goal, they'll be addressed more fully in the rest of this document, along with practical resources for those who want more insight on this form of development.

> The complete set of findings and the detailed modeling assumptions and results for both sites are contained in the document entitled *Energy-Efficient Community Development in California: The Chula Vista Research Project*. The document is available from the California Energy Commission.

Economic Barriers & Solutions

The Split Incentive Dilemma

When we talk about investing in energy-efficient building and community design features, we have to recognize that those making the investments don't often benefit from them financially. This is commonly referred to as the *Split Incentive Dilemma* and is a familiar challenge in commercial and residential leasing markets. Building owners have little economic incentive to invest in energy-efficient features that produce benefits or savings for tenants, who, in turn, are unwilling to pay a premium to receive them. And, tenants have little incentive to improve a leased spaced unless they plan to occupy the space long enough to see a return on investment through energy savings. After all, doing so would only benefit the building owner or the next tenants.

The Split Incentive Dilemma is no less prevalent among large-scale community developers. Most developers are reluctant to invest in energy-efficient building features when the benefits of those features are realized by the eventual homeowner over a long period of time, well beyond the point-of-sale and the opportunity for developers to recapture their investment in these features. And, to complicate matters, given the current real estate market, developers see little demand for these features right now and believe they'd be forced to eliminate profitable upgrades customers are willing to pay for, like granite countertops in kitchens, to accommodate new costly energy-efficiency features.

Potential Solutions

To resolve this barrier the California real estate market must be transformed into one in which:

- *True Cost* pricing of real estate products (homes, commercial structures and planned communities) reflects the externalities associated with their direct and embedded energy consumption
- Real estate appraisers, brokers and buyers are aware of and are willing to pay for the *Total Value* of energy-efficient and environmentally compatible real estate commodities
- Developers/builders integrate energy-efficient and renewable technologies into their projects and are recognized and monetarily rewarded for the energy and emissions savings that they produce
- Residential, commercial, institutional and municipal consumers are aware of and responsible for the energy and water consumption and air emissions associated with their structures and communities

True costs pricing will require additional engineering and economic research to determine the direct and embedded energy consumption and emissions impacts of alternative building and site design features and their costs and benefits relative to the use of conventional features. In addition to material and installation costs associated with these features, there must be a thorough analysis of any additional planning, design and entitlement processing costs required to accommodate those features.

The best way to engage consumers in energy-efficient and environmentally compatible homes and communities—and encourage them to pay for them— is by providing relevant information that can be help them comparison shop. Currently consumers receive little information about the energy efficiency and emissions impacts of a home or its components. They can't judge the overall efficiencies of a new home or commercial structure or what total value means in relation to their buying/leasing decisions, and they certainly can't take that information to make comparisons with other homes, structures and communities.

Uniform adoption of energy-efficiency and emissions performance ratings and labeling for all structures and communities—whether through a voluntary industry initiative or State and/or local government regulations—must be in place to give consumers the tools they need to understand the true value of energy-efficient homes and communities if they are to be expected to choose it and pay for it.

In order for developers/builders to embrace energy-efficient development projects and to be financially rewarded for doing so, there must be a new model or paradigm for project accounting and financial mechanisms put in place that enable them to achieve a return on their capital investments in energy-efficient features at the point-of-sale.

The new paradigm must be one in which a return on investment equals both an internal and an external rate of return, taking into account all related externalities. The financial mechanisms should include incentives, rebates, tax credits or mortgage arrangements that result in the consumers' willingness to pay a premium for energy-efficient features when they buy a home. They should also include third-party economic incentives for developers that offset the incremental first cost of including these features in their products. These incentives are discussed at some length later in this document.

In addition to new accounting and financing mechanisms, there must be new information resources for the development industry that outline best practices and provide guidance on the assessment and use of advanced energy technologies and community design features in a large-scale development projects. Finally, municipal officials will have to address outdated and conflicting development and building ordinances as well as train personnel to assess energy-efficient proposals submitted by developers.

If consumers are to become aware of and responsible for their energy consumption, advances in research, development and structural monitoring demonstrations must be made to enable consumers to see first hand and in real-time the impacts of their resource consumption. So, there must be advances in building systems metering devices, whole-house/building electrical and water monitoring systems and display technologies that convert resource use into information that consumers can use to change behaviors.

The solutions suggested here will require State leadership, and potentially a California Executive Order, along with a portion of public goods funds to be used to plan and execute these initiatives. Toward this end, the investor-owned utilities (IOUs) may want to consider approaching the California Public Utilities Commission (CPUC), the Energy Commission, the Department of Finance and the Treasurers office to incorporate these solutions in a comprehensive strategy to address this critical barrier in the future.

Consumers' Willingness to Pay

With uninformed consumers, state and local policymakers can hardly expect them to appreciate the value of energy-efficient features in their homes, businesses and communities, let alone pay a premium for them. This is not a cause for discouragement, however, given how young this movement is in its evolution. But action must be taken quickly to turn this situation around since it truly is the underpinning of all of the other barriers discussed here.

Potential Solutions

Given the central nature of this barrier, we reference many of the same solutions outlined for several of the other barriers described in this guide. An engaged consumer demanding and willing to pay for more efficient building and community design will be the first clear signal that the needed market transformation is on its way—even though it still may be awhile before the need for government and utility intervention is no longer necessary.

What will a transformed market look like? A market in which energy-efficiency and responsible resources management is truly the norm for consumers, not the exception. It will be a market in which enabling technologies are seamlessly incorporated into the construction of all new structures. And, it will be a market in which the increased sales volume for energy-efficient features results in only a negligible incremental cost to the developer and builder.

Achieving this transformed market will entail a combination of the *market-push* and *market-pull* components listed here and again discussed at greater length under the other six barriers described in this document.

- **Additional Research** on the energy-efficiency and carbon emission reduction potential of alternative building materials, equipment and energy-smart site design features
- **Rating and Labeling** that informs consumers about the energy efficiency and emissions reduction performance of both buildings and entire development sites
- **Performance Monitoring Technologies** that enable residential and commercial property owners to assess and modify their energy and resource consumption practices[1]
- **A New Model of Business Accounting** for the development industry that addresses all environmental components of site, building and infrastructure development

[1] On July 8, 2008, the Centex Corporation announced its *Centex Energy Advantage*, a collection of energy-efficient features that will be standard in all of the company's new homes in 2009. A key feature is an in-home energy monitor that provides homeowners real-time information about electricity usage and expenses and enables them to reduce their electricity consumption by as much as 15%.
For more information visit:
http://www.prnewswire.com/mnr/centex/33930/

- **Consumer Financing Mechanisms and Developer Incentives** such as energy- and location-efficient mortgages that enable both consumers to afford energy-efficient properties and developers to build them profitably
- **Accessible Information Resources** that result in the sharing of best practices among development practitioners in both the public and private sectors
- **Revised Municipal Development Ordinances** that reflect the value of energy-efficient development alternatives and facilitates their use in large-scale development projects
- **Municipal and Utility Incentives/Disincentives** that promote building industry pursuit of this form of development and that discourage inefficient consumer practices.

While all of these solutions are essential, there will also be the need for a broad consumer awareness campaign and a targeted information initiative directed at capital lenders to both inform consumer choice and to encourage lenders to finance those choices.

FHA's Energy Efficient Mortgage program (EEM) helps homebuyers or homeowners save money on utility bills by enabling them to finance the cost of adding energy efficiency features to new or existing housing as part of their FHA-insured home purchase or refinancing mortgage.
To learn more visit:
www.hud.gov/offices/hsg/sfh/eem/energy-r.cfm.

Location-Efficient Mortgages (LEM) enable residents to buy homes more easily in location-efficient communities - those that enable walking and have accessible public transit, which reduces household transportation costs.
To learn more visit:
www.locationefficiency.com/

Who should take the lead in this effort? The consensus among both public and private development professionals in California is that State and local government agencies are best suited to lead. However, these solutions also require the participation of the investor- and municipally-owned utilities, consumer advocacy organizations, the development and capital investment industries and the California universities.

Investment Industry Risks

Attracting investors in early-stage financing is always challenging and it's no different for EECD projects. A vast majority of lenders, investors and developers clearly believe that energy-efficient building projects are more expensive to build—depending on the features, perhaps 5 to 10 percent or more. But they're also convinced that they're more valuable to own than comparable conventional buildings due to the assumption that there are lower owner operating costs. The estimated additional cost of a large-scale energy-efficient development project can be as much as 35 percent more, depending on the advanced site development features.
Another significant barrier to investment is the concern equity investors have that consumers are just not aware of the benefits of energy-efficient buildings and planned communities. They're also concerned about the lack of private incentives. Lenders and developers, on the other hand, are put off by the lack of public financial incentives but also by the lack of consumer awareness.

But the true bottom line is that investors, lenders and developers don't believe tenants would be willing to pay higher rents for energy-efficient space and that the new value of this space may not be recognized by lenders and appraisers.

Potential Solutions

How do you make a new market irresistible to investors? In this case, target additional economic incentives to developers and consumers to address the added costs of producing and acquiring energy-efficient projects and properties and to reduce the impact of the split incentive dilemma. Implicit in this strategy is a connection between the State's carbon reduction goals with the federal government's promotion of consumer energy efficiency and the objective of writing down the costs of energy-efficient development projects. Specific components of such a strategy might include:

- State and local carbon credits for EECD development projects
- Low-interest financing for EECD/or sustainable construction projects
- Tax credits for homeowners in energy-efficient developments
- Federal and state income tax reductions for developers and builders of EECD projects
- Energy-efficient mortgage instruments
- Cash rebates for consumers buying properties in energy-efficient developments
- Discounted insurance rates for energy-efficient construction
- Utility and/or municipal subsidies to developers for EECD design consultant costs
- Deferral of increased property tax until close of escrow
- Deferral of special assessments until close of escrow
- Research to generate means of aligning EECD investments costs with long-term benefits

The strategy should also include the deployment of informational resources necessary to build and promote a defensible *business case* for energy-efficient community development and associated training and municipal procedures. Specific components might include:

- Demonstration projects to document the value of EECD for the development industry
- Development industry case studies and examples of successful EECD projects
- Consumer, lender and appraisal industry education and training initiatives
- *Best Practices* information for public, private and utility planning practitioners
- A centralized source of information on EECD (an information and incentives clearinghouse)
- Professional training resources for public, private and utility development practitioners
- Model design and development guidelines and standards for EECD.

To be successful, federal, State and local government agencies must take the lead on the majority of these solutions to encourage industry investment in the solutions they are best suited to lead (i.e., low-interest loans, mortgage instruments, and industry education and training initiatives).

Development Industry Concerns

Unquestionably, the single greatest barrier to the California building industry's adoption of energy-efficient community building is a lack of financial incentives. It's become especially problematic with the current financial crisis spawned by the sub-prime mortgage debacle. Where once developers and builders were most concerned about expedited entitlement processes, they're now focused on moving existing inventory. So, if developers and builders are to get on board with EECD, they need substantial financial support.

> *"For the foreseeable future, our emphasis is on least cost construction. We have had the worst numbers since records have been kept. If we invest in clean technologies on a community-scale, we will need offsets and incentives to help us make those investments."*

It's not a question of a lack of desire to create more energy-efficient communities, but homebuilders right now are in dire straights and can see no way to embrace EECD without help. In concrete terms, what does this mean? Developers and builders are concerned about the rising cost of development impact fees, which average close to $100,000 per home now. Just 10 years ago that number was closer to $25,000.

High local government fees for multifamily homes are also now keeping potential builders out of the apartment building business.

As if the high fees weren't disincentive enough, industry leaders also don't see consistency among new State and local government and utility financial incentives for energy-efficient building and development. Developers are trying to bridge the gap between higher construction costs for greener construction and what it costs to simply meet code. Incentives, they say, are needed to bridge this gap.

Finally, there is no truly centralized information point for available financial incentives and technical assistance for the development industry, nor is there a uniform set of rules governing how they are to be sought and administered.

One California homebuilder in pursuit of designing a large-scale energy-efficient community development project worked for more than a month with an energy consultant to compile a list and contact representatives of funding sources to determine what incentives were available for various aspects of his project. In the end he determined that there were funds available but that they were extremely difficult to find and scattered across multiple federal, state, regional and municipal government agencies and the electricity, gas and water utilities.

The process ended in exasperation on the part of the homebuilder who also lost valuable time in the development planning process.

> *"There has to be a better, more cost-effective way to investigate incentives and assistance for these large-scale projects" he said. "This is tremendously time-consuming and expensive process"*

Potential Solutions

What's needed, say developers and builders, is an economic stimulus strategy consisting of State and local government and utility incentives that reduce developer/builder costs and increase the prospects for increased profits for those who design and build energy-efficient development projects. The components of this strategy would include:

- **Potential Support from California's *Green Wave* Environmental Investment Initiative**

  Under this initiative, the state's two public pension funds invest in the stocks of emerging clean energy and environmental technology companies and place funds in venture capital firms that invest in them with the objective of building the state's clean tech economy.

  The pensions have also invested in significant energy conservation programs for their considerable real estate holdings in the state and could potentially invest in large-scale, energy-efficient community development projects as well. The creative leveraging of this fund should be investigated by the State Treasurers Office in tandem with the California Department of Housing and Community Development.

- **State: Sustainable Buildings Tax Credit—***The State of New Mexico enacted a Sustainable Buildings Tax Credit (SBTC) in 2007, which could be a model for California. SB 463 established both a personal and a corporate tax credit for sustainable buildings in New Mexico.*

  Here's how it works. Commercial buildings which have been registered and certified by the U.S. Green Building Council at LEED Silver or higher for new construction (NC), existing buildings (EB), core and shell (CS), or commercial interiors (CI) are eligible for a tax credit. The amount of the credit varies according to the square footage of the building and the level of certification achieved. Residential buildings certified as sustainable homes can also qualify for the tax credit.

  Eligible residential buildings include single-family homes and multi-family homes which are certified as either Build Green NM Gold, or LEED-H Silver or higher and *Energy Star*-certified manufactured homes. The amount of the credit also varies according to the square footage of the building and the level of certification achieved.

  To receive the tax credit the building owner must obtain a certificate of eligibility from the Energy, Minerals and Natural Resources Department after the building has been completed. The Department will only grant certificates in any given calendar year until the equivalent of $5,000,000 worth of certificates for commercial buildings and $5,000,000 worth of certificates for residential buildings have been awarded in that calendar year. Further, no more than $1,250,000 of the annual amount for residential buildings can be applied to manufactured housing. The taxpayer must then present their certificate of eligibility to the Taxation and Revenue Department to receive a document granting the SBTC.

If the total amount of a SBTC is less than $25,000, the entire amount of the credit can be applied to the taxpayer's income tax in that year. If the credit is more than $25,000 the credit will be applied in increments of 25 percent over the next four years. If a taxpayer's tax liability is less than the amount of credit due, the excess credit may be carried forward for up to seven years. A solar thermal system or a photovoltaic system may not be used as a component of qualification for this tax credit if a tax credit has already been claimed for it under the State's separate Solar Market Development Tax Credit.

For more information about New Mexico's Sustainable Buildings Tax Credit, contact the New Mexico Energy, Minerals and Natural Resources Department, Energy Conservation and Management Division, 1220 S. St. Francis Drive, Santa Fe, NM 87505.
Phone: (505) 476-3254

- **Municipal: Development Impact Fees Deferral Programs—***The City Council of Ontario, Calif., has pioneered a program to permit the deferral of the payment of Development Impact Fees (DIFs) from the time a building permit is issued to the final building inspection. This easy-to-implement-and-track incentive is the type of low-cost option many California communities could follow.*

While a DIF *does* negatively impact the potential earnings a community would have received during the period of deferral (up to one year), this loss of earnings does not impact General Fund revenues. That's because interest earnings on Development Impact Fees must be segregated from other City revenues and remains in the Development Impact Fee program account.

The City of Ontario requires an administrative fee of $5,500 for those that participate in the Development Impact Fee Deferral Program to help offset the City's costs for initiating and administering the fee deferral agreements.

Through this innovative, temporary fee deferral, a residential developer of multiple units may elect to defer the payment of all DIF fees (except the Inland Empire Utility Agency Sewer Capacity Fee and the City's Species, Habitat Conservation, and Open Space Mitigation fee) on a construction phase of residential units up to a maximum fee amount of $1.8 million. If a developer wishes to defer fees in excess of $1.8 million, then an irrevocable Letter of Credit or other acceptable form of security must be provided to ensure payment of the deferred fee amount. The deferred DIF amounts become due when final inspection is requested on the first completed unit of the construction phase, or after 12 months, whichever comes first.

In order to qualify for the DIF deferral program, a developer of multiple residential units must enter into an agreement with the City acknowledging that the fees are being deferred until the developer requests a final inspection of the first completed unit. The agreement will also provide standard terms to indemnify the City and other provisions that define the specific terms of the DIF deferral for the specific development entity. The resolution authorized the City Manager to execute such agreement without further action by the City Council.

The Ontario Development Impact Fee Deferral Program was designed and approved for an interim time period (initially eight months) and was slated to expire on December 31, 2008, unless extended by an action of the City Council. After the interim period ends, no more deferral agreements will be offered. Any existing deferral agreements will continue until the fees are due under the agreement. The California Building Industry Association would like to see permanent DIF deferral programs established for industry participants in energy-efficient community development projects in communities across California.

> *"It is about going where the money is...if the state doesn't have it, we need to go the local governments for help."* Local industry leader

- **Municipal: Higher Density Allowance / Relaxed Park Fee Incentive—***Another innovation currently in use in Ontario in an area designated as a green development is one in which developers are allowed higher densities through the use of the City's relaxed park fee incentive.*

  In the targeted green development, the density is approved at an overall 4.6 units per gross acre (including parks). However, the City of Ontario collects park fees for only three units per thousand population instead of the allowed five units per thousand population, which frees up additional funds for developers and allows greater net densities (since the park acreage granted by the City is not included in the units allowed per the gross acre calculation). Essentially, developers in Ontario are allowed the higher number of units (closer to a net of 6.0 units per acre according to the City of Ontario Planning Department) while paying less to the City in park-related fees.

- **Municipal: Bond Funds for Developer Loans—***Due to the state of California's current financial/budget crisis, building industry experts believe that local government bond funds would be more important to energy-efficient development projects in the near future.*

  Through this mechanism, the city or county collects the funds through a bond, and then disperses the funds to developers involved in more sustainable construction techniques and practices. Phoenix, Ariz., currently uses such a bond instrument, and offers low-interest loans to developers to assist them with community-scale, sustainability-related development.

- **Utility and State: Financial Incentives for Energy-Efficient Community Design—***This novel proposal holds that utilities should provide design assistance funding to builders through their traditional energy efficiency programs, or come up with some new programs.*

  Some California utilities are considering providing money to builders for LEED design through their energy-efficiency program offerings. This may be an effective way to spur more community-scale green construction.

> *"If the utilities were allowed to give us $5,000 or $10,000…or more…to help us design more sustainable neighborhoods, this would go a long way toward getting us the energy and environmental savings the Governor wants. It takes money to design things right."* Building industry leader

- **Utility: Financial Incentives for Green Build Program Participation**—Currently there are two primary green builder programs in California: the California Green Builder Program (CGBP) and the Build It Green (BIG) program. Builders who participate in these programs should be provided special financial incentives, especially in today's depressed housing market. The financial incentives for building to these standards should be significantly higher than the $250 to $500 per home offered by utilities for building to *EnergyStar* standards.

> *"The data shows that we spend $2,000 to $3,000 on energy efficiency upgrades for most of our homes. Utilities need to help us here."* CBIA leader

Insufficient Infrastructure Investments

Municipal investment in green infrastructure is a pre-requisite to encourage developers to design and build energy- and resource-efficient community development projects. However, development industry leaders don't see these investments being made. Given the budgetary constraints that most municipal governments operate under, these investments will require creative partnerships with the electricity, natural gas and water utilities and the transit authorities serving California communities. These partnerships will be necessary to capitalize green infrastructure projects that enable developers to take advantage of proven distributed and renewable energy technologies, alternative vehicles and transit, water reclamation systems and stormwater runoff and urban heat island reduction measures.

But industry leaders have found that regulatory and utility rules in many cases discourage municipal investment in community energy systems. Plus, there's a lack of awareness and apparent interest on the part of citizens in the subject.

Potential Solutions

One way to effect change entails collaboration between local government advocacy organizations (i.e., Local Government Commission, California League of Cities, etc.), the three major IOUs, Energy Commission, CARB and the CPUC. Among the strategies they could employ to address the barrier would be to:

- **Examine and modify the existing regulatory and utility rules that prevent municipalities and developers from taking advantage of available energy-efficient and renewable energy technologies and systems.** Chief among these are those affecting distributed generation interconnection, sub-metering, standby charges and inter-lot transfers of energy;
- **Provide local governments guidance on the formation of financial arrangements and use of mechanisms that can generate the necessary capital for these investments.** This could include formation of energy-efficient and renewable energy technology districts (e.g., Berkeley's solar district), and utility surcharges to create municipal green technology investment funds whose dividends support revolving loan programs for energy-efficient projects;
- **Develop engaging programs that inform and involve consumers in the responsible use of energy, water and**

material resources. These include public information initiatives that educate consumers about the direct and indirect environmental impacts and costs associated with individual consumption practices; clear utility price signals and in-home displays that communicate the cost of their consumption in real-time; and economic incentives and disincentives, such as a utility or local tax rebate for consumer conservation performance at the end of a calendar year or a carbon-tax/surcharge on excessive consumption.

Again, government and utility leadership on these initiatives will certainly be necessary to lead to private investment. And, other entities, such as regional transit planning organizations, infrastructure industry trade organizations and financing entities, should be included in this effort.

Information Barriers & Solutions

Insufficient Knowledge Among Municipal Officials

Given the relatively recent emergence of energy-efficient community development as a field of research, much less of application, it's not surprising that most elected and appointed municipal officials, as well as planning and building department employees are neither familiar with nor able to evaluate EECD projects.

This is aggravated by the fact that, with the exception of municipally owned utilities, energy supply, transmission and local distribution has long been the exclusive province of the investor-owned utilities. Local planning officials simply haven't had much significant experience with the details of these resources. And, since few municipalities have the funding to develop in-house expertise in the area or even contract out for consulting assistance, the lack of knowledge of energy-related building issues is compounded. Given the dramatic fall-off of funding, thanks to fewer building permits and the diminished growth of local property tax revenues, it's unlikely new funding will be forthcoming that could be used to provide training—and even if it were, that training is hard to come by as so few academic and training institutions are knowledgeable about the subject.

Potential Solutions

The most direct way to address this barrier is the development and demonstration of a model curriculum and training program on energy-efficient community development for California counties and municipalities. The program would include components that:

- Make the county and local government business case for pursuing EECD
- Provide practical case studies of successful and transferable county and municipal program elements found elsewhere in California and the nation
- Provide a standard methodology and a set of decision-support tools that county and municipal officials can use to evaluate proposed EECD projects
- Engage competent vocational and state university trainers to customize the training curriculum for delivery to public planning and building practitioners in the service areas of the three investor-owned utilities

In addition to these components would be the establishment of a Peer-to-Peer network of municipal officials to facilitate the transfer of EECD best practices and create an information clearinghouse for government professionals.

Implementing an EECD training program would require strong leadership and resources. The utilities are best suited to take the lead and to seek CPUC approval to make the related program elements eligible for funding under their innovation and energy efficiency portfolio programs. Organizations such as the Local Government Commission, the California League of Cities, the association of counties and the California State Universities would be valuable partners that could assist the utilities in the formulation and execution of an implementation plan for this strategy.

Policy/Procedural Barriers & Solutions

Insufficient Municipal Policies, Procedures & Incentives

A major impediment for developers considering EECD projects in California is the lack of uniform municipal policies, procedures and related procedural incentives. Most production developers and builders pursue projects in a variety of municipalities across the state, often simultaneously. That means that for each project, they must go through the process of determining which design features will or will not be allowed and incentivized in each jurisdiction. Add to that the task of finding available financial incentives for energy-efficient projects outside of the municipality, and you have developers and builders who want to do the right thing but are struggling with extremely frustrating and time-consuming pursuits for assistance, and of course shouldering the additional expenses associated with those pursuits.

Potential Solutions

One strategy to address this challenge would consist of the development of a voluntary, uniform, energy-efficient site development standard, along with a set of policy and procedural guidelines and State, local and utility incentives for the development/building industry.

There is a precedent for this being pilot-tested nationally and in a number of California communities: the U.S. Green Building Council's LEED standard for Neighborhood Development (LEED-ND). However, industry leaders would like to see a different standard implemented that is specific to California and aligned with the State's climate change goals and objectives. Implementing this standard would include:

- Additional research to quantify and benchmark the energy-efficiency and carbon reduction potential of alternative building, infrastructure, transportation and urban design features

- Translating the research into a set of model EECD site design standards and guidelines and a practical project evaluation tool for use by local planning officials (including EECD carbon metrics and values for alternative site design features)
- Providing a model municipal sustainable community development policy that aligns local economic, environmental and development priorities. Each of these would have specific energy efficiency and greenhouse gas emissions reduction goals.
- Providing guidance to local governments that enables them to translate the development policy into specific modifications for existing municipal codes and standards

Assuming the California-specific standards were implemented, the following key components should be included in a companion incentives program:

Flexibility in Zoning Code Requirements: This incentive, now common in many communities across the nation, allows developers and builders more zoning flexibility in return for their commitment to pursue greener, energy-efficient construction. Allowing decreased setbacks and bonuses, and relaxed parking requirements and street standards in return for greener construction should be the rule, rather than the exception, and will only become more important in community-scale projects into the future.

Cross-Departmental Expedited Plan Review with an Assigned Senior City Coordinator: Expedited plan review is offered by municipal planning and building departments in many California communities today. However, expedited plan review across all relevant municipal departments is still rare and a significant issue with many developers and builders. Specifically, builders have learned that unless all of the relevant municipal departments are involved in the expedited review process, plans can and will get delayed in the departments that are not participating in the process. To remedy this problem, some communities have assigned a senior City official the responsibility of coordinating all relevant departments in the process and in making sure that developer plans do, in fact, make it through cross-department review in a timely fashion.

***Gold-Star* Treatment:** Pioneered by the City of Chula Vista Building Official, this easy-to-implement benefit entails both ensuring that a green builder's plans are affixed with a "Gold Star" when they are received at the City, *and* conducting weekly status reviews to guarantee that the plans are moving expeditiously through the review process. This administrative solution carries a surprising amount of weight with builders when the market is busy, although it's considered less valuable during down markets since delays are at a minimum given the lack of construction underway.

Priority Field Inspections: Like the Gold-Star treatment mentioned above this benefit is not as important during an economic downturn. However, ensuring that greener builders get inspections when they need them is usually a very easy benefit for most communities to provide. It is very low cost, and already currently provided by many jurisdictions.

Sustainability Coordinators: In some jurisdictions, an experienced building official can offer financial and recognition incentives without City manager or city council involvement. A new area for builder benefits could be city-hired *Sustainability Coordinators*, who could help spur greener, energy-efficient development in the future. Sustainability coordinators are now being hired by some cities to help coordinate all green-building functions, so this may be an important trend when it comes to arranging more benefits for green developers and builders.

Accelerated Processing of Entitlement and Permit Applications: Despite the fact that this incentive is not as important now to builders as are direct financial incentives, most still consider it an important and valuable incentive. Shaving time off of the review processes will always reduce a builder's expenses, especially after the market picks up again and city staffs once again become stretched thin. Some cities are able to reduce the entitlement turnaround process by as much as 25 to 50 percent if a builder's homes perform 50 percent above minimum energy code compliance. For an energy-efficient community-scale development project, this benefit will be critical, particularly to reverse the generally held perception that greener projects take longer to move through the entitlement process.

Residential Development Allowances in Commercial Zones: This increasingly popular policy simply entails allowing a builder to construct residential structures in a commercial area in exchange for that builder's commitment to design and build an energy-efficient community-scale project. This is an easy-to-implement incentive for most cities and counties to provide.

A Tiered Utility *EnergyStar-Plus* Incentive: It's becoming clear that the *EnergyStar* label is becoming less important to builders. Instead, utilities should consider structuring their financial incentives more toward an "*EnergyStar*-Plus" category, through which developers and builders are rewarded with more funding for building well beyond *EnergyStar* levels. This two-tiered policy is likely to become commonplace in the near future, and indeed many utilities, such as the Public Service Company of New Mexico, are already offering this two-tier incentive.

Leadership for establishing a new, consistent energy-efficient development standard and the accompanying strategic components should be provided by county and local governments through one of their advocacy organizations. Of course it will also be essential to engage the utilities and the regional planning authorities as well the universities in the needed front-end research for this strategic initiative.

Practical Resources

California is fortunate to have a wealth of resources on hand to draw on as governments and utilities begin to launch their own programs to advance energy-efficient community development within their jurisdictions and service territories.

The resources compiled here include select examples of current municipal, county and utility incentives for green development at both the building and community scale; select profiles and links for EECD projects in California; and publications, papers, presentations and links to other valuable information.

County, Municipal & Utility Incentives

Chula Vista, Calif.

The City of Chula Vista has established a Sustainability Center that provides users with information on all available green-building program guidelines, incentives and rebates as well updates on the initiatives of the City's Climate Change Working Group. The initiative includes activities designed to reduce the City's carbon footprint through:

- The strategic use of alternative fuels
- A city-wide green building ordinance
- Transit-oriented development projects
- Free business energy efficiency and solar energy assessments
- A solar energy and energy efficiency assistance program for commercial and residential property owners
- An outdoor water quality conservation program that assists property owners in replacing turf with drought-resistant plants

The city has also established policies and guidelines designed to mitigate the urban heat island effect through assistance programs for cool roofs and pavements and shade tree plantings.

For more information, visit their website at: www.chulavistaca.gov/City_Services/Development_Services/Planning_Building/SustainabilityCenter/default.asp

Marin County, Calif.

Marin County has developed a website that provides users a comprehensive overview of all current and planned sustainable development programs in the county. The site lists their goals for greening public facilities and services, and community infrastructure, buildings, housing and transportation. The site also provides a regularly updated indicator of progress against the county's planned goals for each of these areas. As an example of the type of program incentives they provide developers/builders, their Residential Green Building Program offers the following:

- Free technical assistance, design consultation, resources and information
- Fast-track building permit processing and waiver of the Title-24 energy review fee. This set of incentives is available only for projects that exceed Title-24 requirements by 20 percent OR those that install a solar electric/renewable energy system to meet 75 percent of electricity needs.

For more information, visit their website at:

http://www.co.marin.ca.us/depts/CD/main/comdev/advance/Sustainability.cfm

San Diego County, Calif.

The County of San Diego has a Green Building Incentive Program designed to promote the use of resource efficient construction materials, water conservation and energy efficiency in new and remodeled residential and commercial buildings. As part of the program, the County will waive the fee for the building permit and plan check for a photovoltaic system. In addition, for qualifying resource conservation measures, the County will reduce building permit and plan check fees by 7.5 percent and grant expedited plan checks, saving approximately seven to 10 days on the project timeline.

For more information, visit their website at:

www.sdcounty.ca.gov/dplu/greenbuildings.html

Santa Monica, Calif.

The Santa Monica Green Building Program awards grants to promote green building throughout the city. Grants for new private-sector buildings are based on the level of certification attained under the LEED standards and include the following:

LEED Certified - $20,000

LEED Silver - $25,000

LEED Gold - $30,000

LEED Platinum - $35,000

All commercial, multi-family residential, mixed-use and affordable housing new construction and renovation projects that register for LEED (LEED-NC) certification are eligible to apply.

For more information, visit their website at:

greenbuildings.santa-monica.org/

San Rafael, Calif.
The City of San Rafael offers various incentives for residential projects that achieve at least a LEED "Gold" rating and residential projects that achieve at least 100 Green Points under the Build It Green's GreenPoint Rating system. These include:

- Expedited building permit plan check (typically a two-week turnaround)
- A bronze plaque for building mounting, identifying the project as meeting the City's Emerald Green Building level
- A City Green Building logo for construction signage
- Listing of the building on the City's website
- Reimbursement for the cost of the Green Point Rater services (max. limit of $1,000)

For more information, visit their website at:

www.cityofsanrafael.org/Government/Community_Development/Planning/Green_Building.htm

Fresno, Calif.
The City of Fresno offers different incentives for certified projects in its voluntary Green Building Program. These include:

- A 25 percent fee reduction of many planning fees
- A 20 percent minor deviation from development standards, if needed (25 percent if public art is incorporated into the project)
- Expedited processing through the Green Team
- Eligibility for a Fresno Green award and use of the Fresno Green brand for the project

Developers have a choice of three different methods for becoming certified as a Fresno Green project:

1. Satisfy the requirements of one of the USGBC's LEED Programs
2. Qualify for Build-It-Green's GreenPoint rating system for residential building
3. Follow the Fresno Green checklists

For more information, visit their website at:

fresnogreen.net/pages/incentive.html

San Diego Gas & Electric – Sustainable Communities Program
The utility's Sustainable Communities program is intended to encourage sustainable development, promote green building design practices and create a variety of demonstration sites to serve as models for similar projects in their service area. The program provides incentives for qualified projects that significantly exceed the Title-24, 2005 California Energy Efficiency Standards, that obtain LEED certification or the equivalent and that evaluate on-site renewable energy systems.

For multi-family residential projects, cash incentives are paid to building owners or to builder/developers. These incentives range from $165 to $220 per dwelling unit for residential projects, with a per project maximum of $50,000. For nonresidential projects incentives range from $0.10 to $0.25 per annualized kWh saved and $0.34 to $1.00 per annualized therm saved with an additional 20 percent incentive available for projects that exceed Title-24 by 20 percent, achieve LEED rating (or its equivalent) and complete an on-site renewable energy assessment. The maximum incentive for a nonresidential project is $150,000. Additional incentives are also available for design teams on nonresidential projects.

For more information, visit their website at:

www.sdge.com/environment/sustainablecommunities/aboutSustainable.shtml

Model Community Development Projects in California

Village Homes
Davis, Calif.
Developers: Michael Corbett and Town Planners
Website: www.villagehomesdavis.org

The earliest example of an energy-efficient community development dates back to 1973 and is known as the Village Homes project in the City of Davis, Calif. A mixed-use residential and commercial development on a 68-acre site, the project consists of 220-detached, single-family homes and 20 apartments; a commercial office complex and a community center all featuring passive solar design and construction, solar hot water heaters and natural cooling systems. The site also includes narrow, tree-lined streets that reduce the urban heat island effect, natural stormwater control features, a communal garden and a plan that promotes walking and biking

The 1,000 residents of Village Homes consume 36 percent less energy for vehicular driving, 47 percent less electricity and 31 percent less natural gas than residents of a conventional housing development and they enjoy ambient air temperatures that are 10 percent cooler than surrounding neighborhoods. Village Homes continues to inspire enlightened sustainable community planning across the country.

Additional profiles for energy-efficient, sustainable community development projects around the nation and the World can be found in the Urban Land Institute's "Development Case Studies" at

Terramor Village at Ladera Ranch
Orange County, Calif.
Developer: Rancho Mission Viejo, LLC
Website: www.laderaranch.com

Located within the 4,000-acre Ladera Ranch in Orange County, Calif., Terramor Village is home to 1,258 residents who reside in single-family homes and condominiums featuring solar photovoltaics, *EnergyStar* appliances, energy-efficient indoor lighting, low-voltage outdoor lighting, drip irrigation systems, low-flow toilets, formaldehyde-free insulation and low-VOC wall and floor coverings. The site also features drought-resistant plantings and an accessible, pedestrian- and biker-friendly circulation plan that knit together its 12 neighborhoods.

Otay Ranch
Chula Vista, Calif.
Developers: Pacific Coast Communities, Oakwood Development, Rimrock Communities, The Sunrise Company, Kane Development, The Corky McMillin Companies, HomeFed/Otay Land Company, Otay Ranch Company
Website: www.otayranch.com

This 5,300-acre site is located on the eastern half of the City of Chula Vista and just west of the U.S. Olympic Team's warm-weather training facility. The Ranch is designed around most smart growth principles and features a network of pedestrian, bike and hiking trails along with a green *paseo* system that knits together its many planned communities. All of its communities also feature community clubhouses and recreational amenities.

The Ranch will be served by a light-rail transit corridor and will contain a large, transit-oriented mixed-use urban center featuring energy-efficient residential, civic and commercial retail and office buildings. A district cooling system is being considered for the urban center that will be bordered by a shared university campus. Residents will have a choice of a wide variety of energy-efficient housing options all within walking distance of elementary, middle schools and high schools.

Mountain House
Mountain House, Calif.
Developer: Trimark Communities, LLC
Website: www.mountainhouse.net

Mountain House is designed as a self-sufficient master-planned community that will house 43,500 residents upon its completion in 2025. The 4,800-acre community, located in the San Francisco Bay area, features a smart growth development plan consisting of 12 five-acre villages of single-family and multi-family structures clustered around a mixed-use commercial core. All structures feature energy-efficient appliances and envelope improvements, and all villages are linked together by walking and biking trails.

The development was designed to provide residents access to employment, education, shopping, parks and recreational amenities all within walking distance or a short drive, thereby reducing vehicle miles traveled by approximately 40 percent. The community also features a separate commercial and industrial area to provide nearby employment opportunities.

RiverPark
Oxnard, CA
RiverPark Development, LLC
Website: www.riverparklife.com

RiverPark is a 702-acre planned community development that will feature 1,800 single-family detached homes and 1,000 rental townhomes and apartments surrounding a 2.5- million square-foot commercial complex consisting of a convention center, shops, restaurants and an open farmer's market. Home builders are including a variety of energy-efficient building envelope enhancements, domestic hot water systems and advanced space conditioning and lighting controls.

Sonomoa Mountain Village
Rohnert Park, CA
Developer: Coddington Enterprises
Website: www.sonomamountainvillage.com

The 200-acre Sonoma Mountain Village is designed as a mixed-use sustainable community designed around smart growth, smart code and new urban design principles. It's targeting a platinum certification under the U.S. Green Building Council's LEED-ND pilot program. The Village consists of 1,900 homes in a variety of energy-efficient housing types, surrounding a central urban square containing a community civic center and an assortment of retail, dining and entertainment options.

The Sonoma Mountain Business Cluster will offer employment to 3,000 residents and will consist primarily of sustainable technology start-up firms and a steel-frame company operating on reused materials. The majority of the community's commercial core is now powered by a $7.5 million solar energy system that produces 1.14 megawatts of electricity for commercial tenants. The system is comprised of 5,845 photovoltaic panels all mounted on one roof.

Recreational and education amenities will include an international all-weather soccer field, a fitness center, a lifelong learning center, and access to Sonoma State University located within one mile of the community. It is designed so that all residents will be within a five-minute walk of parks and recreational amenities and within walking distance to shopping and transit corridors. Neighborhoods are linked by walking and hiking trails.

For a listing of California developers, production builders and housing developments featuring solar energy technologies visit Environment California at: www.environmentcalifornia.org/energy/million-solar-roofs/solar-home-developments

Publications, Papers & Presentations

Although energy-efficient community development is only now emerging as a new field of inquiry among California state research and regulatory organizations, a number of related reference publications, papers, presentations and websites are now available that contain valuable resources on the subject. A select number of these are presented below.

Advanced Building and District Energy Technologies

Building Load Profiles and Optimal CHP Systems. 2002. Czachorski, M., W. Ryan, J. Kelly, presented at ASHRAE Summer Meeting, Honolulu, Hawaii,

Commercial Buildings Energy Consumption Survey. 1999. Energy Information Administration. U.S. Department of Energy

Community - District Energy Systems: Preliminary Planning & Design Standards. 2007. Newman, D., National Energy Center for Sustainable Communities and the International District Energy Association. Available at: http://www.necsc.us/docs/CommunityDistrictEnergy_Systems.pdf

Comparing Economics of Various Methods of Improving Energy Efficiency of Commercial Buildings. Czachorski, M., T. Kingston, J. Wurm. Presented at CLIMA 2007 Congress, June 10-14 2007, Helsinki, Finland.

Economics of CHP Systems. Czachorski, M., Presented at 4th Conference of International Building Performance Simulation Association - Czech Republic, IBPSA-CZ, Praha, Czech Republic November 7, 2006.

Economics of Commercial Building Cogeneration and Desiccant Technology Combinations. Czachorski, M., J. Wurm. Presented at 14th International Conference VYKUROVANIE Tatranske Matliare, Czech Republic, March 6 - 10, 2006

Economics of Installing Desiccant Dehumidifier in Commercial Buildings Application of Cooling Heating and Power Generation Systems. 2005. Czachorski, M. Presented at ASHRAE Summer Meeting, Denver, Colorado. 2005.

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Evaluating Active Desiccant Systems for Ventilating Commercial Buildings. 2000. L. Harriman, M. Witte, M. Czachorski, D. Kosar, Published in ASHRAE Journal.

Improving the Economy of Ventilation in Commercial Buildings. 2004. Czachorski, M., J. Wurm. VVI Magazine, No. 3, Vol. 13, Published (in Czech) by the Society for Environmental Technology, Novotného Lávka 5, 11668 Prague 1, Czech Republic.

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http://www.wiley.com/WileyCDA/WileyTitle/productCd-0471475815.html

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Community Planning, Design and Development Policies

A Renewable Energy Community: Key Elements. 2008. N. Carlisle, J. Elling, and T. Penney, National Renewable Energy Laboratory. A reinvented community to meet untapped customer needs for shelter and transportation with minimal environmental impacts, stable energy costs, and a sense of belonging. Available at: http://www.nrel.gov/applying_technologies/pdfs/42774.pdf

Assessment of Local Models and Tools for Analyzing Smart-Growth Strategies. 2007. Loudon, William et al. Prepared for the State of California Business, Transportation and Housing Agency, and the California Department of Transportation by DKS Associates and the University of California, Irvine

Blueprint for Urban Sustainability: Integrating Sustainable Energy Practices into Metropolitan Planning. Containing the winning entries from the U.S. Competition on Metropolitan Energy Design. 2003. Gas Technology Institute. Available at: http://www.necsc.us/docs/Blueprint_Urban_Sustainability.pdf

Characterizing the Fabric of the Urban Environment: A Case Study of Greater Houston, Texas. 2003. Rose, L.S., H. Akbari, and H. Taha. Lawrence Berkeley National Laboratory Report LBNL-51448

Chicago's Urban Forest Ecosystem: Results of the Chicago Urban Forest Climate Project. 1994. McPherson, Gregory, David Nowak and Rowan Rowntree. eds. Gen. Tech. Rep. NE-186. Radnor, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station.

City Green: Calculating the Value of Nature: Technical Manual. 2004. Western Climate Initiative - Western Governors' Association. http://www.westernclimateinitiative.org/ American Forests

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Figures for Average Annual Emissions and Fuel Consumption for Passenger Cars and Light Trucks. 2005. US Environmental Protection Agency. Ann Arbor, MI

Green Building Incentives That Work: A Look at How Local Governments are Incentivizing Green Development. 2007. Yudelson and Associates, the National Association of Industrial and Office Properties. Available at: www.naiop.org/foundation/greenincentives.pdf

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Helpful Organizations & Sites

- American Council for an Energy-Efficient Economy
  www.aceee.org
- American Planning Association
  www.planning.org
- California Center for Sustainable Energy
  www.sdreo.org
- California Environmental Protection Agency – Air Resources Board
  www.arb.ca.gov/homepage.htm
- California Integrated Waste Management Board Green Building Program
  www.ciwmb.ca.gov/GreenBuilding/
- City of Berkeley, Energy and Sustainable Development
  www.ci.berkeley.ca.us/SubUnitHome.aspx?id=15404
- City of Chula Vista – Sustainability Center
  http://www.chulavistaca.gov/City_Services/Development_Services/Planning_Building/SustainabilityCenter/default.asp
- City of Oakland Environmental Services Division Green Building Resource Center
  www.oaklandpw.com/page273.aspx
- City of San Jose, Mayor Reed's Green Vision for San Jose
  www.sanjoseca.gov/mayor/goals/environment/GreenVision/GreenVision.asp
- City of San Francisco Green Building Program
  www.sfenvironment.org/our_programs/topics.html?ssi=8&ti=19
- City of Santa Monica, Residential Green Building Program
  http://greenbuildings.santa-monica.org/mainpages/whatsnew.htm
- City of Santa Monica Sustainable City Plan
  www01.smgov.net/epd/scp/
- Congress for New Urbanism
  www.cnu.org
- County of Marin, Countywide Plan
  www.co.marin.ca.us/depts/CD/main/comdev/ADVANCE/cwp/index.cfm
- Global Energy Network for Sustainable Communities
  www.globalenergynetwork.org
- National Energy Center for Sustainable Communities
  www.necsc.us

- **Renewable Energy and Energy Efficiency Partnership**
  www.reeep.org

- **Santa Barbara County, Innovating Building Review Committee**
  www.sbcountyplanning.org/projects/ibrp/index.cfm

- **Smart Communities Network – National Center for Appropriate Technologies**
  www.smartcommunities.ncat.org

- **Smart Code Central**
  www.smartcodecentral.org

- **Urban Land Institute**
  www.uli.org

- **U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy**
  www.eere.energy.gov

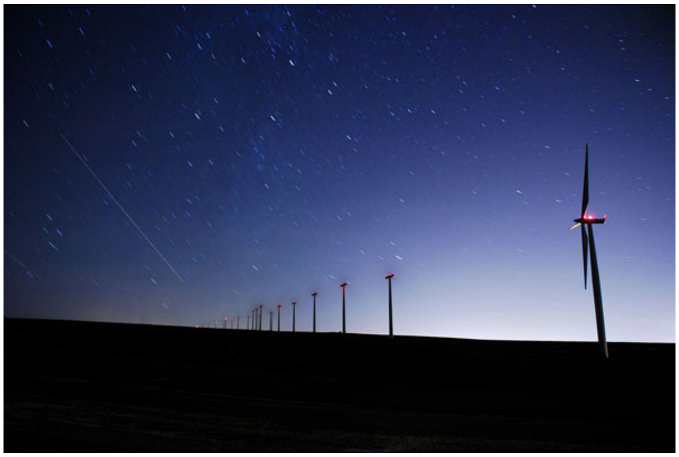
- **U.S. Department of Housing and Urban Development – Energy Efficient Mortgage Program**
  www.hud.gov/offices/hsg/sfh/eem/energy-r.cfm

- **U.S. Green Building Council – LEED-ND**
  www.usgbc.org/DisplayPage.aspx?CMSPageID=148

- **U.S. Environmental Protection Agency – Smart Growth Website**
  www.epa.gov/smartgrowth

Glossary

Acronym	Definition
BAU	Business-As-Usual, or a conventional approach to development
CBIA	California Building Industry Association
CCHP	Combined Cooling Heat and Power technology
CEC	California Energy Commission
CPUC	California Public Utility Commission
CARB	California Air Resources Board
CO_2	Carbon Dioxide
CVRP	Chula Vista Research Project
DG	Distributed Generation technologies
DR	Demand Response
EE	Energy Efficiency
EECD	Energy-Efficient Community Development
EE-PB	Energy Efficiency and Photovoltaic technology option
EE-DG	Energy Efficiency and Distributed Generation technology option
EEM	Energy-Efficient Mortgage
ET&CD	Energy Technology and Community Design options
GHG	Greenhouse Gas emissions
HVAC	Heating, Ventilation and Air Conditioning equipment
kWh	Kilowatt hours
LEED	Leadership in Energy and Environmental Design
LEM	Location-Efficient Mortgage
ROI	Return-On-Investment
SANDAG	San Diego Association of Governments
SBTC	Sustainable Buildings Tax Credit
SDG&E	San Diego Gas and Electric
SDSU	San Diego State University
T-24	California's Title-24 building energy efficiency standard, 2005
UHI	Urban Heat Island effect
USDOE	US Department of Energy
USEPA	US Environmental Protection Agency
VMT	Vehicle Miles Traveled
ZNE	Zero Net Energy



For More Information

SDG&E Contact Here:

City of Chula Vista Contact Here:

National Energy Center for Sustainable Communities

the Energy to Lead

REPORT

GTI PROJECT NUMBER: 20144/20106

Integrated Energy System for Marriott Hotel on the Island of Kauai

Report Issued:

June 2009

Prepared For:

Tom George, NETL Project Manager
National Energy Technology Laboratory (NETL)
Prime Contract No. DE-FC26-04NT42106 with NETL

Gas Technology Institute
1700 S. Mount Prospect Rd.
Des Plaines, Illinois 60018
www.gastechnology.org

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Abstract

Combined heat and Power (CHP) applications provide a promising high load factor sales opportunity for the propane industry. This is particularly true for larger remote commercial applications. The electric demand for commercial buildings in the U.S. is over 1.3 trillion kWh, or approximately twenty percent of the country's primary energy consumption. The demand has more than tripled in the past forty years, and is projected to increase another forty percent to 1.8 trillion kWh by 2030. The DOE Annual Energy Outlook 2009 projects a need for over 200 gigawatts of new electricity generation capacity to meet future demands.

The prospect of increasing on-peak electricity prices coupled with legislative and regulatory drivers for clean power, offer unprecedented opportunities to develop efficient, clean, reliable, and cost effective advanced integrated energy systems for commercial buildings. These opportunities have resulted in the observed and predicted growth in distributed generation (DG), or on-site power generation, as an alternative to conventional utility power purchased from mainly central coal-fired power plants. DG provides the benefits above plus reduced or eliminated reliance on the nation's transmission and distribution infrastructure, which is strained in many areas of the country. These market dynamics together with advanced prime mover technology have led to a renewed focus on CHP applications, long a mainstay of industry, across new commercial users. CHP systems offer commercial users the benefit of on-site generation with recovery of the waste heat to meet space and water heating and cooling needs, resulting in 60-80% efficient systems and significant savings to their operations, compared to 30% efficiency with typical power generation alone.

The Propane industry can play a strong role in this future energy market in both distributed generation and CHP applications. Propane currently supplies 4% of our nation's energy needs. One of its major uses is as a heating and cooking fuel in the residential and commercial sectors of the Midwest, Northeast, and other rural or isolated areas. Expanding the propane market to include power generation applications could be very significant. Additionally, current industrial and agricultural markets with on-site generation and/or CHP can be expanded. This new market growth would lead to both expanded and year-round propane sales in both urban and rural areas, particularly where natural gas is not available or the "spark spread" is favorable (i.e. the cost to generate electricity on site with propane is more economical than utility power purchase from the grid).

Developing alternate energy supplies across commercial markets, as well as industrial and residential sectors and in rural areas, ultimately offers decreased dependence on piping and electrical infrastructures. That improves the national security by reducing vulnerability of these networks as well as decreasing foreign imports, namely oil. If the technology and application of propane-fueled DG/CHP systems can be proven and promoted to both current propane users and into untapped markets, the potential for the propane industry is vast.

This project provided the opportunity to develop and verify the performance of a propane-fueled DG/CHP system for a major US commercial user in a high profile application. It is with hope that the completion and successes of this project provide needed in-service performance information on propane-fired engine technology; and that applications extend beyond current "back-up" or emergency generation, to continuous use in DG/CHP applications in new markets.

Executive Summary

As part of a DOE-sponsored program administered through the AGA's 2003 National Accounts Energy Alliance (NAEA) Testing and Verification Program, an industry need was recognized to develop efficient, clean, reliable, and cost effective advanced integrated energy systems for commercial buildings to help meet future energy demands. The NAEA specifically targeted the energy-intensive National Account chain customers in the retail, supermarket, food service, hotel, and healthcare industries in order to field test and verify the performances of advanced energy systems.

In July 2004 the Propane Education & Research Council (PERC) joined a foregoing Gas Technology Institute (GTI) research project with the American Gas Association (AGA) and the US Department of Energy (DOE) to develop an advanced integrated energy system at a national hotel resort. PERC's involvements in the research project effectively expanded the scope to add elaborate performance testing and fuel analyses for the proposed energy system.

In October 2008, after several years of significant design and installation complications, the project reached culmination with the startup of approximately 800 kW of on-site propane-fueled power generation and heat recovery to an absorption chiller, domestic hot water (DHW), and swimming pool heating at Marriott's one million square foot resort hotel in Lihue, Hawaii.

If the technology and application of propane-fueled DG/CHP systems can be proven and promoted to both current propane users and into untapped markets, the potential for the propane industry is vast. The propane industry can play a strong role in the future energy market by helping to meet the growing electric demand for commercial buildings with clean power. This project provided the opportunity to develop and verify the performance of a propane-fueled BCHP system for a major US commercial user in a high profile application; Marriott's resort hotel in Lihue demonstrates about 85% to 95% efficient use of clean fuel and heat with a world-class system that provides:

- Almost 800 kW of continuous on-site power generation at about 90% capacity factor
- About 50% of the resort's daily electric load and 70% of the resort's nightly electric load
- At least 50% of the resort's cooling load
- At least 75% of the resort's domestic hot water heating load
- 100% of the heating requirements for one of the largest resort pools in Hawaii
- Considerable annual energy cost savings

The on-site BCHP monitoring program measured the overall mechanical and economical performance of the system in its real-world environment for one year. The following tables summarize the monthly BCHP system performance.

Performance Parameter	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09
Capacity factor	73.2%	92.4%	74.8%	90.8%	87.8%	92.0%	90.0%
Electrical efficiency	N/A	N/A	N/A	31.9%	29.1%	29.2%	29.0%
Total system boundary heat efficiency	N/A	N/A	N/A	84.2%	95.0%	85.0%	78.1%
CHP System boundary fuel efficiency	N/A	N/A	N/A	67.1%	70.5%	63.6%	58.5%
Bottom line savings	N/A	N/A	N/A	$10,588	$19,112	$12,173	$18,874

Introduction

Background

As part of a DOE-sponsored program administered through the AGA's 2003 National Accounts Energy Alliance (NAEA) Testing and Verification Program, an industry need was recognized to develop efficient, clean, reliable, and cost effective advanced integrated energy systems for commercial buildings to help meet future energy demands. The NAEA specifically targeted the energy-intensive National Account chain customers in the retail, supermarket, food service, hotel, and healthcare industries in order to field test and verify the performances of advanced energy systems.

In July 2004 the Propane Education & Research Council (PERC) joined a foregoing Gas Technology Institute (GTI) research project with the American Gas Association (AGA) and the US Department of Energy (DOE) to develop an advanced integrated energy system at a national hotel resort. PERC's involvements in the research project effectively expanded the scope to add elaborate performance testing and fuel analyses for the proposed energy system.

In Hawaii, The Gas Company (TGC) supplies liquefied petroleum gas (LPG or propane), imported or locally refined, to many commercial and residential utility and non-utility customers statewide. As such, TGC promotes propane-fueled DG/CHP systems to their commercial customers to take advantage of the more economical fuel option combined with the increased efficiency and marked fuel cost savings realized with heat recovery systems. This customer-focus, coupled with the benefits of the NAEA program, led TGC and GTI to collaborate with Marriott, operator of the Kauai Marriott Resort and Beach Club (KMRBC) in Lihue, Hawaii. Because fuel supplied by TGC to the KMRBC is propane, it was selected for evaluation of a propane-fueled building cooling, heating, and power (BCHP) system. As a result of the evaluation, Marriott made the decision to design, install, and field test a BCHP system at the KMRBC. Subsequently, the team further collaborated with the Propane Education & Research Council (PERC), Caterpillar (a leading engine manufacturer), and a local design-build contractor. Ultimately, the project was sponsored at various levels by the portfolio of team members mentioned above.

In October 2008, after several years of significant design and installation complications, the project reached culmination with the startup of approximately 800 kW of on-site power generation and heat recovery to an absorption chiller, domestic hot water (DHW), and swimming pool heating.

Host Site

Marriott's resort hotel in Lihue, Hawaii is a one million square foot facility consisting of three 12-story buildings, with over 350 hotel rooms and 200 time-share apartments, along with two one-story common buildings interconnecting them. Prior to the BCHP system startup, the hotel purchased all of its electricity and used the following major equipment:

- Two new 450-ton electric chillers for cooling
- Two 20-year old 140-ton heat pumps for DHW and cooling to augment the

electric chillers

- Two propane-fired steam boilers for laundry and kitchen use and back-up to the heat pumps for DHW

The electric chillers supplied 500 to 600 tons of cooling on a typical design day with the heat pumps supplementing about 100 tons of cooling. The heat pumps operated at only about 40% capacity. The heat pumps also met the domestic heating load, but operated at only about 60% capacity, which was below their original heating capacity. No space heating was required and no pool heating was done.

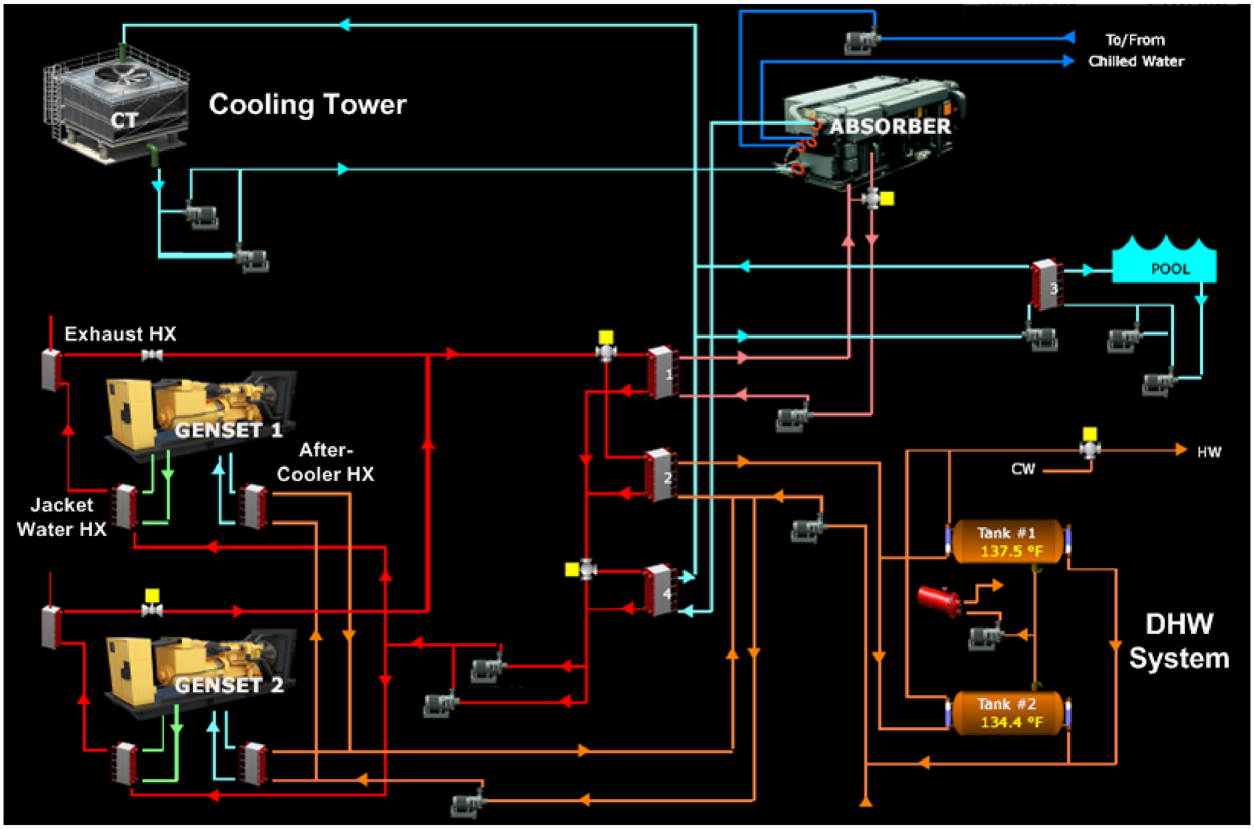
Building Cooling Heating and Power System

The hotel BCHP system is supplemental; sized to meet a portion of the electric, heating, and cooling loads while augmenting the existing electric chillers and the steam boilers. The aged, low performing heat pumps were eliminated. An underlying premise for the sizing design was that the hotel must maintain a majority commitment of their electric load from utility power so not to disturb the local electric rate structure.

The BCHP system includes two Caterpillar model G3412C TA propane gas generator sets with Caterpillar switchgear for continuous power application. Each machine is rated at 405 KW, 506 KVA, 480 volts, 1800 RPM, 3 phase, and 60 Hz. The machines are interconnected to the utility electrical power grid via Caterpillar switchgear and a utility transformer. As Figure 1 shows, each machine is equipped with a heat recovery system designed to extract jacket water, after-cooler, and exhaust heat from the engines via heat exchangers. The heat recovery systems supply heat to a 244-ton absorption chiller, the hotel's domestic water heating system and the 26,000-sq-ft swimming pool. The remaining heat is rejected via a 600-ton cooling tower. It is estimated that the BCHP system is providing about 50% of the daily electric load and 70% of the nightly electric load while providing at least 50% of the facility cooling load, at least 75% of the domestic water heating load, and 100% of the swimming pool heating requirements. Fuel is supplied to the machines from the utility at a regulated pressure of 1.5 to 5 psig and with fuel characteristics in accordance with the Caterpillar guidelines to achieve the expected performance. The engines are installed with sound attenuated weather protective enclosures in an open area, out of guest-site, directly adjacent to the existing hotel's boiler plant. Refer to Appendix A for installation pictures of the BCHP system.

During commissioning of the BCHP system, two anomalies were observed. One, the engines were unable to supply the anticipated 405 kW generation capacity without exceeding maximum gas manifold temperatures; two, heat rejection from the jacket water could not be maintained without lowering the jacket water heat exchanger supply water temperature. As such, the units were de-rated and maximum capacity of the absorption chiller could not be achieved. Upon investigation, it was determined that the methane number of the fuel was slightly below the minimum number recommended by Caterpillar for the particular engine model. Corrections to engine timing were made, but did not resolve the issues. After evaluation and consultation with Caterpillar, the factory determined that the existing units could not be adjusted to meet the original design criteria and that the existing engines would need to be replaced. In June, 2009 new Caterpillar model 3412LE engines were installed to replace the G3412C's.

Figure 1 - Hotel BCHP Process Diagram



Project Objective and Related Goals

PERC funding expanded this research project to incorporate detailed laboratory testing of the system. With PERC's involvement, this research project originally included shipment of one engine and heat recovery package to GTI's Distributed Energy Test Center in Des Plaines, IL. Intentions were to expose the system to a full range of performance testing on multiple grades of propane within a controlled environment. However, as the project matured, complications with the system design and installation resulted in multiple delays. As such, there were scheduling concerns with the preceding delivery of the system to GTI. Furthermore, it became evident that the engine manufacturer would not warrant the system after it was subjected to testing at GTI's labs. Alternatively, GTI applied PERC funding for an extensive on-site BCHP monitoring program that included the development of a web-based data acquisition and performance-monitoring system.

The completion and success of this project provides needed testing and in-service performance information on commercial sized propane-fired engine technology; toward its application beyond its current use as "back-up" or emergency generation to its continuous use in DG/CHP applications in new markets. This project potentially enhances market development and validation for propane CHP in larger-scale commercial facilities, providing the industry with substantial load potential in high load factor (year-round) applications.

Design and Testing Details

Design Materials

The following principal design drawings are included in Appendix B:

Site Map – Drawing T-0

Site Plan – Drawing M-0

One-Line Diagram – Drawing E-4

Overall Piping Schematic – Drawing M-11

Hot Water Piping Schematic – Drawing M-11a

Process Flow Diagram – Drawing C1.0

Network Layout – C1.1

Detailed design materials, including all mechanical and electrical drawings, equipment submittals and schedules, permits, and manuals were provided to the project research team. These materials are extensive and therefore, are not included within this report.

Summary of BCHP System Operation

A Delta Direct Digital Control (DDC) system automatically controls the operation of mechanical equipment associated with the BCHP system. Before running the generators, all supporting equipment must be activated by the Delta DDC system. All of the pumps are first staged ON and flow is confirmed with flow transmitters. The after-cooler radiators are staged ON and all of the motorized valves are opened. If there are problems with any one of these operations, an alarm is signaled. When all of the supporting equipment is confirmed ON, the DDC enables one or both of the generators to operate. Upon start-up of both generators and after a 30-minute warm-up period, the Delta DDC system enables the Broad absorption chiller to operate. During normal operation, the Delta DDC system automatically controls operation of the system and alarms if normal operation is not maintained. The generators have the ability to track electrical demand and run part load in response to lower loads. However, because the BCHP system is sized to meet only a portion of the electric load, the generators can run at full capacity year-round.

When operating only one generator, domestic hot water heating and absorption cooling cannot take place simultaneously. As such, domestic hot water heating and chiller operation take place during alternating pre-programmed time periods. If domestic hot water heating is required during a pre-programmed period when the absorber is running, heating is provided by the facility boilers.

Test Objectives

An on-site BCHP monitoring program was developed that would measure and define the overall mechanical and economical performance of the system in its real-world environment. Specifically, the on-site test objectives were to define, on a monthly basis, the following key criterion:

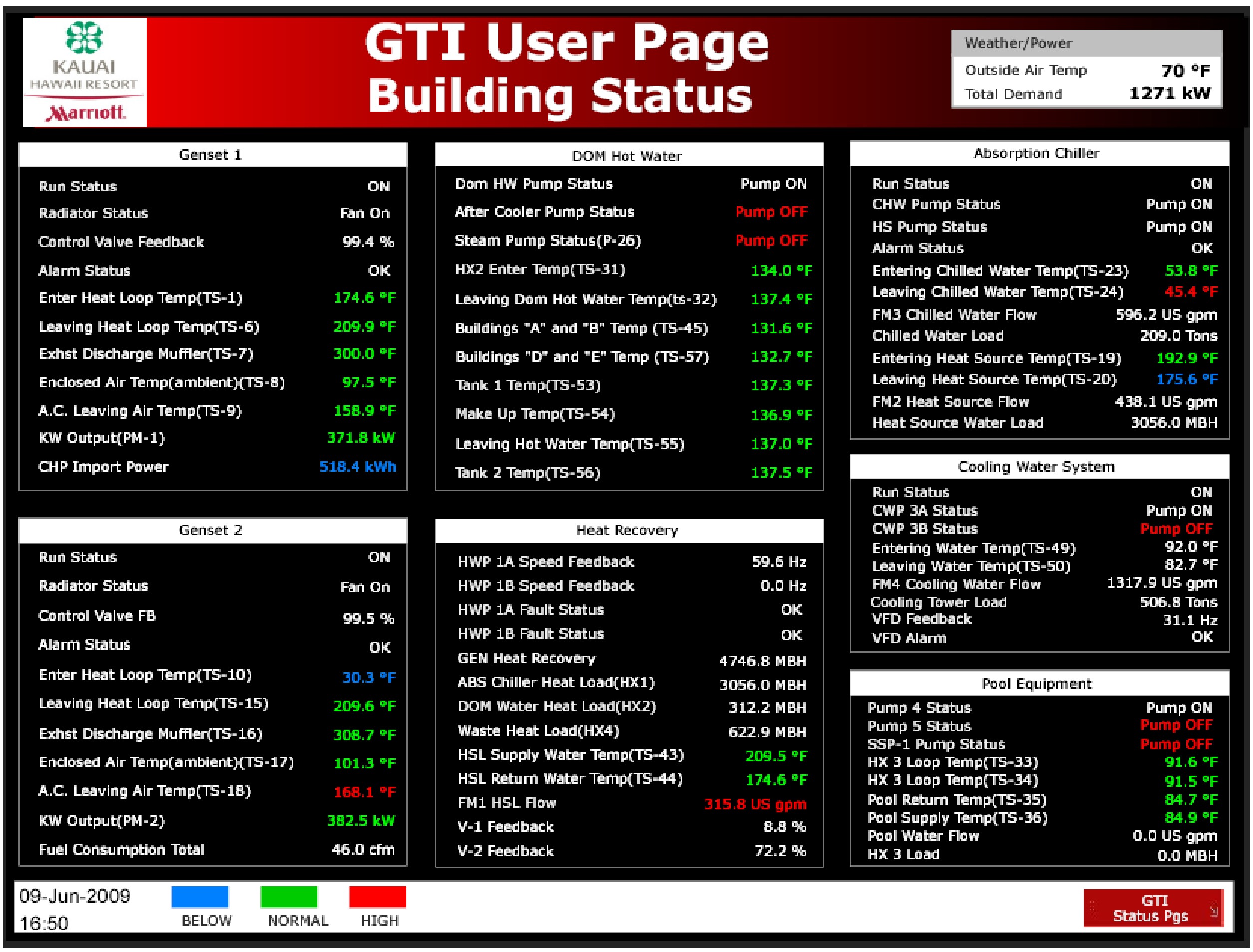
1. System Performance
2. Cost to Operate
3. Savings from Operation
4. Bottom Line Savings (net savings)

By testing on-site as opposed to a controlled environment, it allowed the research team to monitor effects of external variables on the key criterion. Such variables included, fuel composition, heating and cooling demands, ambient temperatures, and parasitic losses.

Data Acquisition

Using the Delta DDC system, an extensive web-based program was developed that allowed the research team to monitor the entire system in real time and collect required interval data. In order to meet the test objectives, the DDC system historian stored data at 15-minute intervals for one year from about fifty instruments placed within the BCHP system. Figure 2 shows a screenshot of the main dashboard for the web-based program. Appendix C contains additional screenshots of the program.

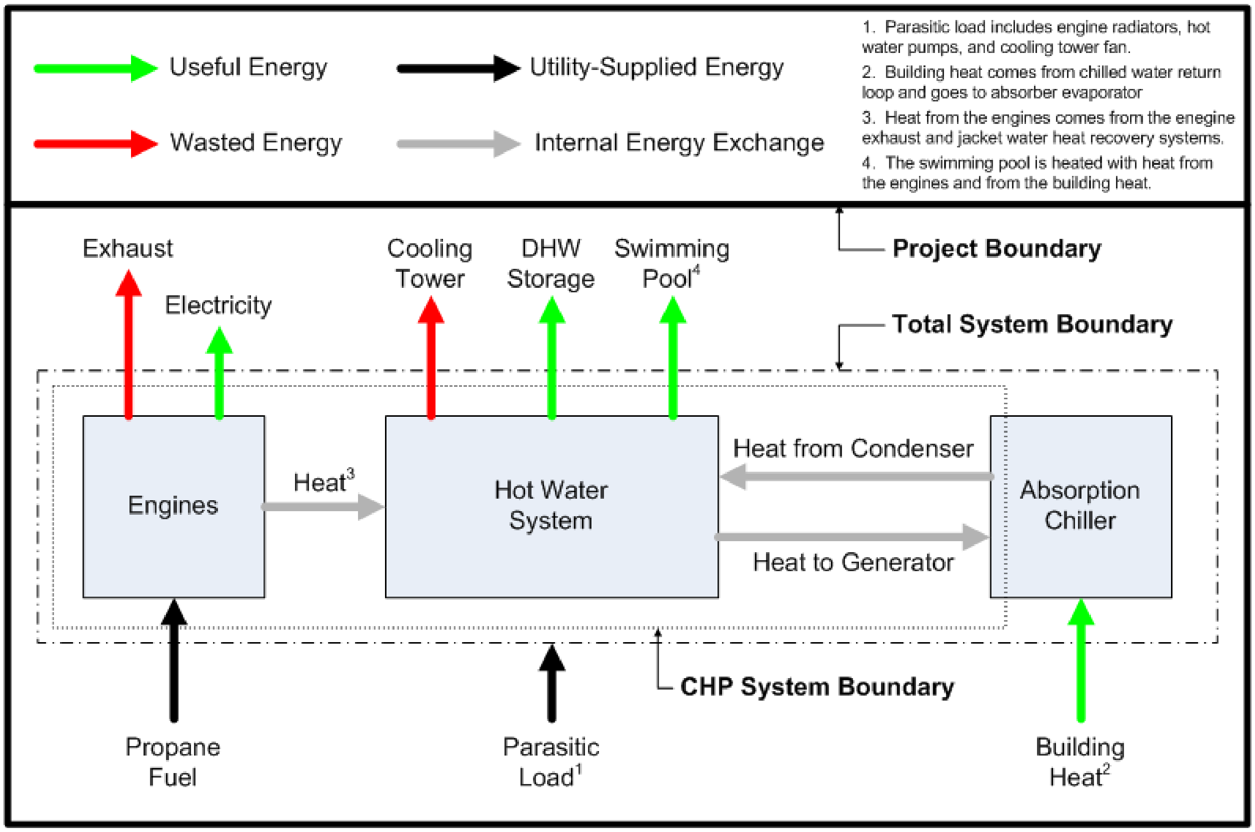
Figure 2 – Delta DDC Web-Based Monitoring



System Boundaries

The system boundary diagram, shown in Figure 3, defines the components that are part of the total system and the components that are part of the CHP subsystem. The diagram is an essential guide to calculating the parameters that make up the energy balance and ultimately define the key performance criterion.

Figure 3 – System Boundary Diagram



Energy Balance

An energy balance is a systematic observation of energy flows and, in some cases, transformations in a system. The basis for an energy balance is that the energy put into the system must be equivalent to the energy exiting the system. The energy balance for the BCHP system can be formulated by examining the system boundary diagram. In this case, the energy put into the system is the summation of the propane fuel consumed by the generators; the electrical energy consumed by the auxiliary pumps and fans, also known as parasitic load; and the building heat picked up by the chiller cooling water return. The equivalent energy out of the system is the summation of the electricity produced by the generators; the heat exhausted out the stacks; the heat delivered, by way of the heat exchangers, to the domestic hot water storage system and pool; and heat dumped to the cooling tower.

Fuel Composition

The Gas Company's non-utility business includes the sale of a commercial grade of propane known as HD-5 to customer sites on Kauai, including the Kauai Marriott Resort and Beach Club. "HD-5" stands for Heavy Duty (propane) containing a maximum of 5% propylene and a maximum of 2.5% butanes and heavier hydrocarbons (also shown as C4+). The Caterpillar engine generators are designed for HD-5 and the aforementioned hydrocarbon composition.

Owing to chemical properties which result in HD-5 becoming liquid at atmospheric temperature and elevated pressure, HD-5 can be transported and stored easily. As such, it is held by TGC as liquid/vapor in a dedicated storage tank near the resort. Liquid propane remains at the bottom of the tank while propane vapor is drawn from the top for fueling the generators. A coalescing filter is used between the tank and the generators to assure condensed liquid does not enter the fuel stream. As vapor forms within the tank, lighter hydrocarbons, such as propane, evaporate leaving heavier fractions, such as butanes, behind. Unchecked, the butanes can accumulate in the tank to levels above the maximum recommended by Caterpillar for combustion.

To identify hydrocarbon trends and manage the stored propane over time, TGC tracks the propane composition. Liquid propane and propane vapor in the tank, as well as propane vapor downstream of the coalescing filter, were sampled and analyzed at regular intervals throughout the one-year testing program. GTI used the sampled data to calculate the HD-5 heating values per ASTM D3588-98(03) (standard industry practice for calculating heat value). The heating value of a fuel is the amount of heat released during the combustion of a specified amount of it. It is measured in units of energy per unit of volume (e.g. Btu/ft3). The quantity known as higher heating value (HHV) is the gross heating value determined by bringing all the products of combustion back to the original pre-combustion temperature, and in particular condensing any vapor produced. HHV accounts for water in the exhaust leaving as vapor, and includes liquid water in the fuel prior to combustion. The quantity known as lower heating value (LHV) is the net heating value determined by subtracting the heat of vaporization of the water vapor from the higher heating value. It is the LHV (net heating value) that is used here to calculate system performances. Appendix D shows a sample output from GTI's gas properties calculation tool.

Performance Criterion

System performance

The system performance is defined by the following measures:

Capacity Factor: The ratio of the actual electrical output of the system over a period of time and its output if it had operated at full nameplate capacity the entire time.

Useful Energy: The useful energy extracted from the total system boundary is the summation of the electricity produced by the generators; the heat delivered, by way of the heat exchangers, to the domestic hot water storage system and pool; and the building heat picked up by the chiller cooling water return. The building heat is useful because this system was strategically designed to recover that heat to the hot water loop.

Electrical Efficiency: The electrical output of the system minus its parasitic losses divided by the total fuel consumed.

Total System Boundary Heat Efficiency: This calculation takes credit for the building heat from the chilled water return loop that enters the system boundary and goes to the absorber evaporator. The building heat is useful energy that is used, in conjunction with heat recovery from the engines, to heat the swimming pool. Hence, the Total System Boundary Heat Efficiency is the electrical output of the system minus the parasitic losses; plus the thermal energy transferred to the domestic hot water system and the swimming pool; plus the cooling energy transferred to the chilled water system; all divided by the total fuel consumed.

CHP System Boundary Fuel Efficiency: This calculation does not take credit for the building heat from the chilled water return loop because it is outside of the CHP system boundary. Though the building heat is useful energy, it is not produced by the CHP system. However, since the building heat ultimately ends up in the system by way of rejected heat from the absorber condenser, it must be accounted for as energy put into the system. Hence, the CHP System Boundary Fuel Efficiency is the electrical output of the system minus the parasitic losses; plus the thermal energy transferred to the domestic hot water system and the swimming pool; plus the cooling energy transferred to the chilled water system; all divided by the total fuel consumed plus the building heat from the chilled water return loop.

Peak Demand Reduction: The peak demand reduction is an important performance measure because the resort pays the electric utility a demand charge based on its highest monthly power demand. When the generators are running, they reduce the peak power demand. The Peak Demand Reduction is the highest simultaneous power output of the combined generators during the billing month.

Cost to Operate

The Cost to Operate is defined by the following measures:

Cost of Fuel: The cost of fuel is simply the amount of money the resort pays the gas utility for fuel to power the generators.

Cost of Standby Power: When operating on-site power generation the resort must pay the electric utility a monthly Standby charge to assure that the utility will provide equivalent power if the generators are not running. The standby charge is a fee for backup capacity.

Cost of Operation and Maintenance: The cost labor and materials needed to run and maintain system (does not include fuel cost)

Saving from Operation

The Savings from Operation is defined by the following measures:

Savings from Power Generation: Every kilowatt-hour of electricity produced by the generators reduces the amount of electricity that the resort must purchase from the electric utility. The electric utility charges the resort a single-stepped energy charge, where the rate is higher for the first 400 kilowatt-hours per kilowatt of demand than for energy use over 400 kilowatt-hours per kilowatt of demand. In this case, it is assumed the electric energy from the power generators displaces the lower utility energy charge.

Savings from Demand Reduction: The most effective means of incurring cost savings from peak demand is by running the generators at full capacity during the highest monthly power demand. If the generators are at part load or off during the highest monthly power demand, that time period will default to the highest monthly power demand regardless of the demand reduction accomplished at all other times during the month.

Savings from Absorption Cooling: Because the aged, low performing heat pumps were eliminated, the alternative to absorption cooling would be to use the existing electric chillers. Therefore, estimated savings from absorption cooling is based on the displacement of electricity that would otherwise be used for the electric chillers that run at an approximate efficiency of 0.65 kW per refrigeration ton.

Savings from Domestic Hot Water Heating: If heat is not recovered from the BCHP system, the existing boilers would need to provide it. Therefore, estimated savings from domestic hot water heating via the BCHP system is based on the displacement of propane fuel that would otherwise be used to fire the boilers that run at an approximate efficiency of 75%.

Savings from Swimming Pool Heating: It is important to note that the swimming pool was not heated prior to the BCHP project. As with domestic hot water, the swimming pool is heated with recovered heat from the generators and from building heat that returns to the system via the chilled water loop. An alternative to heating the pool would be to use separate propane-fired pool heaters that are known to be about 82% efficient. The estimated savings from swimming pool heating via the BCHP system is based on the displacement of propane fuel that would otherwise be used for the pool heaters.

Bottom Line Savings

The bottom line savings is simply the net savings to the resort. It is the savings from operation minus the cost to operate.

Testing Instrumentation and Calculations

The instruments listed in Table 1 are permanently installed on-site and were used for data acquisition and system performance calculations. All calculations are referenced in Appendix E.

Table 1 – On-Site Instrumentation for Testing

Parameter	Instrument	Measure	Accuracy
Generator 1 power output	Tyco/Cromton Potential Transformer @ +/- 0.6% w/ ITI Instrument Class Current	Kilowatts	+/- 4.8%
Generator 2 power output			
Hot Water Pump 1A VFD Current	Sentry AC Instrument Class Current Transducer	Amps	+/- 1%
Hot Water Pump 1B VFD Current			
After Cooler Water Pump 1 Current			
Heat Source Water Pump 2 Current			
Domestic Hot Water Pump 1 Current			
Steam Pump P-26 Current			
Pool Heat Source (SSP-1) Motor Current			
Existing Pool 4 Pump Motor Current			
Existing Pool 5 Pump Motor Current			
Chilled Water Pump 3 Current			
Cooling Water Pump 3A Current			
Cooling Water Pump 3B Current			
Cooling Tower VFD Current			

Radiator 1 Motor Current			
Radiator 2 Motor Current			
Propane Fuel Consumption	Dresser Roots Meter Series	SCFM	+/- 1%
Heat Source Water Flow	ONICON Insertion Turbine Flow Meters	GPM	+/- 1%
Chilled Water Flow			
HX4 Cooling Water Loop Flow			
After Cooler Loop Water Flow			
HX2 Hot Water Loop Flow			
HX3 Pool Loop Flow			
After Cooler Loop Return Water Temp	Kele Platinum RTD and High Rangeable Transmitter	ºF	~ +/- 1%
After Cooler Loop Supply Water Temp			
Cooling Water to Absorber Temp			
Cooling Water from Absorber Temp			
Chilled Water Return Temp			
Chilled Water Supply Temp			
HX1 Absorber Heat Loop Entering Water			
HX1 Absorber Heat Loop Leaving Water			
HX2 Entering Hot Water Temp			
HX2 Domestic Hot Water Leaving Temp			
HX3 Entering Cooling Water Temp			
HX3 Leaving Cooling Water Temp			
HX4 Entering Cooling Water Temp			
HX4 Leaving Cooling Water Temp			
Heat Source Loop Supply Water Temp			
Heat Source Loop Return Water Temp			
After Cooler Supply Water Temp			
Leaving Cooling Water Temp			
Outside Air Temp			

Test Results

The following results summarize the four months on-site BCHP monitoring program and define the overall energy efficiency and economics of the system in its real-world environment. Monthly operating performance details in tabular and pie chart formats are provided in Figures 4 through 7. Summaries of the trends in the propane storage tank fuel composition and heating value changes due to concentration of heavier fractions are shown in Figures 13 and 14.

Table 2 – BCHP System Performance Monthly Details

System Parameters	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09
Capacity factor	**73.2%**	**92.4%**	**74.8%**	**90.8%**	**87.8%**	**92.0%**	**90.0%**
Fuel consumption kWh	1,171,336	1,420,635	1,112,778	1,274,265	1,372,811	1,399,472	1,415,468
Electricity generated kWh	**421,675**	**549,700**	**430,621**	**488,393**	**522,800**	**529,881**	**536,130**
Heat delivered to chiller generator kWh	522,219	636,612	386,800	563,185	621,479	622,900	630,068
Heat delivered to DHW storage kWh	84,567	111,626	114,534	108,388	112,006	107,186	103,607
Heat delivered to HX4 kWh	63,878	108,411	164,844	98,066	105,202	123,197	131,819
Heat rejected from absorber condenser kWh	884,739	1,045,750	600,175	865,509	1,057,261	1,055,170	1,060,175
Heat rejected to cooling tower kWh	N/A	863,085	490,324	670,705	743,223	903,903	1,031,493
Building heat to absorber evap. kWh	395,361	456,314	227,678	326,323	478,017	472,169	473,163
Heat delivered to swimming pool kWh	58,166	231,674	223,281	231,705	314,016	201,355	118,487
Heat exhausted to stacks	N/A	N/A	N/A	182,758	281,438	250,456	225,128
Useful heat kWh	**N/A**	**799,614**	**565,493**	**666,416**	**904,040**	**780,710**	**695,258**
Parasitic losses (Rads, fans, pumps) kWh	N/A	N/A	N/A	81,360	122,657	121,139	126,214
Electrical efficiency	N/A	N/A	N/A	**31.9%**	**29.1%**	**29.2%**	**29.0%**
Total system boundary heat efficiency	N/A	N/A	N/A	**84.2%**	**95.0%**	**85.0%**	**78.1%**
CHP System boundary fuel efficiency	N/A	N/A	N/A	**67.1%**	**70.5%**	**63.6%**	**58.5%**
Peak demand reduction kW	N/A	N/A	N/A	**760**	**760**	**739**	**741**
Savings from power generation kWh	N/A	N/A	N/A	$70,014	$72,814	$71,440	$84,205
Savings from demand reduction kW	N/A	N/A	N/A	$9,977	$9,977	$9,703	$9,724
Savings from absorption cooling	N/A	N/A	N/A	$10,374	$16,076	$15,252	$17,964
Savings from DHW heating	N/A	N/A	N/A	$11,668	$12,058	$10,209	$9,869
Savings from swimming pool heating	N/A	N/A	N/A	$22,814	$30,919	$17,542	$10,323
Cost of fuel for power generation	N/A	N/A	N/A	-$102,884	-$110,840	-$99,975	-$101,118
Cost for standby power kW	N/A	N/A	N/A	-$4,050	-$4,050	-$4,050	-$4,050
Cost of operation & maintenance	N/A	N/A	N/A	-$7,326	-$7,842	-$7,948	-$8,042
Bottom line savings	N/A	N/A	N/A	**$10,588**	**$19,112**	**$12,173**	**$18,874**

Figure 4 - February 2009 BCHP Operating Performance Details

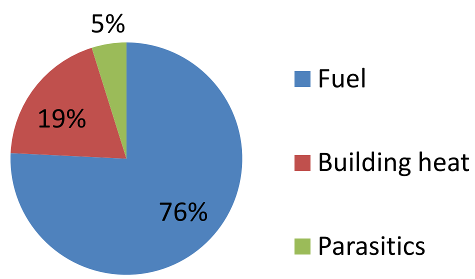
System Performance

Capacity factor	90.8%
Useful Energy produced kWh	1,154,809
Electrical efficiency	31.9%
Total system boundary heat efficiency	84.2%
CHP System boundary fuel efficiency	67.1%
Peak demand reduction kW	760

Energy Rates

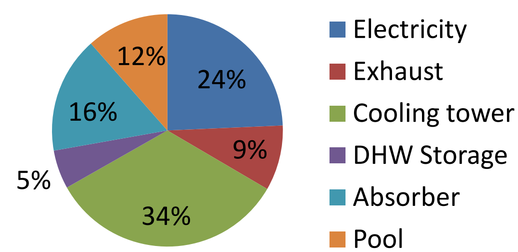
Demand charge per kW monthly demand	$13.13
Standby charge per kW of generation	$5.00
Energy charge (first 400 kWh/kW	$0.19027
Energy charge (over 400 kWh/kW)	$0.17201
Propane fuel charge per kWh	$0.08074
Operation & maintenance $/kWh	$0.015

Energy into System



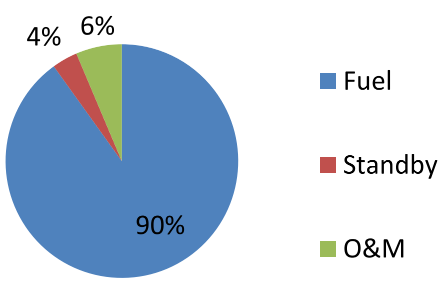
Fuel consumption kWh	1,274,265
Building heat to absorber evap. kWh	326,323
Parasitic losses (Rads, fans, pumps) kWh	81,360
Total energy into system kWh	**1,681,948**

Energy out of System



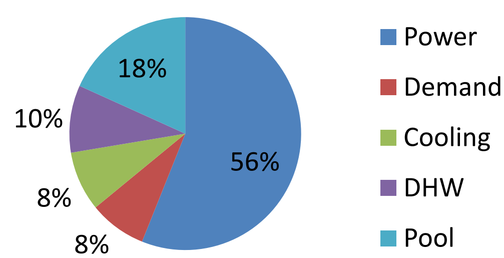
Electricity generated kWh	488,393
Heat exhausted to stacks	182,758
Heat dumped to cooling tower kWh	670,705
Heat delivered to DHW storage kWh	108,388
Building heat to absorber evap. kWh	(326323)
Heat delivered to swimming pool kWh	231,705
Total energy out of system kWh	**1,681,948**

Cost to Operate



Cost of fuel for power generation	$102,884
Cost for standby power kW	$4,050
Cost of operation & maintenance	$7,326
Total cost to operate	**$114,259**

Savings from Operation

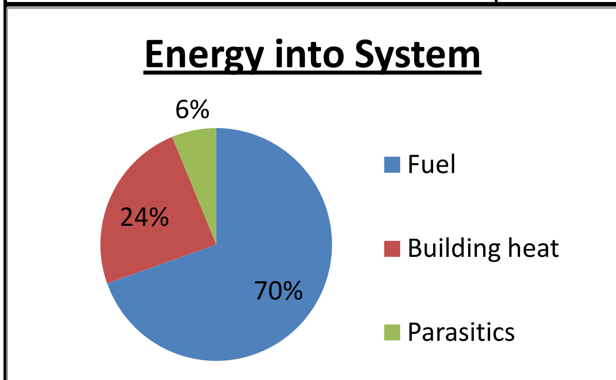


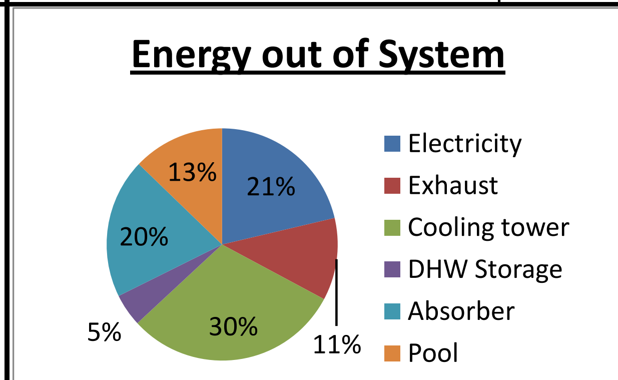
Savings from power generation kWh	$70,014
Savings from demand reduction kW	$9,977
Savings from absorption cooling	$10,374
Savings from DHW heating	$11,668
Savings from swimming pool heating	$22,814
Total savings from operation	**$124,847**
Bottom Line Savings	**$10,588**

Figure 5 - March 2009 BCHP Operating Performance Details

System Performance	
Capacity factor	87.8%
Useful Energy produced kWh	1,426,839
Electrical efficiency	29.1%
Total system boundary heat efficiency	95.0%
CHP System boundary fuel efficiency	70.5%
Peak demand reduction kW	760

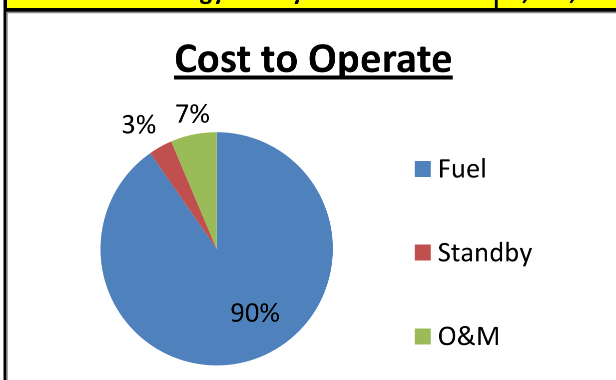
Energy Rates	
Demand charge per kW monthly demand	$13.13
Standby charge per kW of generation	$5.00
Energy charge (first 400 kWh/kW	$0.20023
Energy charge (over 400 kWh/kW)	$0.18197
Propane fuel charge per kWh	$0.08074
Operation & maintenance $/kWh	$0.015

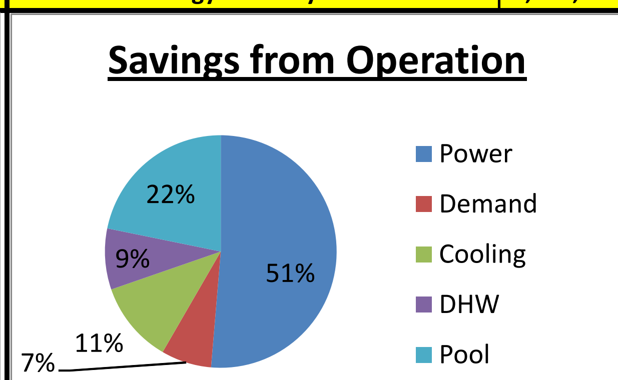




Fuel consumption kWh	1,372,811
Building heat to absorber evap. kWh	478,017
Parasitic losses (Rads, fans, pumps) kWh	122,657
Total energy into system kWh	**1,973,484**

Electricity generated kWh	522,800
Heat exhausted to stacks	281,438
Heat dumped to cooling tower kWh	743,223
Heat delivered to DHW storage kWh	112,006
Building heat to absorber evap. kWh	(478017)
Heat delivered to swimming pool kWh	314,016
Total energy out of system kWh	**1,973,484**





Cost of fuel for power generation	$110,840
Cost for standby power kW	$4,050
Cost of operation & maintenance	$7,842
Total cost to operate	**$122,732**

Savings from power generation kWh	$72,814
Savings from demand reduction kW	$9,977
Savings from absorption cooling	$16,076
Savings from DHW heating	$12,058
Savings from swimming pool heating	$30,919
Total savings from operation	**$141,844**
Bottom Line Savings	**$19,112**

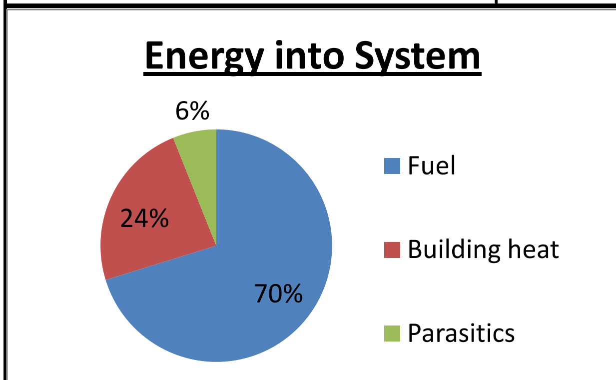
Figure 6 - April 2009 BCHP Operating Performance Details

System Performance

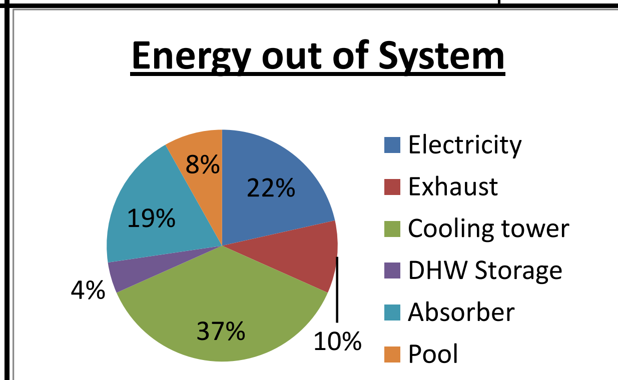
Capacity factor	92.0%
Useful Energy produced kWh	1,310,591
Electrical efficiency	29.2%
Total system boundary heat efficiency	85.0%
CHP System boundary fuel efficiency	63.6%
Peak demand reduction kW	739

Energy Rates

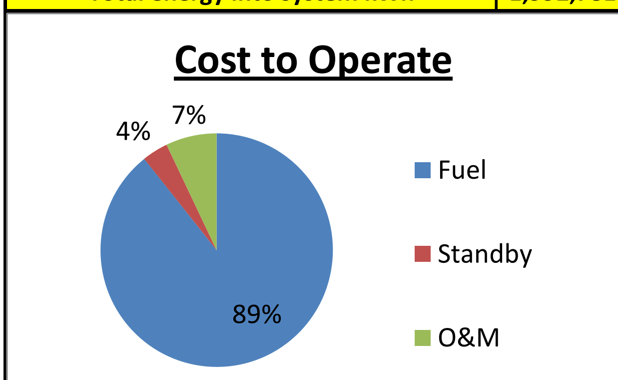
Demand charge per kW monthly demand	$13.13
Standby charge per kW of generation	$5.00
Energy charge (first 400 kWh/kW	$0.19304
Energy charge (over 400 kWh/kW)	$0.17478
Propane fuel charge per kWh	$0.07144
Operation & maintenance $/kWh	$0.015



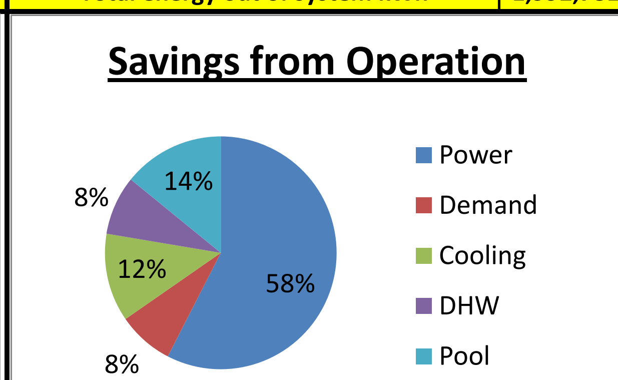
Fuel consumption kWh	1,399,472
Building heat to absorber evap. kWh	472,169
Parasitic losses (Rads, fans, pumps) kWh	121,139
Total energy into system kWh	**1,992,781**



Electricity generated kWh	529,881
Heat exhausted to stacks	250,456
Heat dumped to cooling tower kWh	903,903
Heat delivered to DHW storage kWh	107,186
Building heat to absorber evap. kWh	(472169)
Heat delivered to swimming pool kWh	201,355
Total energy out of system kWh	**1,992,781**



Cost of fuel for power generation	$99,975
Cost for standby power kW	$4,050
Cost of operation & maintenance	$7,948
Total cost to operate	**$111,973**



Savings from power generation kWh	$71,440
Savings from demand reduction kW	$9,703
Savings from absorption cooling	$15,252
Savings from DHW heating	$10,209
Savings from swimming pool heating	$17,542
Total savings from operation	**$124,147**
Bottom Line Savings	**$12,173**

Figure 7 - May 2009 BCHP Operating Performance Details

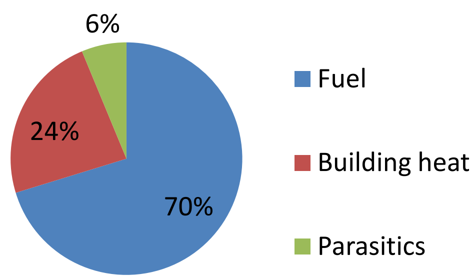
System Performance

Capacity factor	90.0%
Useful Energy produced kWh	1,231,387
Electrical efficiency	29.0%
Total system boundary heat efficiency	78.1%
CHP System boundary fuel efficiency	58.5%
Peak demand reduction kW	741

Energy Rates

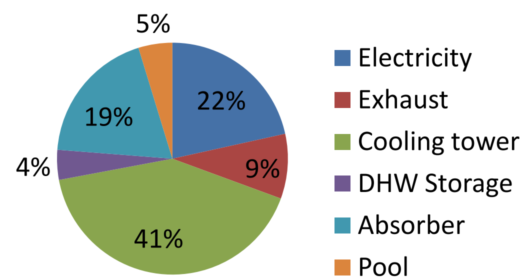
Demand charge per kW monthly demand	$13.13
Standby charge per kW of generation	$5.00
Energy charge (first 400 kWh/kW	$0.22368
Energy charge (over 400 kWh/kW)	$0.20542
Propane fuel charge per kWh	$0.07144
Operation & maintenance $/kWh	$0.015

Energy into System



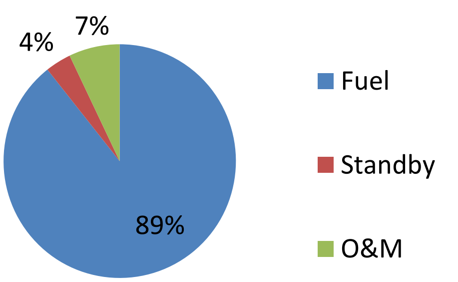
Fuel consumption kWh	1,415,468
Building heat to absorber evap. kWh	473,163
Parasitic losses (Rads, fans, pumps) kWh	126,214
Total energy into system kWh	**2,014,845**

Energy out of System



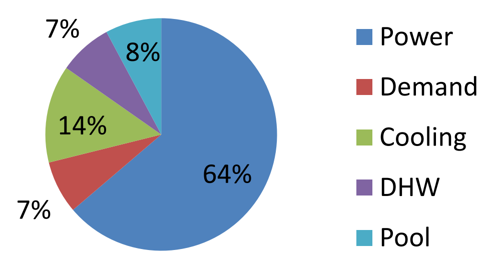
Electricity generated kWh	536,130
Heat exhausted to stacks	225,128
Heat dumped to cooling tower kWh	1,031,493
Heat delivered to DHW storage kWh	103,607
Building heat to absorber evap. kWh	(473163)
Heat delivered to swimming pool kWh	118,487
Total energy out of system kWh	**2,014,845**

Cost to Operate



Cost of fuel for power generation	$101,118
Cost for standby power kW	$4,050
Cost of operation & maintenance	$8,042
Total cost to operate	**$113,210**

Savings from Operation



Savings from power generation kWh	$84,205
Savings from demand reduction kW	$9,724
Savings from absorption cooling	$17,964
Savings from DHW heating	$9,869
Savings from swimming pool heating	$10,323
Total savings from operation	**$132,084**
Bottom Line Savings	**$18,874**

Figure 8 - Liquid and Vapor Fuel Concentrations in Tank

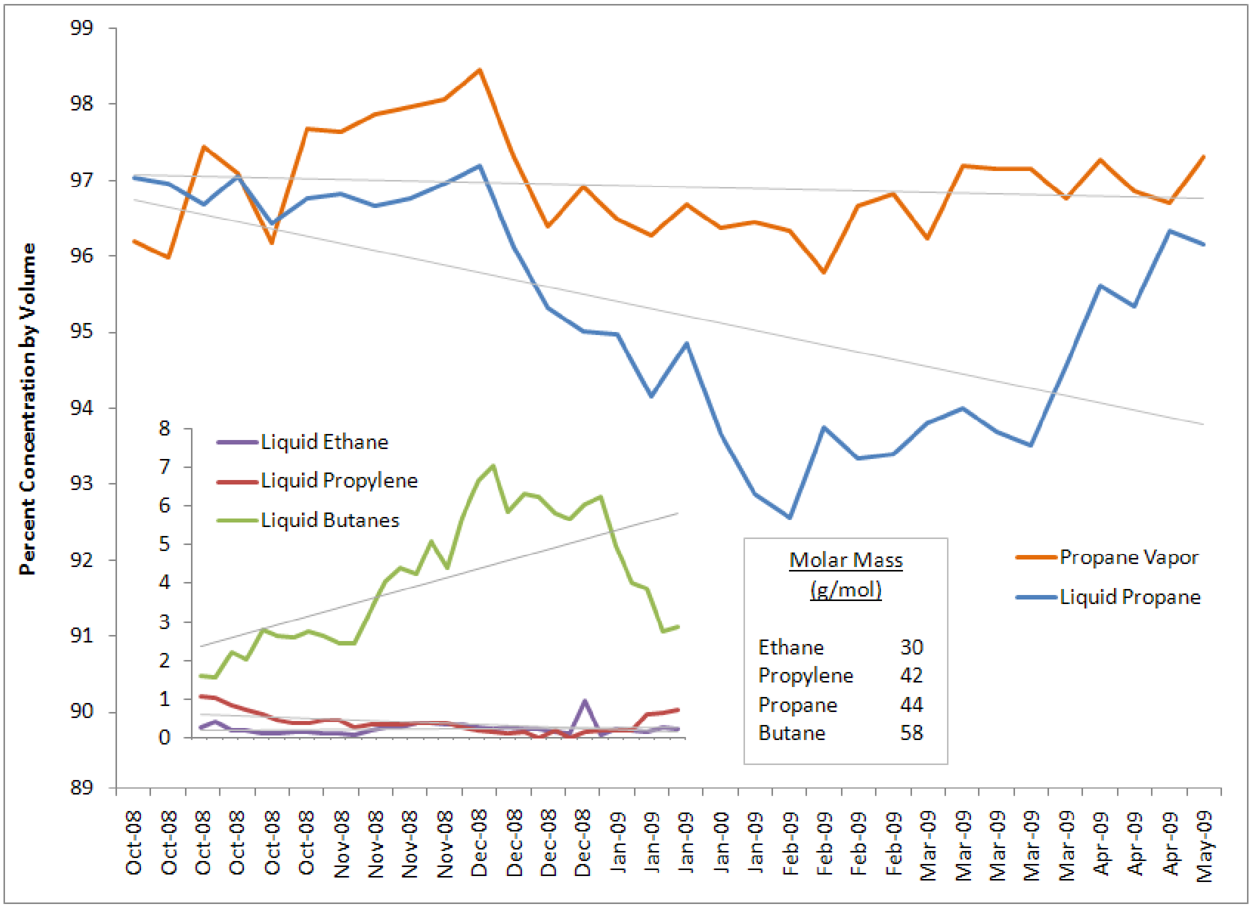
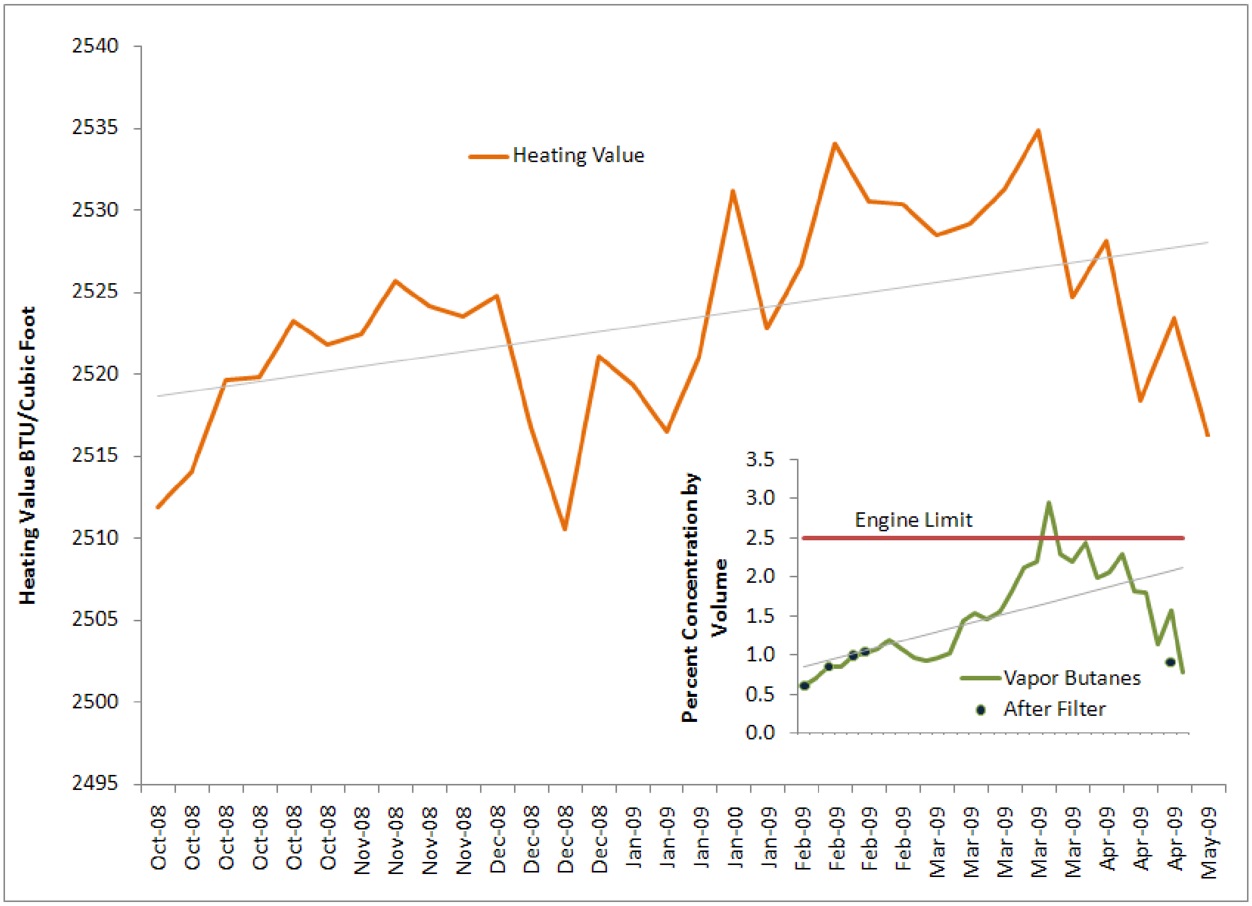


Figure 9 - Fuel Heating Value and Heavy Vapor Fractions



Conclusions and Summary of Field Performance Evaluation

If the technology and application of propane-fueled DG/CHP systems can be proven and promoted to both current propane users and into untapped markets, the potential for the propane industry is vast. The propane industry can play a strong role in the future energy market by helping to meet the growing electric demand for commercial buildings with clean power. This project provided the opportunity to develop and verify the performance of a propane-fueled BCHP system for a major US commercial user in a high profile application; Marriott's resort hotel in Lihue, Hawaii demonstrates about 85% to 95% efficient use of clean fuel and heat with a world-class system that provides:

- Almost 800 kW of continuous on-site power generation at about 90% capacity factor
- About 50% of the resort's daily electric load and 70% of the resort's nightly electric load
- At least 50% of the resort's cooling load
- At least 75% of the resort's domestic hot water heating load
- 100% of the heating requirements for one of the largest resort pools in Hawaii
- Considerable annual energy cost savings

The on-site BCHP monitoring program measured the overall mechanical and economical performance of the system in its real-world environment for one year. The following tables summarize the monthly BCHP system performance.

Table 3 – BCHP System Performance Monthly Summary

Performance Parameter	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09	May-09
Capacity factor	73.2%	92.4%	74.8%	90.8%	87.8%	92.0%	90.0%
Electrical efficiency	N/A	N/A	N/A	31.9%	29.1%	29.2%	29.0%
Total system boundary heat efficiency	N/A	N/A	N/A	84.2%	95.0%	85.0%	78.1%
CHP System boundary fuel efficiency	N/A	N/A	N/A	67.1%	70.5%	63.6%	58.5%
Bottom line savings	N/A	N/A	N/A	$10,588	$19,112	$12,173	$18,874

Appendix A – BCHP System Installation Pictures

Caterpillar Engine Generator (G3412C)

Caterpillar Switchgear

Utility Transformer

Jacket Water Heat Recovery Heat Exchangers

gti

Exhaust Heat Recovery Silencers

Broad 244-ton Absorption Chiller

SPX Cooling Technologies 600-ton Cooling Tower

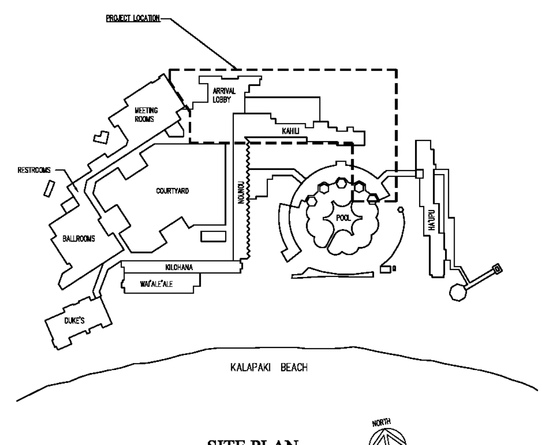
Caterpillar Generator Enclosure

Appendix B - Principal Design Drawings

Mariott Kauai Resort & Beach Club
Cogen / CHP Pool Heating Project

3610 Rice Street
Lihue Kauai 96766

T.M.K. 3-5-002 : 002

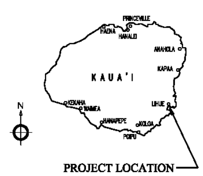


SITE PLAN
NOT TO SCALE

PROJECT SHEET CONTENTS:

SHEET	CONTENTS
T-0	TITLE SHEET
M-0	LOCATION SITE PLAN
M-1	CHILLER PLANT – MECHANICAL DEMOLITION
M-1A	CHILLER PLANT – NEW MECHANICAL
M-2	CHILLER PLANT – NEW EQUIPMENT
M-2A	CHILLER PLANT – NEW CONTROLS
M-3	ROOF PLANS – MECHANICAL
M-4	ROOF PLANS – POOL HEATING PIPING
M-5	GROUND FLOOR PLAN – POOLING HEATING PIPING
M-6	POOL LEVEL PLAN – POOL HEATING PIPING
M-7	POOL PUMP ROOM LEVEL PLAN – MECHANICAL
M-8	HWST ROOM PLAN – DEMO AND NEW MECHANICAL
M-9	HWST ROOM PLAN – ENLARGED SCALE MECHANICAL
M-10	HWST ROOM PIPING DIAGRAM
M-11	OVERALL NEW PIPING SCHEMATIC
M-11A	NEW HOT WATER PIPING SCHEMATIC
M-12	NEW MECHANICAL EQUIPMENT SCHEDULE
A-1	PARTIAL FOURTH FLOOR PLAN
A-2	PARTIAL FIFTH FLOOR PLAN AND ROOF PLAN
A-3	BUILDING SECTIONS AND ELEVATIONS
A-4	MISCELLANEOUS DETAILS
S-1	COOLING TOWER PLATFORM FRAMING PLAN
S-2	MISCELLANEOUS STRUCTURAL DETAILS AND ELEVATIONS
E-1	ELECTRICAL SITE PLAN AND LEGEND
E-2	EXISTING ONE LINE DIAGRAM
E-3	ELECTRICAL REMOVAL WORK PLAN
E-4	NEW WORK ONE LINE DIAGRAM
E-5	NEW WORK ELECTRICAL INSTALLATION PLAN
E-6	MISCELLANEOUS DETAILS
E-7	MECHANICAL EQUIPMENT SWITCHBOARD

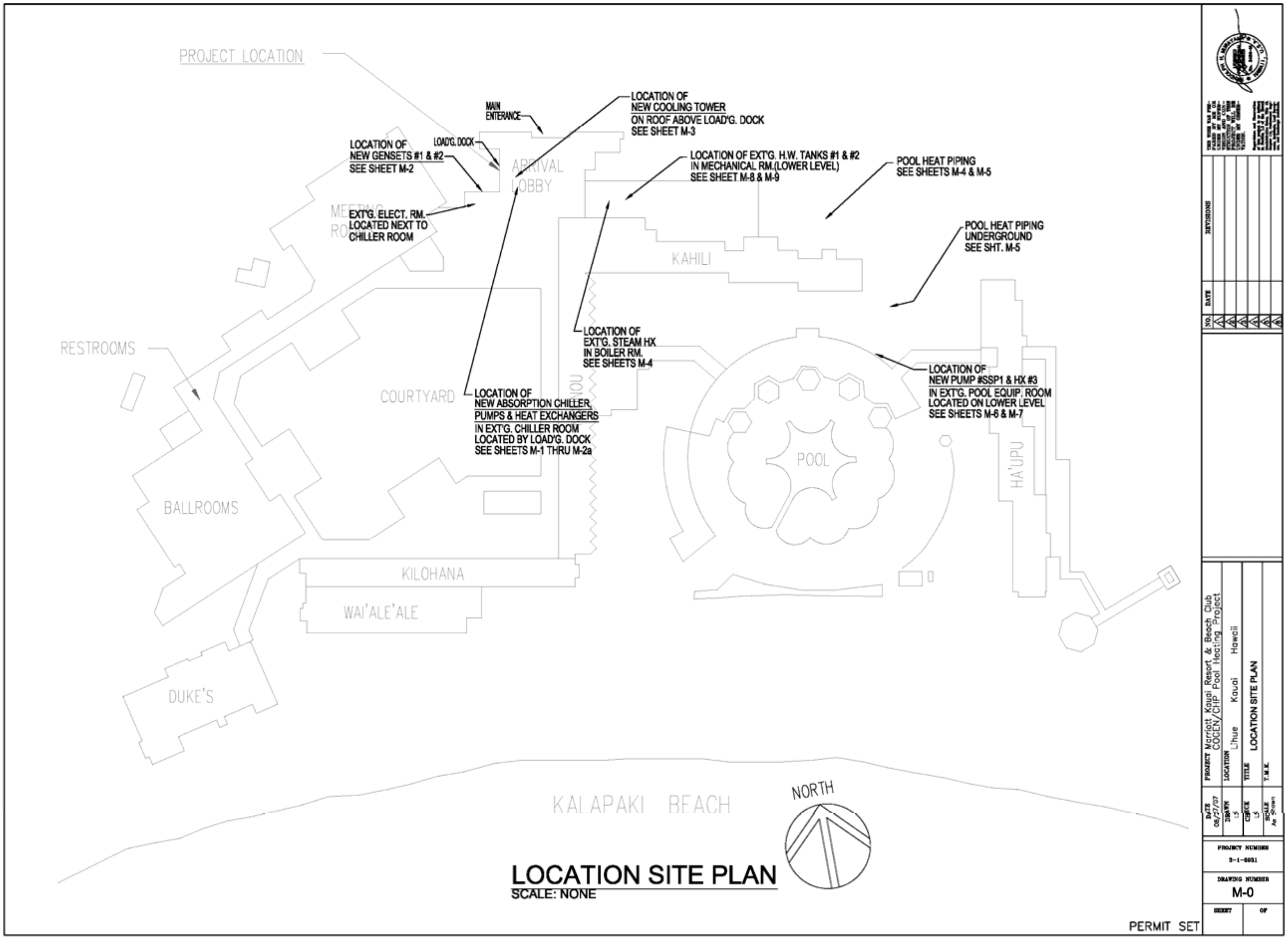
LOCATION MAP

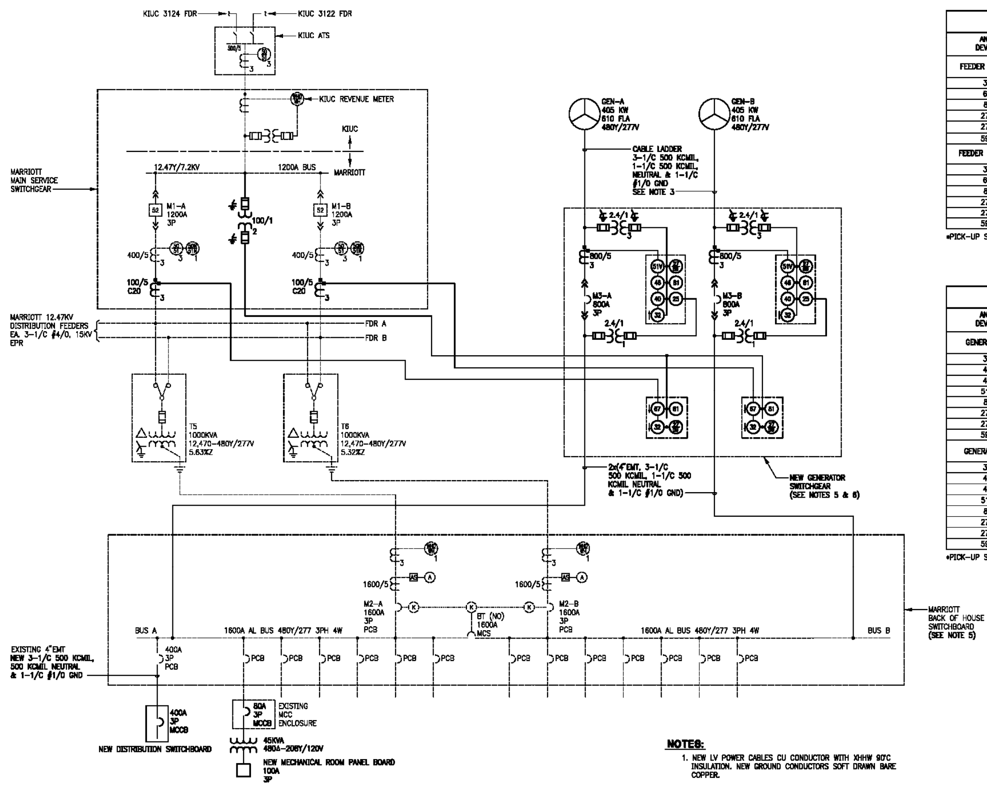


PERMIT SET

PROJECT Mariott Kauai Resort & Beach Club COGEN/CHP Pool Heating Project
LOCATION Lihue Kauai Hawaii
TITLE TITLE SHEET
T.M.K.
DATE 08/27/07
DRAWN LS
CHECK LS
SCALE As Shown
PROJECT NUMBER 3-1-6931
DRAWING NUMBER T-0
SHEET OF

REVISIONS | NO. | DATE


PROJECT LOCATION
MAIN ENTERANCE
LOCATION OF NEW COOLING TOWER ON ROOF ABOVE LOAD'G. DOCK SEE SHEET M-3
LOAD'G. DOCK
LOCATION OF NEW GENSETS #1 & #2 SEE SHEET M-2
ARRIVAL LOBBY
LOCATION OF EXT'G. H.W. TANKS #1 & #2 IN MECHANICAL RM.(LOWER LEVEL) SEE SHEET M-8 & M-9
POOL HEAT PIPING SEE SHEETS M-4 & M-5
EXT'G. ELECT. RM. LOCATED NEXT TO CHILLER ROOM
POOL HEAT PIPING UNDERGROUND SEE SHT. M-5
KAHILI
RESTROOMS
LOCATION OF EXT'G. STEAM HX IN BOILER RM. SEE SHEETS M-4
LOCATION OF NEW PUMP #SSP1 & HX #3 IN EXT'G. POOL EQUIP. ROOM LOCATED ON LOWER LEVEL SEE SHEETS M-6 & M-7
COURTYARD
LOCATION OF NEW ABSORPTION CHILLER, PUMPS & HEAT EXCHANGERS IN EXT'G. CHILLER ROOM LOCATED BY LOAD'G. DOCK SEE SHEETS M-1 THRU M-2a
POOL
HA'UPU
BALLROOMS
KILOHANA
WAI'ALE'ALE
DUKE'S
KALAPAKI BEACH
NORTH
LOCATION SITE PLAN
SCALE: NONE
PERMIT SET
PROJECT Marriott Kauai Resort & Beach Club COGEN/CHP Pool Heating Project
LOCATION Lihue Kauai Hawaii
TITLE LOCATION SITE PLAN
REVISIONS
DRAWING NUMBER
M-0



RECOMMENDED FEEDER RELAY SETTING SCHEDULE

ANSI DEVICE	DEVICE	MANUFACTURER	MODEL	CT RATIO	PT RATIO	PICKUP (SEE *NOTE BELOW)	DEFINITE TIME	INSTANTANEOUS OR CHARACTERISTICS
FEEDER RELAY A								
32	ISO SWGR A	BASLER	IPS100	100:5	100:1	150W	3s	
67	ISO SWGR A	BASLER	IPS100	100:5	100:1	0.5	0.1	E1/DISABLED
81	ISO SWGR A	BASLER	IPS100	100:5	100:1	59Hz/61Hz	0.4s	
27R	ISO SWGR A	BASLER	IPS100	100:5	100:1	125V		
27P	ISO SWGR A	BASLER	IPS100	100:5	100:1	100V	0.5s	
59P	ISO SWGR A	BASLER	IPS100	100:5	100:1	137V	1s	
FEEDER RELAY B								
32	ISO SWGR A	BASLER	IPS100	100:5	100:1	150W	3s	
67	ISO SWGR A	BASLER	IPS100	100:5	100:1	0.5	0.1	E1/DISABLED
81	ISO SWGR A	BASLER	IPS100	100:5	100:1	59Hz/61Hz	0.4s	
27R	ISO SWGR A	BASLER	IPS100	100:5	100:1	125V		
27P	ISO SWGR A	BASLER	IPS100	100:5	100:1	100V	0.5s	
59P	ISO SWGR A	BASLER	IPS100	100:5	100:1	137V	1s	

*PICK-UP SETTINGS LISTED ARE SECONDARY INSTRUMENT TRANSFORMER VALUES.

RECOMMENDED GENERATOR RELAY SETTING SCHEDULE

ANSI DEVICE	DEVICE	MANUFACTURER	MODEL	CT RATIO	PT RATIO	PICKUP (SEE *NOTE BELOW)	TIME DIAL OR DELAY	INSTANTANEOUS OR CHARACTERISTICS
GENERATOR A								
32	N/A	BASLER	GPS100	800:5	2.4:1	105W	5s	
40	N/A	BASLER	GPS100	800:5	2.4:1	792VAR	0.2s	
46	N/A	BASLER	GPS100	800:5	2.4:1	0.2A	30s	
51V	G1-A-1	BASLER	GPS100	800:5	2.4:1	5	9.9	E1/DISABLED
81	N/A	BASLER	GPS100	800:5	2.4:1	59Hz/61Hz	0.5s	
27R	N/A	BASLER	GPS100	800:5	2.4:1	115V		
27P	N/A	BASLER	GPS100	800:5	2.4:1	92V	0.5s	
59P	N/A	BASLER	GPS100	800:5	2.4:1	127V	1s	
GENERATOR B								
32	N/A	BASLER	GPS100	800:5	2.4:1	105W	5s	
40	N/A	BASLER	GPS100	800:5	2.4:1	792VAR	0.2s	
46	N/A	BASLER	GPS100	800:5	2.4:1	0.2A	30s	
51V	G1-B-1	BASLER	GPS100	800:5	2.4:1	5	9.9	E1/DISABLED
81	N/A	BASLER	GPS100	800:5	2.4:1	59Hz/61Hz	0.5s	
27R	N/A	BASLER	GPS100	800:5	2.4:1	115V		
27P	N/A	BASLER	GPS100	800:5	2.4:1	92V	0.5s	
59P	N/A	BASLER	GPS100	800:5	2.4:1	127V	1s	

*PICK-UP SETTINGS LISTED ARE SECONDARY INSTRUMENT TRANSFORMER VALUES.

NOTES:

1. NEW LV POWER CABLES CU CONDUCTOR WITH XHHW 90°C INSULATION. NEW GROUND CONDUCTORS SOFT DRAWN BARE COPPER.
2. EXISTING PCB 35 KAIC @ 480V.
3. DO NOT GROUND GENERATOR NEUTRALS AT GENERATORS. CONNECT GENERATOR NEUTRALS TO BACK OF HOUSE SWITCHBOARD NEUTRAL BUS AT POINT OF CONNECTION TO GROUND.
4. GENERATORS WILL OPERATE AT OR BELOW CONTINUOUS RATING (i.e., 610A).
5. PROVIDE WARNING SIGNS NEXT TO EACH BACK OF HOUSE SWITCHBOARD AND GENERATOR SWITCHGEAR MAIN CIRCUIT BREAKER, WITH WHITE LETTERS ON RED BACKGROUND THAT READ: "CAUTION – MULTIPLE POWER SUPPLIES. DISCONNECT AND LOCKOUT ALL SOURCES BEFORE SERVICING."
6. PROVIDE WARNING SIGN NEXT TO EACH GENERATOR SWITCHGEAR MAIN CIRCUIT BREAKER WITH WHITE LETTERS ON RED BACKGROUND THAT READS: "KIUC TO PADLOCK IN OPEN POSITION TO ISOLATE GENERATOR POWER."
7. FEEDER RELAYS A & B TRIP GENERATOR MAIN CIRCUIT BREAKERS M3-A & M3-B, RESPECTIVELY.

NEW WORK SYSTEM ONE-LINE DIAGRAM

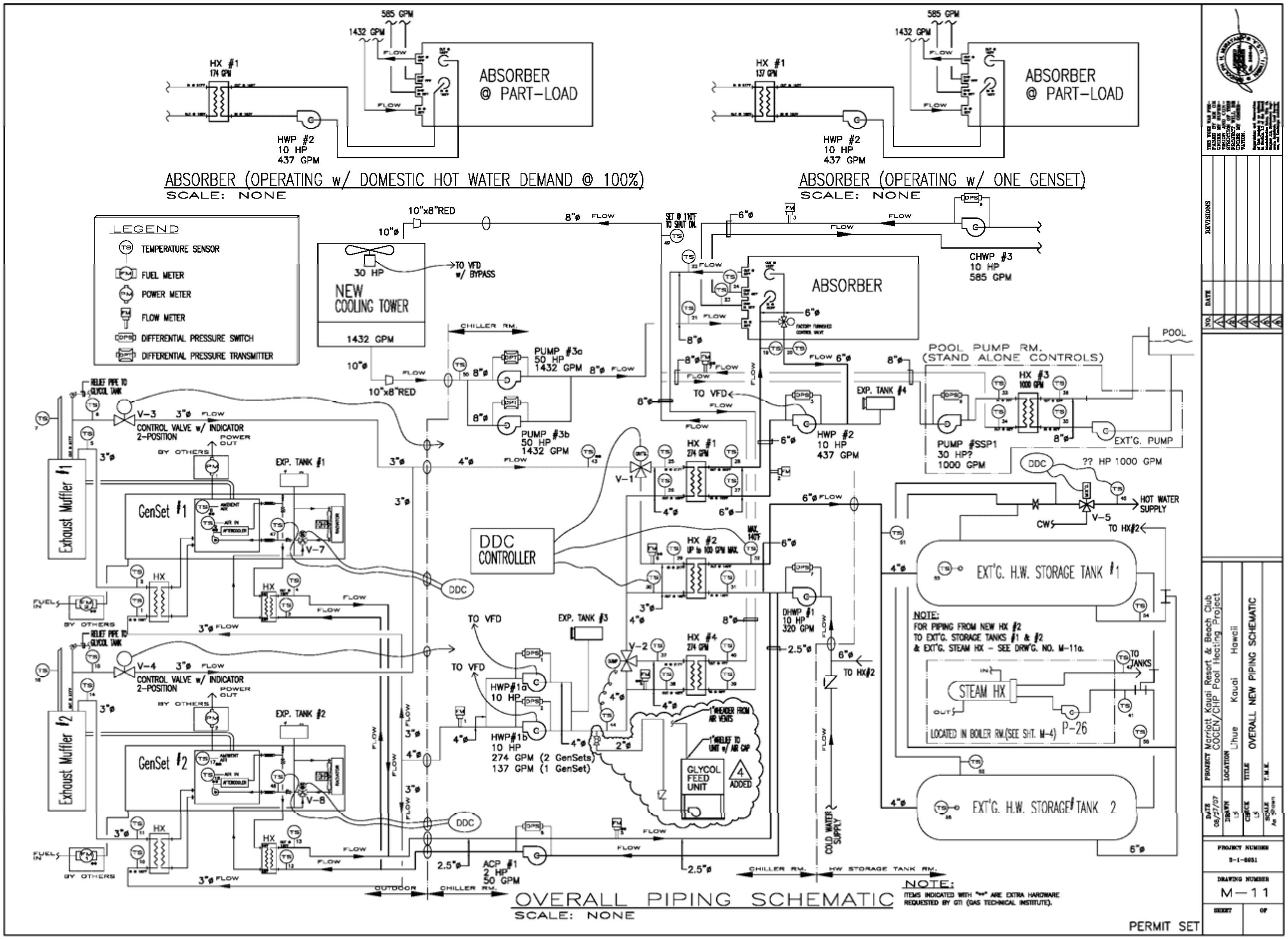
PERMIT SET

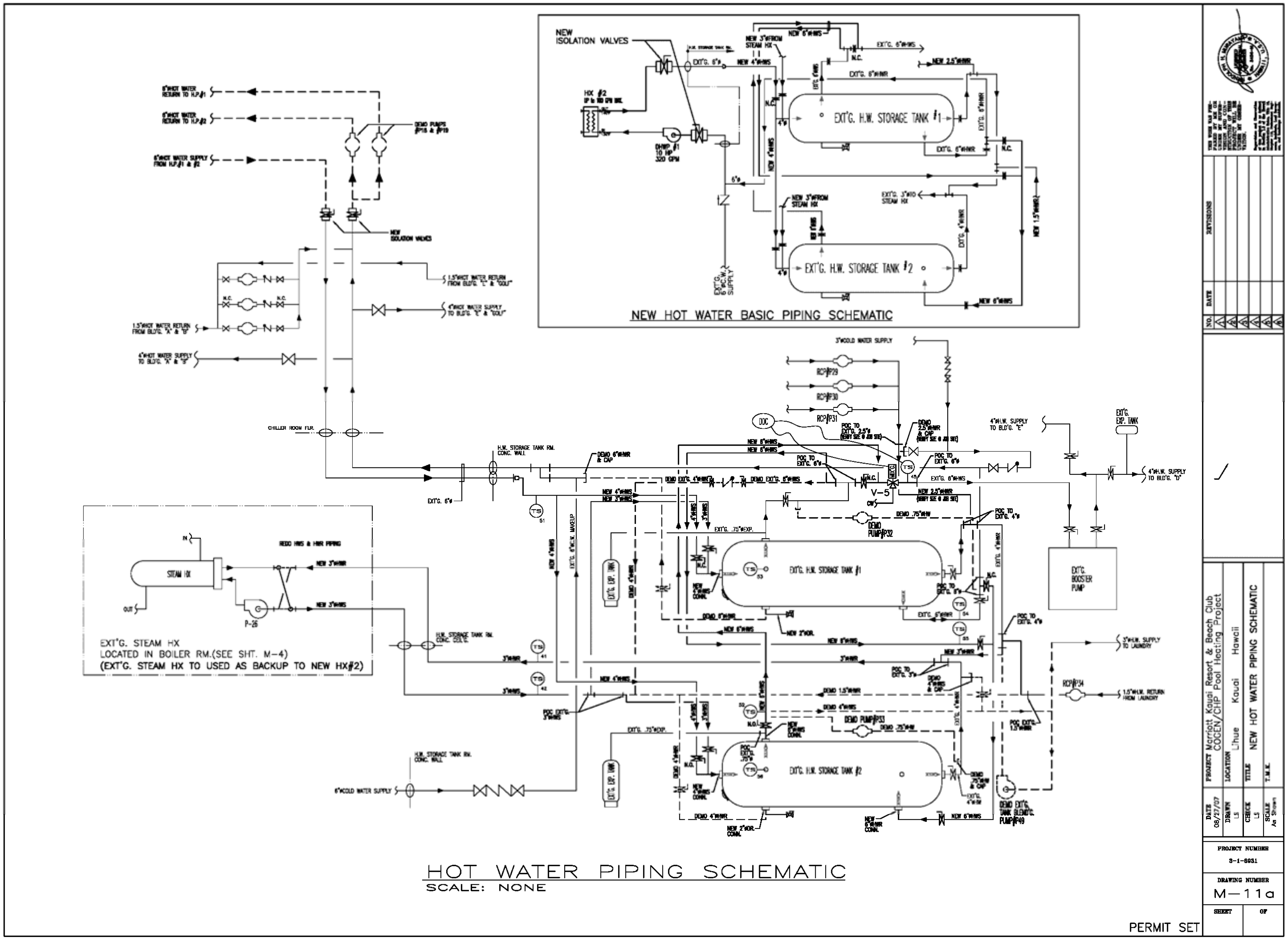
HHMI Corporation
CONSULTING ELECTRICAL ENGINEERS

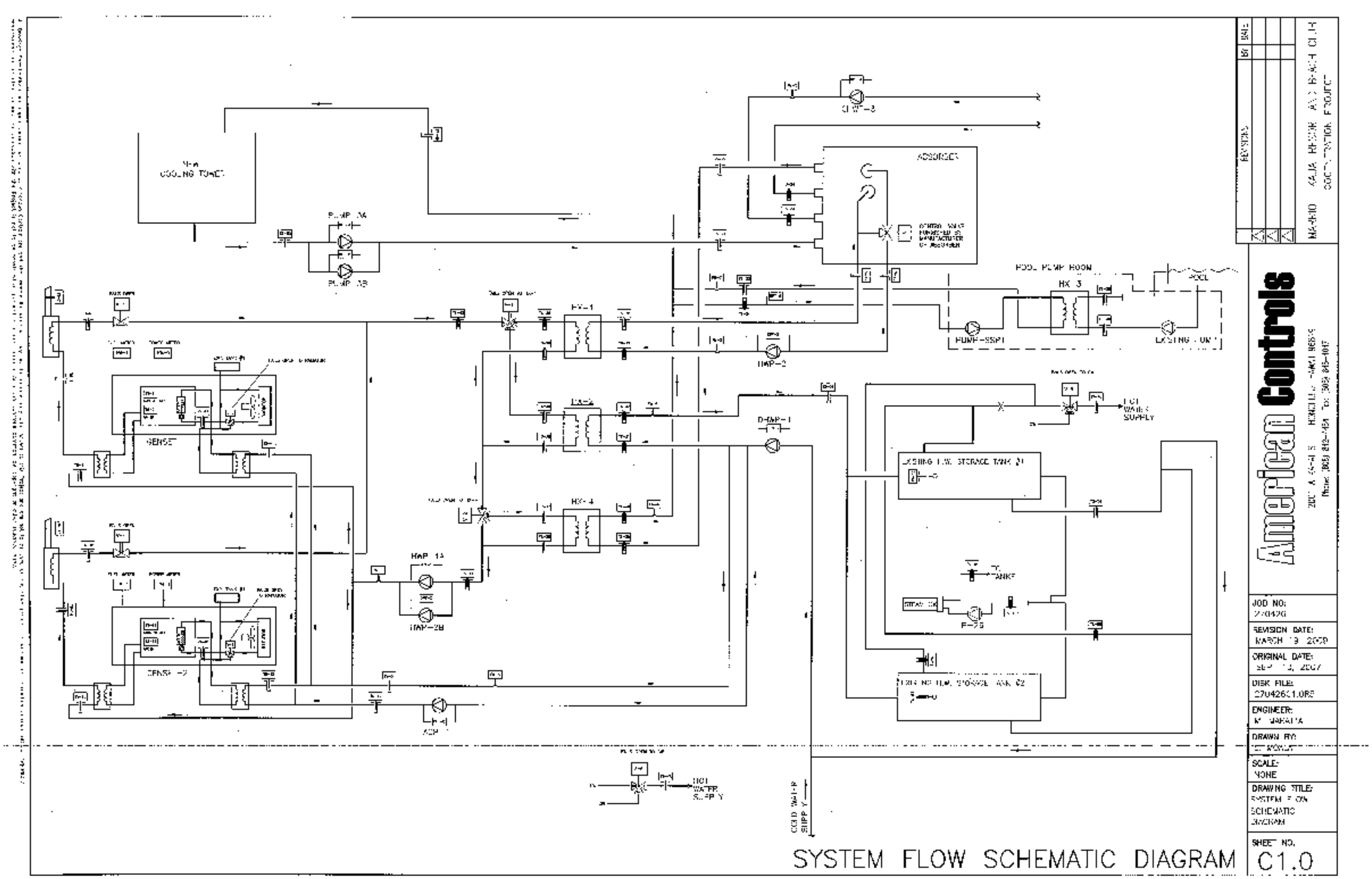
PROJECT Marriott Kauai Resort & Beach Club COGEN/CHP Pool Heating Project
LOCATION Lihue Kauai Hawaii
TITLE NEW WORK ONE-LINE DIAGRAM

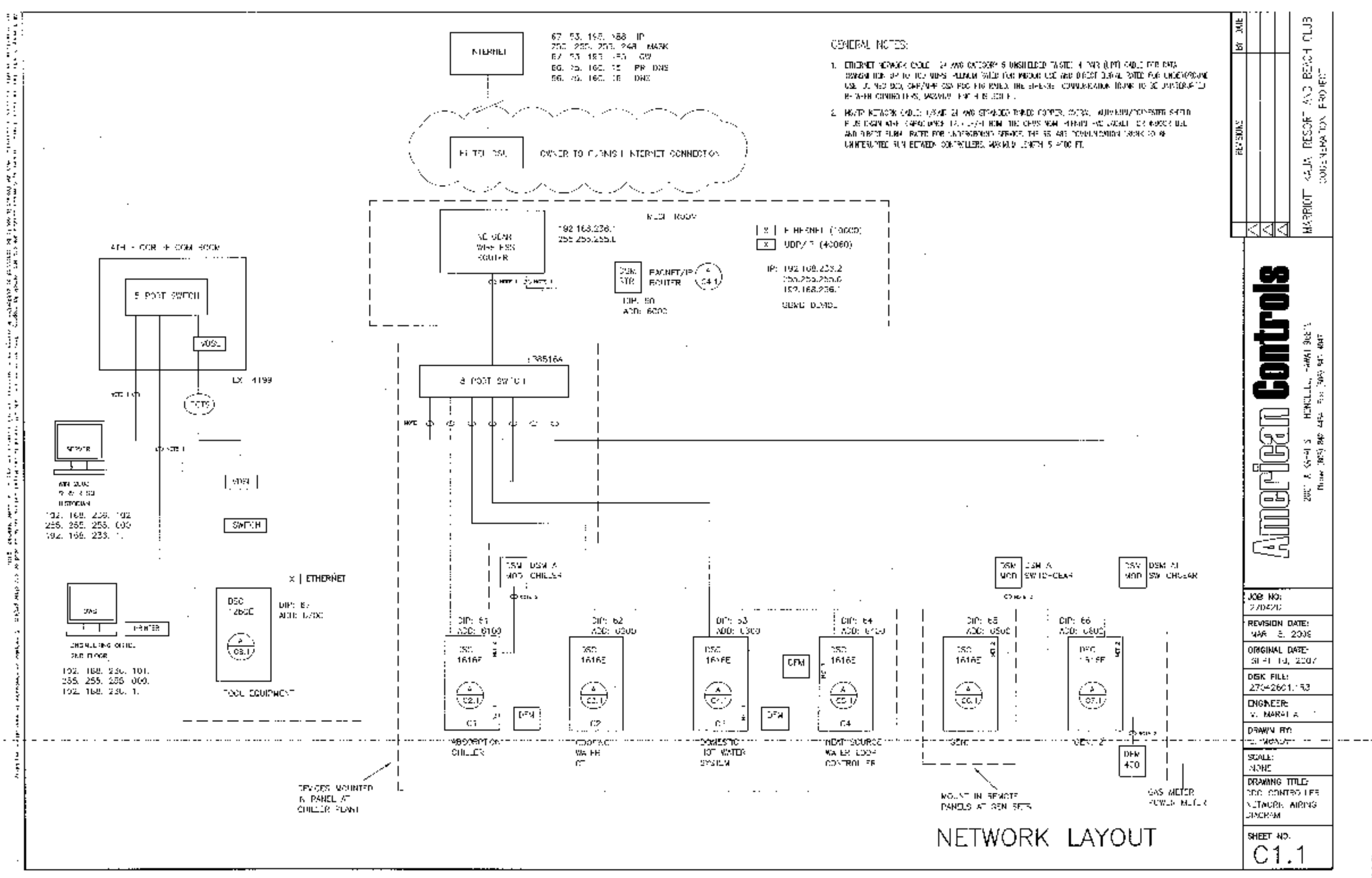
DATE 08/27/07
DRAWN JRG
CHECK RDR
SCALE As Shown

PROJECT NUMBER 3-1-8931
DRAWING NUMBER
SHEET E-4 OF

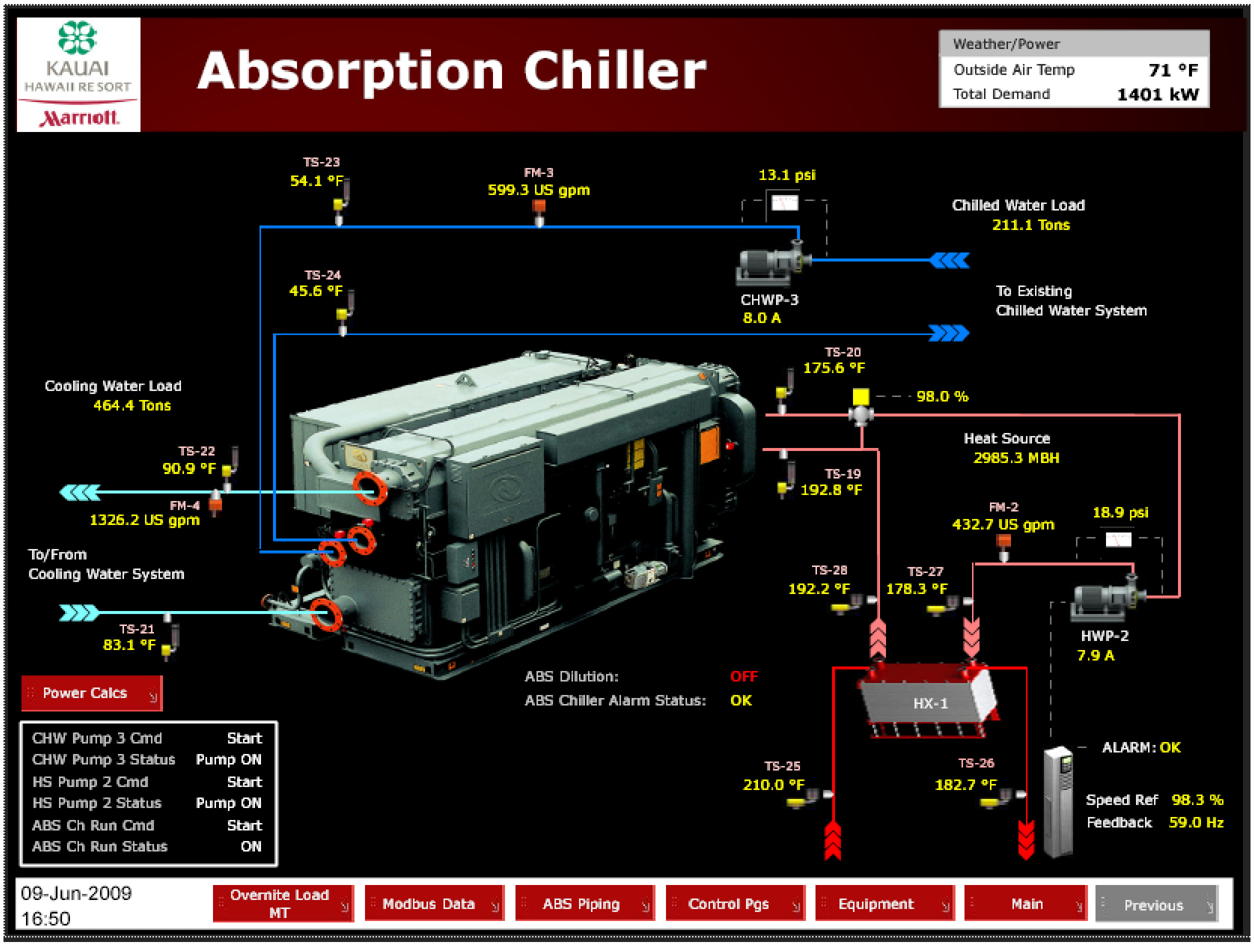

ABSORBER @ PART-LOAD
HX #1
HWP #2
10 HP
437 GPM
585 GPM
1432 GPM
ABSORBER (OPERATING w/ DOMESTIC HOT WATER DEMAND @ 100%)
SCALE: NONE
ABSORBER (OPERATING w/ ONE GENSET)
SCALE: NONE
LEGEND
TEMPERATURE SENSOR
FUEL METER
POWER METER
FLOW METER
DIFFERENTIAL PRESSURE SWITCH
DIFFERENTIAL PRESSURE TRANSMITTER
NEW COOLING TOWER
30 HP
1432 GPM
TO VFD w/ BYPASS
CHILLER RM.
PUMP #3a
50 HP
1432 GPM
PUMP #3b
50 HP
1432 GPM
ABSORBER
CHWP #3
10 HP
585 GPM
POOL
POOL PUMP RM. (STAND ALONE CONTROLS)
HX #3
1000 GPM
PUMP #SSP1
30 HP?
1000 GPM
EXT'G. PUMP
?? HP 1000 GPM
HOT WATER SUPPLY
Exhaust Muffler #1
Exhaust Muffler #2
GenSet #1
GenSet #2
CONTROL VALVE w/ INDICATOR 2-POSITION
EXP. TANK #1
EXP. TANK #2
EXP. TANK #3
EXP. TANK #4
DDC CONTROLLER
HX #1
HX #2
HX #4
DHWP #1
10 HP
320 GPM
EXT'G. H.W. STORAGE TANK #1
EXT'G. H.W. STORAGE TANK 2
NOTE:
FOR PIPING FROM NEW HX #2 TO EXT'G. STORAGE TANKS #1 & #2 & EXT'G. STEAM HX - SEE DRW'G. NO. M-11a.
STEAM HX
LOCATED IN BOILER RM.(SEE SHT. M-4)
P-26
HWP#1a
HWP#1b
10 HP
274 GPM (2 GenSets)
137 GPM (1 GenSet)
GLYCOL FEED UNIT
ADDED
ACP #1
2 HP
50 GPM
COLD WATER SUPPLY
OUTDOOR
CHILLER RM.
HW STORAGE TANK RM.
OVERALL PIPING SCHEMATIC
SCALE: NONE
NOTE:
ITEMS INDICATED WITH "**" ARE EXTRA HARDWARE REQUESTED BY GTI (GAS TECHNICAL INSTITUTE).
PERMIT SET
REVISIONS
PROJECT Marriott Kauai Resort & Beach Club COGEN/CHP Pool Heating Project
LOCATION Lihue Kauai Hawaii
TITLE OVERALL NEW PIPING SCHEMATIC
M-11

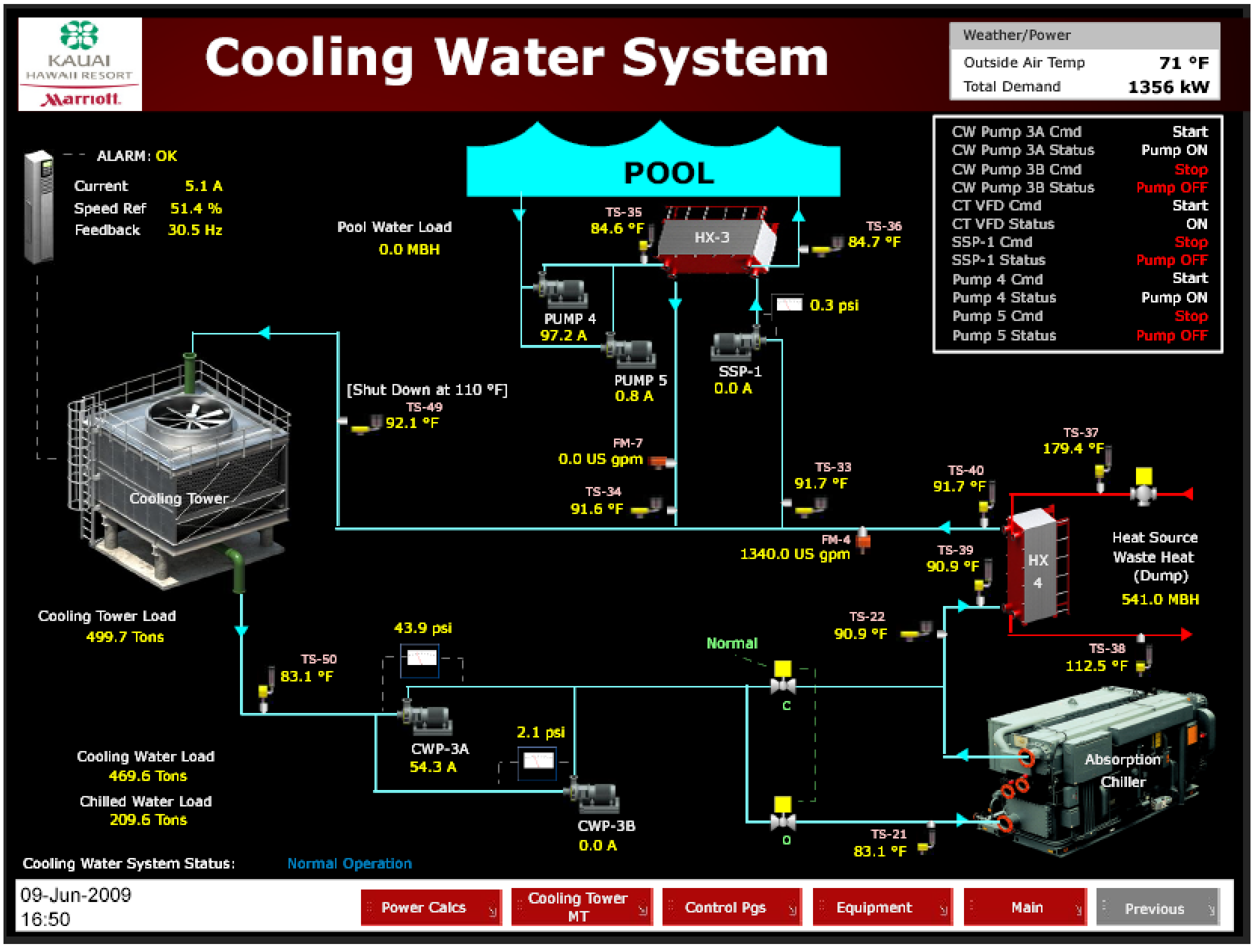

NEW HOT WATER BASIC PIPING SCHEMATIC
NEW ISOLATION VALVES
EXT'G. H.W. STORAGE TANK #1
EXT'G. H.W. STORAGE TANK #2
EXT'G. STEAM HX
LOCATED IN BOILER RM.(SEE SHT. M-4)
(EXT'G. STEAM HX TO USED AS BACKUP TO NEW HX#2)
STEAM HX
P-26
EXT'G. BOOSTER PUMP
EXT'G. EXP. TANK
V-5
HOT WATER PIPING SCHEMATIC
SCALE: NONE
PERMIT SET
PROJECT Marriott Kauai Resort & Beach Club COGEN/CHP Pool Heating Project
LOCATION Lihue Kauai Hawaii
TITLE NEW HOT WATER PIPING SCHEMATIC
DATE 08/27/07
SCALE As Shown
PROJECT NUMBER
DRAWING NUMBER
M-11a
REVISIONS


ABSORBER
PUMP 1A
PUMP 1B
GENSET
HX-1
HX-4
HX 3
HAP-2
HAP-2B
POOL PUMP ROOM
POOL
HOT WATER SUPPLY
American Controls
JOB NO:
REVISION DATE:
ORIGINAL DATE:
DISK FILE:
ENGINEER:
DRAWN BY:
SCALE:
NONE
DRAWING TITLE:
SHEET NO.
SYSTEM FLOW SCHEMATIC DIAGRAM
C1.0

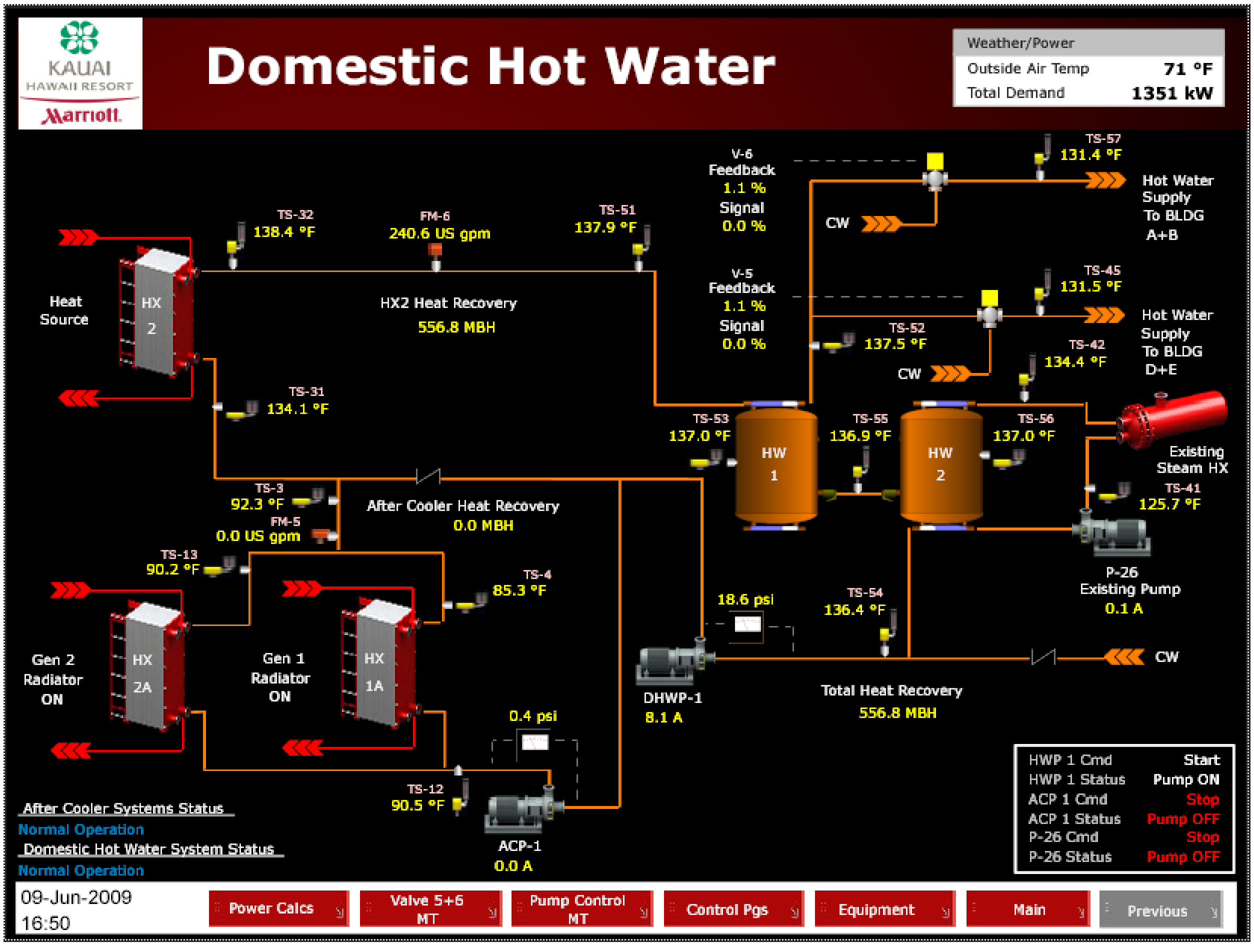

GENERAL NOTES:
INTERNET
ETHERNET
NETWORK LAYOUT
American Controls
MARRIOTT KAUAI RESORT AND BEACH CLUB
SHEET NO.
C1.1

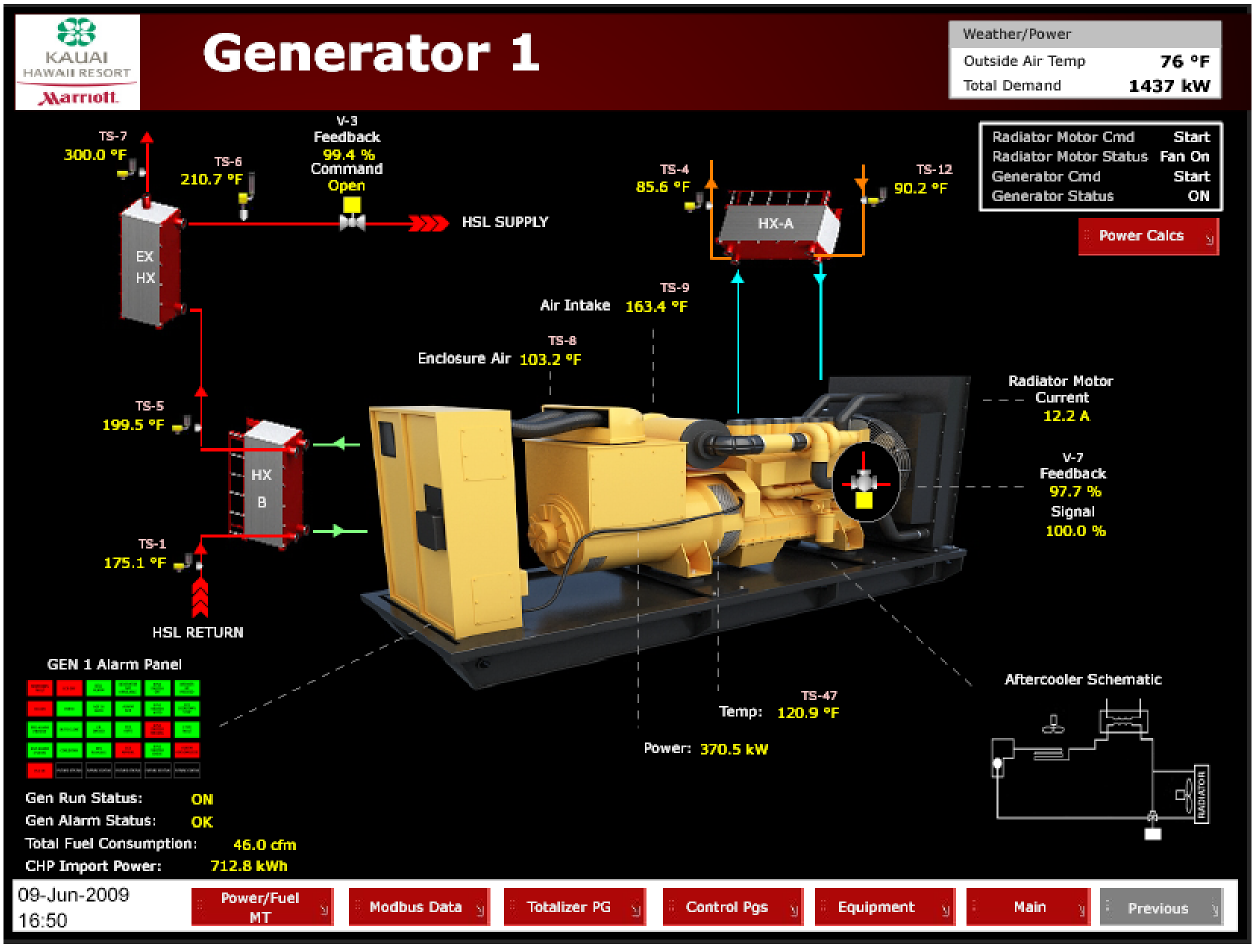
Appendix C – Web-Based Monitoring Screenshots

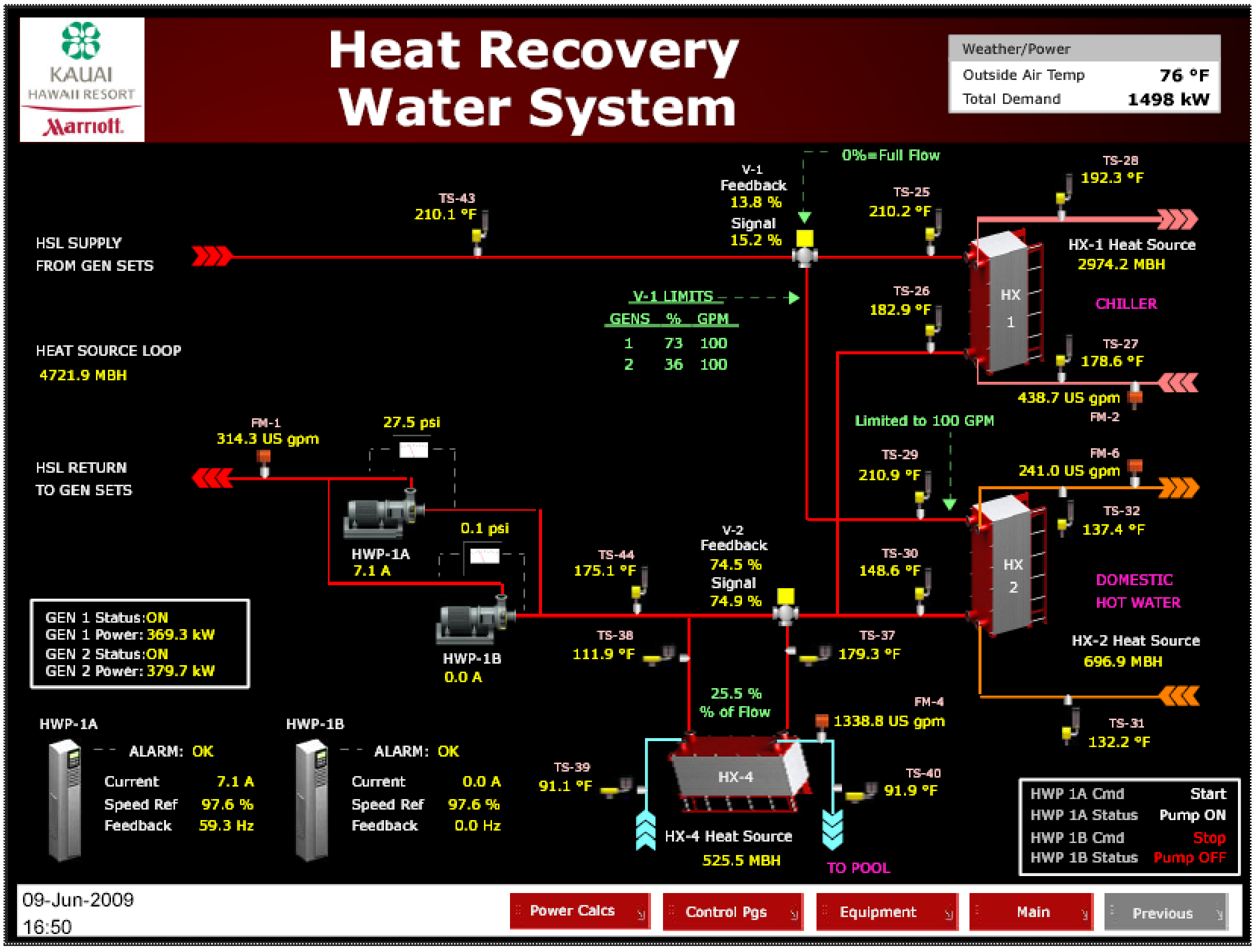


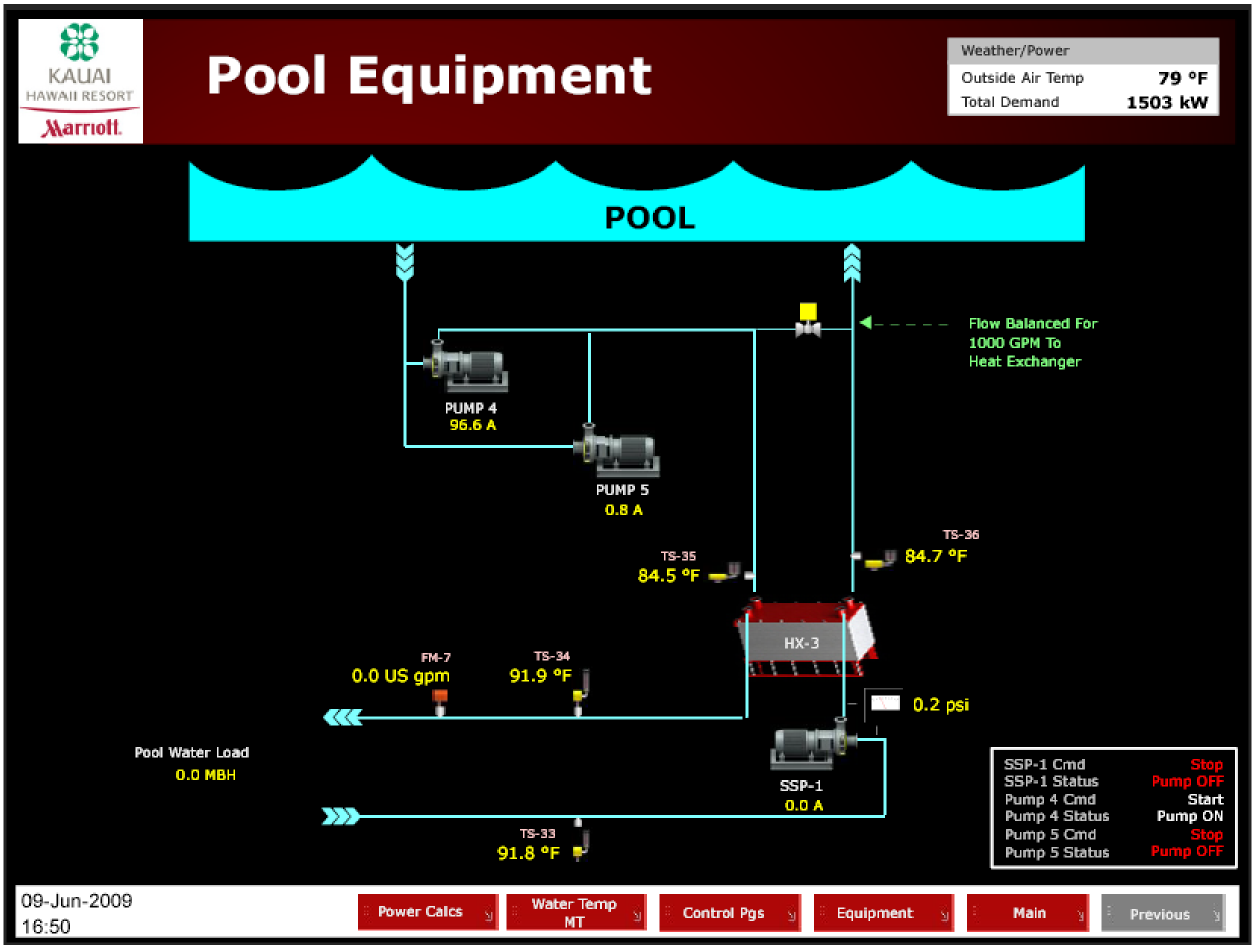


Cooling Water System
KAUAI HAWAII RESORT
Marriott
Weather/Power
Outside Air Temp 71 °F
Total Demand 1356 kW
ALARM: OK
Current 5.1 A
Speed Ref 51.4 %
Feedback 30.5 Hz
POOL
Pool Water Load
0.0 MBH
TS-35
84.6 °F
HX-3
TS-36
84.7 °F
0.3 psi
PUMP 4
97.2 A
PUMP 5
0.8 A
SSP-1
0.0 A
CW Pump 3A Cmd Start
CW Pump 3A Status Pump ON
CW Pump 3B Cmd Stop
CW Pump 3B Status Pump OFF
CT VFD Cmd Start
CT VFD Status ON
SSP-1 Cmd Stop
SSP-1 Status Pump OFF
Pump 4 Cmd Start
Pump 4 Status Pump ON
Pump 5 Cmd Stop
Pump 5 Status Pump OFF
[Shut Down at 110 °F]
TS-49
92.1 °F
FM-7
0.0 US gpm
TS-34
91.6 °F
TS-33
91.7 °F
TS-40
91.7 °F
TS-37
179.4 °F
Cooling Tower
FM-4
1340.0 US gpm
TS-39
90.9 °F
HX 4
Heat Source
Waste Heat
(Dump)
541.0 MBH
Cooling Tower Load
499.7 Tons
43.9 psi
Normal
TS-22
90.9 °F
TS-38
112.5 °F
TS-50
83.1 °F
2.1 psi
CWP-3A
54.3 A
Cooling Water Load
469.6 Tons
Chilled Water Load
209.6 Tons
CWP-3B
0.0 A
Absorption
Chiller
TS-21
83.1 °F
Cooling Water System Status:
Normal Operation
09-Jun-2009
16:50
Power Calcs
Cooling Tower MT
Control Pgs
Equipment
Main
Previous


KAUAI
HAWAII RESORT
Marriott
Domestic Hot Water
Weather/Power
Outside Air Temp 71 °F
Total Demand 1351 kW
V-6
Feedback
1.1 %
Signal
0.0 %
TS-57
131.4 °F
Hot Water
Supply
To BLDG
A+B
CW
TS-32
138.4 °F
FM-6
240.6 US gpm
TS-51
137.9 °F
Heat
Source
HX
2
HX2 Heat Recovery
556.8 MBH
V-5
Feedback
1.1 %
Signal
0.0 %
TS-45
131.5 °F
Hot Water
Supply
To BLDG
D+E
TS-52
137.5 °F
TS-42
134.4 °F
CW
TS-31
134.1 °F
TS-53
137.0 °F
TS-55
136.9 °F
TS-56
137.0 °F
HW
1
HW
2
Existing
Steam HX
TS-41
125.7 °F
TS-3
92.3 °F
FM-5
0.0 US gpm
After Cooler Heat Recovery
0.0 MBH
TS-13
90.2 °F
TS-4
85.3 °F
P-26
Existing Pump
0.1 A
18.6 psi
TS-54
136.4 °F
CW
Gen 2
Radiator
ON
HX
2A
Gen 1
Radiator
ON
HX
1A
DHWP-1
8.1 A
Total Heat Recovery
556.8 MBH
0.4 psi
HWP 1 Cmd Start
HWP 1 Status Pump ON
ACP 1 Cmd Stop
ACP 1 Status Pump OFF
P-26 Cmd Stop
P-26 Status Pump OFF
TS-12
90.5 °F
After Cooler Systems Status
Normal Operation
Domestic Hot Water System Status
Normal Operation
ACP-1
0.0 A
09-Jun-2009
16:50
Power Calcs
Valve 5+6 MT
Pump Control MT
Control Pgs
Equipment
Main
Previous


KAUAI
HAWAII RESORT
Marriott
Generator 1
Weather/Power
Outside Air Temp 76 °F
Total Demand 1437 kW
Radiator Motor Cmd Start
Radiator Motor Status Fan On
Generator Cmd Start
Generator Status ON
Power Calcs
TS-7
300.0 °F
TS-6
210.7 °F
V-3
Feedback
99.4 %
Command
Open
HSL SUPPLY
EX
HX
TS-4
85.6 °F
HX-A
TS-12
90.2 °F
Air Intake
TS-9
163.4 °F
TS-8
Enclosure Air 103.2 °F
TS-5
199.5 °F
HX
B
TS-1
175.1 °F
HSL RETURN
Radiator Motor
Current
12.2 A
V-7
Feedback
97.7 %
Signal
100.0 %
GEN 1 Alarm Panel
Aftercooler Schematic
RADIATOR
TS-47
Temp: 120.9 °F
Power: 370.5 kW
Gen Run Status: ON
Gen Alarm Status: OK
Total Fuel Consumption: 46.0 cfm
CHP Import Power: 712.8 kWh
09-Jun-2009
16:50
Power/Fuel MT
Modbus Data
Totalizer PG
Control Pgs
Equipment
Main
Previous


KAUAI
HAWAII RESORT
Marriott.
Heat Recovery
Water System
Weather/Power
Outside Air Temp 76 °F
Total Demand 1498 kW
0%=Full Flow
V-1
Feedback
13.8 %
Signal
15.2 %
TS-43
210.1 °F
TS-28
192.3 °F
TS-25
210.2 °F
HSL SUPPLY
FROM GEN SETS
HX-1 Heat Source
2974.2 MBH
V-1 LIMITS
GENS % GPM
1 73 100
2 36 100
TS-26
182.9 °F
HX
1
CHILLER
HEAT SOURCE LOOP
4721.9 MBH
TS-27
178.6 °F
438.7 US gpm
FM-2
FM-1
314.3 US gpm
27.5 psi
Limited to 100 GPM
HSL RETURN
TO GEN SETS
TS-29
210.9 °F
FM-6
241.0 US gpm
TS-32
137.4 °F
0.1 psi
HWP-1A
7.1 A
TS-44
175.1 °F
V-2
Feedback
74.5 %
Signal
74.9 %
TS-30
148.6 °F
HX
2
DOMESTIC
HOT WATER
GEN 1 Status:ON
GEN 1 Power:369.3 kW
GEN 2 Status:ON
GEN 2 Power:379.7 kW
HWP-1B
0.0 A
TS-38
111.9 °F
TS-37
179.3 °F
HX-2 Heat Source
696.9 MBH
25.5 %
% of Flow
FM-4
1338.8 US gpm
TS-31
132.2 °F
HWP-1A
ALARM: OK
Current 7.1 A
Speed Ref 97.6 %
Feedback 59.3 Hz
HWP-1B
ALARM: OK
Current 0.0 A
Speed Ref 97.6 %
Feedback 0.0 Hz
TS-39
91.1 °F
HX-4
TS-40
91.9 °F
HX-4 Heat Source
525.5 MBH
TO POOL
HWP 1A Cmd Start
HWP 1A Status Pump ON
HWP 1B Cmd Stop
HWP 1B Status Pump OFF
09-Jun-2009
16:50
Power Calcs
Control Pgs
Equipment
Main
Previous



KAUAI
HAWAII RESORT
Marriott.
Pool Equipment
Weather/Power
Outside Air Temp 79 °F
Total Demand 1503 kW
POOL
Flow Balanced For
1000 GPM To
Heat Exchanger
PUMP 4
96.6 A
PUMP 5
0.8 A
TS-35
84.5 °F
TS-36
84.7 °F
HX-3
FM-7
0.0 US gpm
TS-34
91.9 °F
0.2 psi
Pool Water Load
0.0 MBH
SSP-1
0.0 A
TS-33
91.8 °F
SSP-1 Cmd Stop
SSP-1 Status Pump OFF
Pump 4 Cmd Start
Pump 4 Status Pump ON
Pump 5 Cmd Stop
Pump 5 Status Pump OFF
09-Jun-2009
16:50
Power Calcs
Water Temp MT
Control Pgs
Equipment
Main
Previous

Appendix D – Heating Value Analysis

Major Component Gas Analysis By Gas Chromatography (ASTM D1945 / D1946)

Report Date: 19-Jun-09
Client Name: [Name]
GTI Sample Number: [#]
Sample Description: [Desc]
Date Analyzed: [Date] **Analyst:** KKF

Component	Mol %	Det. Limit	Weight %
Helium	0.0%	0.1%	0.000%
Hydrogen	0.0%	0.1%	0.00%
Carbon Dioxide	0.00%	0.03%	0.00%
Oxygen/Argon	0.00%	0.03%	0.00%
Nitrogen	0.00%	0.03%	0.00%
Carbon Monoxide	0.00%	0.03%	0.00%
Methane	0.000%	0.002%	0.000%
Ethane	0.206%	0.002%	0.140%
Ethene	0.000%	0.002%	0.000%
Ethyne	0.000%	0.002%	0.000%
Propane	96.173%	0.002%	95.390%
Propene	0.729%	0.002%	0.690%
Propadiene	0.000%	0.002%	0.000%
Propyne	0.000%	0.002%	0.000%
i-Butane	2.104%	0.002%	2.750%
n-Butane	0.788%	0.002%	1.030%
1-Butene	0.000%	0.002%	0.000%
i-Butene	0.000%	0.002%	0.000%
trans-2-Butene	0.000%	0.002%	0.000%
cis-2-Butene	0.000%	0.002%	0.000%
1,3-Butadiene	0.000%	0.002%	0.000%
i-Pentane	0.000%	0.002%	0.000%
n-Pentane	0.000%	0.002%	0.000%
neo-Pentane	0.000%	0.002%	0.000%
Pentenes	0.000%	0.002%	0.000%
Hexane Plus	0.000%	0.002%	0.000%
Hydrogen Sulfide	0.000000%	0.10%	0.00000%
Carbonyl Sulfide	N.A.	0.000005%	N.A.
Total	**100.0%**		**100.0%**

Calculated Real Gas Properties per ASTM D3588-98(03)

Temp. (°F) =	**60.0**	**60.0**	
Press. (psia) =	**14.696**	**14.73**	
Compressibility Factor [z] (Dry) =	0.98229	0.98225	
Compressibility Factor [z] (Sat.) =	0.98180	0.98176	
Relative Density (Dry) =	1.5622	1.5623	1.5622
Gross HV (Dry) (Btu/ft³) =	2580.3	2586.4	2583.3141
Gross HV (Sat.) (Btu/ft³) =	2536.7	2542.6	2539.6409
Wobbe Index =	2064.4	2069.2	
Net HV (Dry) (Btu/ft³) =	2374.4	2380.0	2377.2420
Net HV (Sat.) (Btu/ft³) =	2334.3	2339.8	2337.0526

Notes: All blank values are below detection limit
N.A. - Not Analyzed

Appendix E – Calculations

Variables and Calculated Values Table

Variable	Description	Source
HWP1A	Hot Water Pump 1A VFD Current	Data Acquisition
HWP1B	Hot Water Pump 1B VFD Current	Data Acquisition
ACP	After Cooler Water Pump 1 Current	Data Acquisition
HWP2	Heat Source Water Pump 2 Current	Data Acquisition
DHWP1	Dom Hot Water Pump 1 Current	Data Acquisition
P26	Steam Pump P26 Current	Data Acquisition
SSP1	Pool Heat Source SSP1 Motor Current	Data Acquisition
EX5	Existing Pool 5 Pump Motor Current	Data Acquisition
EX4	Existing Pool 4 Pump Motor Current	Data Acquisition
CHWP3	Chilled Water Pump 3 Current	Data Acquisition
P3A	Cooling Water Pump 3A Current	Data Acquisition
P3B	Cooling Water Pump 3B Current	Data Acquisition
CTFAN	Cooling Tower VFD Current	Data Acquisition
RAD1	Radiator Motor Current	Data Acquisition
RAD2	Radiator Motor Current	Data Acquisition
PL	Parasitic Load	Calculation
FUEL	Fuel Consumption	Calculation
ELEC	Electricity Generated	Calculation
PM1	Generator 1 Power Output	Data Acquisition
PM2	Generator 1 Power Output	Data Acquisition
FM1	Propane Fuel Consumption	Data Acquisition
FM2	Heat Source Water Flow	Data Acquisition

FM3	Chilled Water Flow	Data Acquisition
FM4	HX4 Cooling Water Loop Flow	Data Acquisition
FM5	After Cooler Loop Water Flow	Data Acquisition
FM6	HX2 Hot Water Loop Flow	Data Acquisition
FM7	HX3 Pool Loop Flow	Data Acquisition
TS3	After Cooler Loop Return Water Temp	Data Acquisition
TS12	After Cooler Loop Supply Water Temp	Data Acquisition
TS21	Cooling Water to Absorber Temp	Data Acquisition
TS22	Cooling Water from Absorber Temp	Data Acquisition
TS23	Chilled Water Return Temp	Data Acquisition
TS24	Chilled Water Supply Temp	Data Acquisition
TS27	HX1 Absorber Heat Loop Entering Water	Data Acquisition
TS28	HX1 Absorber Heat Loop Leaving Water	Data Acquisition
TS31	HX2 Entering Hot Water Temp	Data Acquisition
TS32	HX2 Domestic Hot Water Leaving Temp	Data Acquisition
TS33	HX3 Entering Cooling Water Temp	Data Acquisition
TS34	HX3 Leaving Cooling Water Temp	Data Acquisition
TS39	HX4 Entering Cooling Water Temp	Data Acquisition
TS40	HX4 Leaving Cooling Water Temp	Data Acquisition
TS43	Heat Source Loop Supply Water Temp	Data Acquisition
TS44	Heat Source Loop Return Water Temp	Data Acquisition
TS48	After Cooler Supply Water Temp	Data Acquisition
TS50	Leaving Cooling Water Temp	Data Acquisition
TS60	Outside Air Temp	Data Acquisition
HV	Propane Heating Value	Note

DHW	Heat Delivered to DHW Storage	Calculation
CT	Heat Dumped to Cooling Tower	Calculation
BH	Building Heat to Absorber Evaporator	Calculation
SP	Heat Delivered to Swimming Pool	Calculation
EXH	Heat Exhausted to Stacks	Calculation
CF	Capacity Factor	Calculation
DC	Monthly Data Point Count	Data Acquisition
UE	Useful Energy Produced	Calculation
EE	Electrical Efficiency	Calculation
SHE	Total System Boundary Heat Efficiency	Calculation
CHPE	CHP System Boundary Fuel Efficiency	Calculation
PRATE	Propane Fuel Charge	Utility
PCOST	Cost of Fuel for Power Generation	Calculation
SBRATE	Standby charge per kW of generation	Utility
SBCOST	Cost for Standby Power kW	Calculation
OMCOST	Cost of Operation & Maintenance	Calculation
ESAVE	Savings from Power Generation	Calculation
ECOST	Energy charge (over 400 kWh/kW)	Utility
DSAVE	Savings from Demand Reduction	Calculation
DCOST	Demand Charge per kW Monthly Demand	Utility
DR	Peak Demand Reduction	Data Acquisition
ABSSAVE	Savings from Absorption Cooling	Calculation
DHWSAVE	Savings from DHW Heating	Calculation
SPSAVE	Savings from Swimming Pool Heating	Calculation
BLSAVE	Bottom Line Savings	Calculation

Parasitic Load calculations

The Parasitic Load is the summation of motor and pump currents times the voltage of 480 volts, times the square root of 3, all divided by 1000 watts per kilowatt. Pumps and fans without variable frequency drives operate at 0.9 power factor.

$$PL = \left((ACP + DHWP1 + P26 + SSP1 + EX5 + EX4 + CHWP3 + P3A + P3B + RAD1 + RAD2) * 0.09 + (HWP1A + HWP1B + HWP2 + CTFAN)\right) * 0.83138$$

Energy Flow Calculations

$$FUEL = \sum \frac{FM1 * HV}{3412}$$

$$ELEC = \sum PM1 + \sum PM2$$

$$DHW = \frac{\sum\left(FM6 * 501.7 * (TS32 - TS31)\right) + \sum\left(FM5 * 501.7 * (TS3 - TS12)\right)}{3412}$$

$$CT = \frac{\sum\left(FM4 * 501.7 * (TS34 - TS50)\right)}{3412}$$

$$BH = \frac{\sum\left(FM3 * 501.7 * (TS23 - TS24)\right)}{3412}$$

$$SP = \frac{\sum\left(FM7 * 501.7 * (TS33 - TS34)\right)}{3412}$$

$$EXH = FUEL + BH + PL - ELEC - DHW - SP - CT$$

System Performance Criterion Calculations

$$CF = \frac{\sum(PM1 + PM2)}{800 * DC}$$

$$UE = ELEC + DHW + BH + SP$$

$$EE = \frac{ELEC - PL}{FUEL}$$

$$SHE = \frac{ELEC - PL + DHW + SP + BH}{FUEL}$$

$$CHPE = \frac{ELEC + PL + DHW + SP + BH}{FUEL + BH}$$

Cost to Operate Performance Criterion Calculations

$$PCOST = FUEL * PRATE$$

$$SBCOST = 810 * SBRATE$$

$$OMCOST = ELEC * 0.015$$

Savings from Operation Performance Criterion Calculations

$$ESAVE = (ELEC - PL) * ECOST$$

$$DSAVE = DR * DCOST$$

$$ABSSAVE = \frac{BH * 3412}{12000 * .065 * ECOST}$$

$$DHWSAVE = \frac{DHW}{0.75 * PCOST}$$

$$SPSAVE = \frac{SP}{0.82 * PCOST}$$

Bottom Line Savings Performance Criterion Calculations

$$BLSAVE = ESAVE + DSAVE + ABSSAVE + DHWSAVE + SPSAVE - PCOST - SBCOST - OMCOST$$

the Energy to Lead

REPORT

GTI PROJECT NUMBER: 20144/20147

ShopRite Supermarket Integrated Energy System

Report Issued:

June 2009

Prepared For:

Tom George, NETL Project Manager
National Energy Technology Laboratory (NETL)
Prime Contract No. DE-FC26-04NT42106 with NETL

Gas Technology Institute
1700 S. Mount Prospect Rd.
Des Plaines, Illinois 60018
www.gastechnology.org

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Executive Summary

As part of a DOE-sponsored program administered through the AGA's 2003 National Accounts Energy Alliance (NAEA) Testing and Verification Program, an industry need was recognized to develop efficient, clean, reliable, and cost effective advanced integrated energy systems for commercial buildings to help meet future energy demands. The NAEA specifically targeted the energy-intensive National Account chain customers in the retail, supermarket, food service, hotel, and healthcare industries in order to field test and verify the performances of advanced energy systems.

This report analyzes the potential of an Integrated Energy System (IES) configured as a Combined Heat and Power (CHP) installation at a Shoprite Supermarket on McDonald Avenue in Brooklyn, NY. This CHP system is unique in that it uses engine waste heat to drive an absorption chiller that provides subcooling to the low and medium refrigeration racks at the store. Refrigerant subcooling is a desirable cooling load for a CHP system because it occurs continuously throughout the year and displaces a significant amount of compressor demand. Specifically, a Hess Microgen 140-kW synchronous genset was installed to provide base load power for the Supermarket, while recovered heat was used to indirectly fire a 20-ton Yazaki absorption chiller. The chilled water was used to provide subcooling for the store's refrigeration system. This configuration aimed to maximize generator power output, while recovering maximum thermal energy from the engine.

On average, the ShopRite CHP system was able lower the supermarket monthly electric consumption by 52,000 kWh with monthly reductions ranging from 30,609 kWh to 72,339 kWh. The average overall thermal efficiency of the system was 53% with the monthly values ranging from 42% to 66%. The cumulative CHP system operating cost was $45,513 and the electric utility cost savings were $46,214 for a small savings of $701 recorded over six month of operation. The bottom line savings were strongly affected by spike in natural gas prices which averaged ~$14.0 per MMBtu during the six month testing period.

Introduction

Background

As part of a DOE-sponsored program administered through the AGA's 2003 National Accounts Energy Alliance (NAEA) Testing and Verification Program, an industry need was recognized to develop efficient, clean, reliable, and cost effective advanced integrated energy systems for commercial buildings to help meet future energy demands. The NAEA specifically targeted the energy-intensive National Account chain customers in the retail, supermarket, food service, hotel, and healthcare industries in order to field test and verify the performances of advanced energy systems.

The goal of the specific project described in this report was to demonstrate the technical and economic viability of an Integrated Energy System (IES) configured as a Combined Heat and Power (CHP) installation at a ShopRite Supermarket in Brooklyn, NY. Specifically, by demonstrating that IES can economically utilize heat recovered from a power generator engine in an absorption chiller system that will provide subcooling for the refrigeration racks.

Electric use and demand charges in supermarkets are attributable primarily to the operation of the refrigeration systems, with contributions from HVAC and lighting. Because these loads represent such a large component of the total energy usage, an IES application that can lower refrigeration system loads can provide significant benefits to the supermarket industry and local electric utilities.

Supermarkets operate with very low profit margins, with their energy costs consuming almost half of their profit. Any reduction in their energy costs would directly affect their net profit. The combination of on-site cogeneration with absorption cooling provides the greatest potential to reduce their peak demand for refrigeration, while also providing protection against power outages that can cause thousands of dollars in product losses. A typical supermarket has a summer peak of 500 - 600 kW where 100 - 150 kW of this peak occurs from 10 am to 8 p.m. Consequently, there is a potential to reduce summer peaks with an IES application, which can result in reduced peak demand throughout the year. This approach can cost-effectively meet the supermarket's reliability/outage protection requirements, while saving energy and reducing operating costs.

Host Site

Growing from a small, struggling cooperative with seven members – who each owned their own grocery store – ShopRite has evolved into the largest retailer-owned cooperative in the United States, and the largest employer in New Jersey. The cooperative today is comprised of 43 members who individually own and operate supermarkets under the ShopRite banner. Today, more than 50,000 people are employed by Wakefern Food Corporation, the merchandising and distribution arm of the company, and the 190 ShopRite stores in New Jersey, New York, Connecticut, Pennsylvania and Delaware.

The 50,000-square-foot Brooklyn ShopRite store, owned and operated by Glass Gardens Inc., sits on a major thoroughfare in the densely populated neighborhood of Borough Park in Brooklyn NY. The store is open 24 hours, 7 days a week.

The Store's electric demand peaks at 550 kW and drops as low as 300 KW at night. The variable portion of the load is due to 75 kW of additional lighting and equipment loads during the day (6 am to 8 pm). The remaining 175 kW is assumed to be ambient temperature dependent refrigeration and space cooling loads, varying from 0 kW at 50ºF up to 175 kW at 95ºF.

System Configuration and Operation

The CHP system at ShopRite is based on a natural gas fueled, 140 kW synchronous Hess Microgen system (see Appendix B) installed in the store's basement parking garage (see Figure 1). Electricity is produced in parallel with the utility grid though all of the energy is consumed on-site. Heat recovered as hot water from the engine coolant jacket and exhaust is used to operate a 20 RT Yazaki absorption chiller (see Appendix B) or rejected to atmosphere depending on immediate needs. Chilled water from the absorption machine is circulated in series with an electric chiller and used to sub-cool liquid refrigerant being distributed to the display cases. This produces a low temperature refrigeration effect equal to the amount of cooling provided by the absorption chiller. The chilled water can also be circulated through the engine intercooler to enhance performance. Figure 2 provides detailed diagram showing system configuration.

During a power outage the synchronous generator can be operated grid-isolated, serving various dedicated loads in the store that include:

- Selected Low and Medium Temperature Refrigeration Compressors
- Corresponding Refrigerator/Freezer Cases and Roof-top Condensers

The major components that make up the overall CCHP system include:

- Hess 140 kW Synchronous Genset
- Drake Electric Intercooler Chiller
- Yazaki 20RT Absorption Chiller
- Witt Balance Radiator
- Evapco Cooling Tower
- Subcooling Heat Exchangers
- ASCO Series 7000 Automatic Transfer Switch

Figure 1 – ShopRite IES Partial Floor Plan Equipment Layout

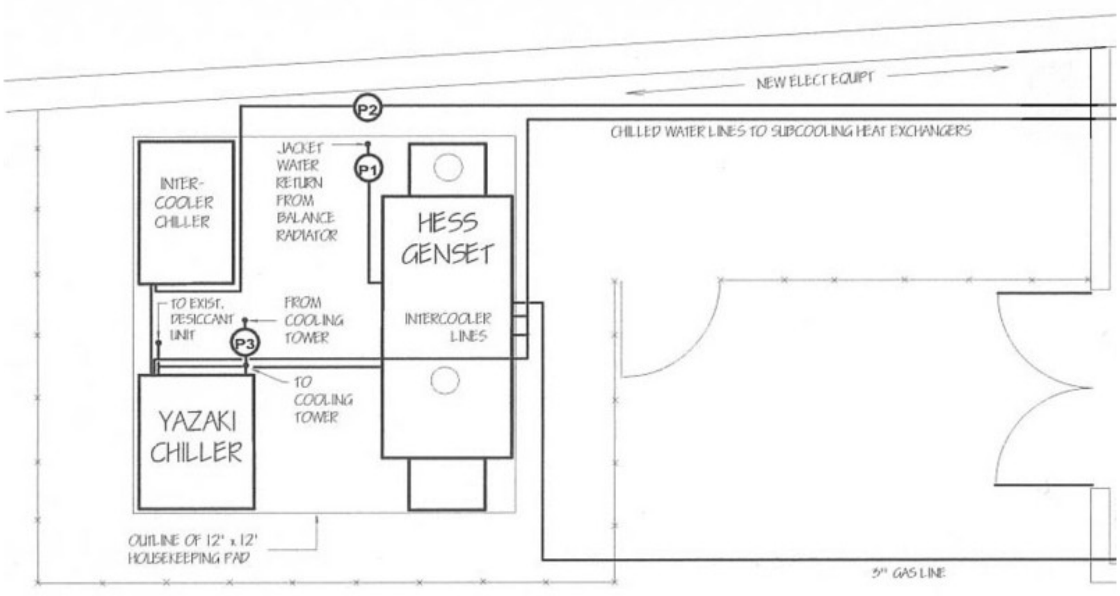
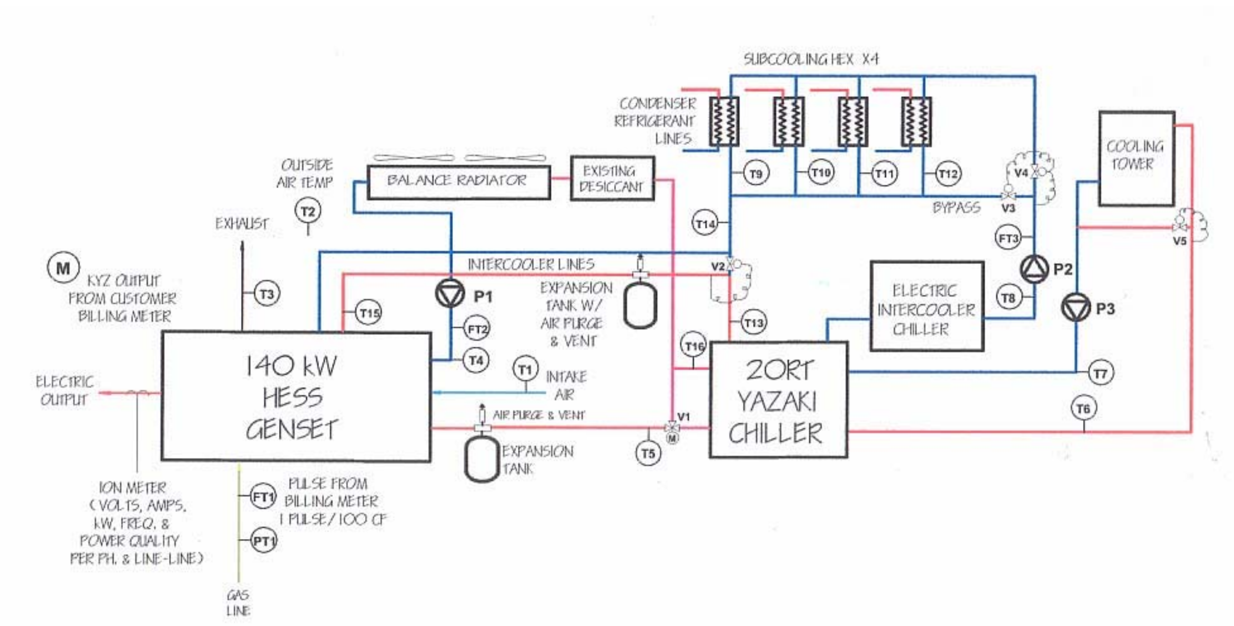


Figure 2 – ShopRite IES Configuration Diagram



The Hess unit is controlled using a dedicated PC that has the Hess Nexgen Operator Program v3.05d software installed. Once the PC is connected to a router inside the Hess control cabinet, the operator can lunch the Nexgen program and establishes a connection to the Nexgen controller. After the generator is commanded to start, the Hess controls activate the Heat Medium Pump (P1), the Chilled Water Pump (P2), the Balance Radiator Fans and the Drake Electric Chiller that is initially used to provide cooling for the engine's Intercooler. Once the Hess engine is started and proper voltage and frequency is being produced by the generator, the ASCo Automatic Transfer Switch transfers the dedicated loads off of the utility electric service and onto the CHP System (see Figure 3).

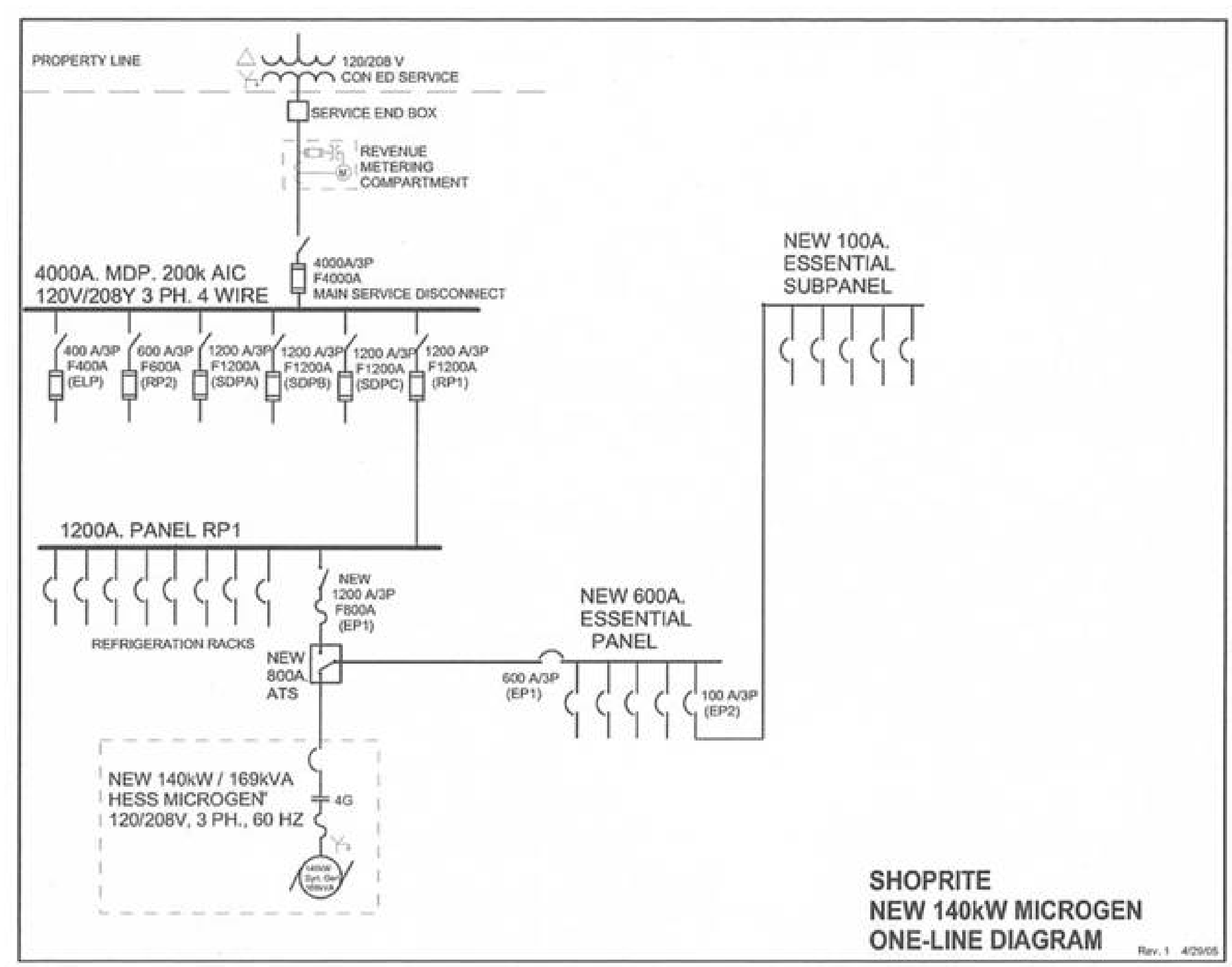
As the Hess generator picks up load, the engine and exhaust waste heat is transferred to the Heat Medium loop and used to thermally activate the Yazaki absorption chiller. Once this loop is up to the required minimum temperature the Yazaki Chiller is started. The Chiller controls then energize the Cooling Water Pump (P3). As the absorption chiller begins to pick up load, the Drake Chiller cycles off. The chilled water produced by the absorption chiller is then be directed to four (4) subcooling Heat Exchangers that sub-cool liquid refrigerant on four (4) low and medium temperature refrigeration racks located inside the equipment room adjacent to the CHP system. Heat extracted from the liquid refrigerant is transferred to the Chilled Water loop. The Chiller then transfers this heat to the Condenser Water loop. This thermal energy is then rejected to the atmosphere using the rooftop Evapco Cooling Tower.

In the event that the entire engine's thermal output is not fully consumed by the absorption chiller, a rooftop Balance Radiator rejects any excess thermal energy to keep the Engine's jacket water at proper operating temperature.

The ShopRite IES CHP system was designed to operate 24/7 year-round. Planned shutdowns for maintenance will be scheduled off-hours or in conjunction with the testing of the store's existing

100 kW emergency generator in an effort to minimize any impact to ShopRite's peak electric demand.

Figure 3 – ShopRite IES Electric Line Diagram



Data Acquisition and Performance Indicators

Connected Energy Inc. (CE) data acquisition system provided data for the ShopRite site performance monitoring and evaluation via comma-separated variable (CSV) files uploaded once a day. The data set consists of 90 channels. The data are provided at 15-minute intervals. The data set includes channels for electrical generation, heat recovery performance and power quality parameters for the generator and loop equipment. Figures 4 to 7 show details of the user interface and include a site overview screen (Figure 4), engine-generator (Figure 5), heat recovery – chiller (Figure 6), and generated power quality screen (Figure 7).

Figure 4 – ShopRite Web-Based Monitoring – Site Overview Interface

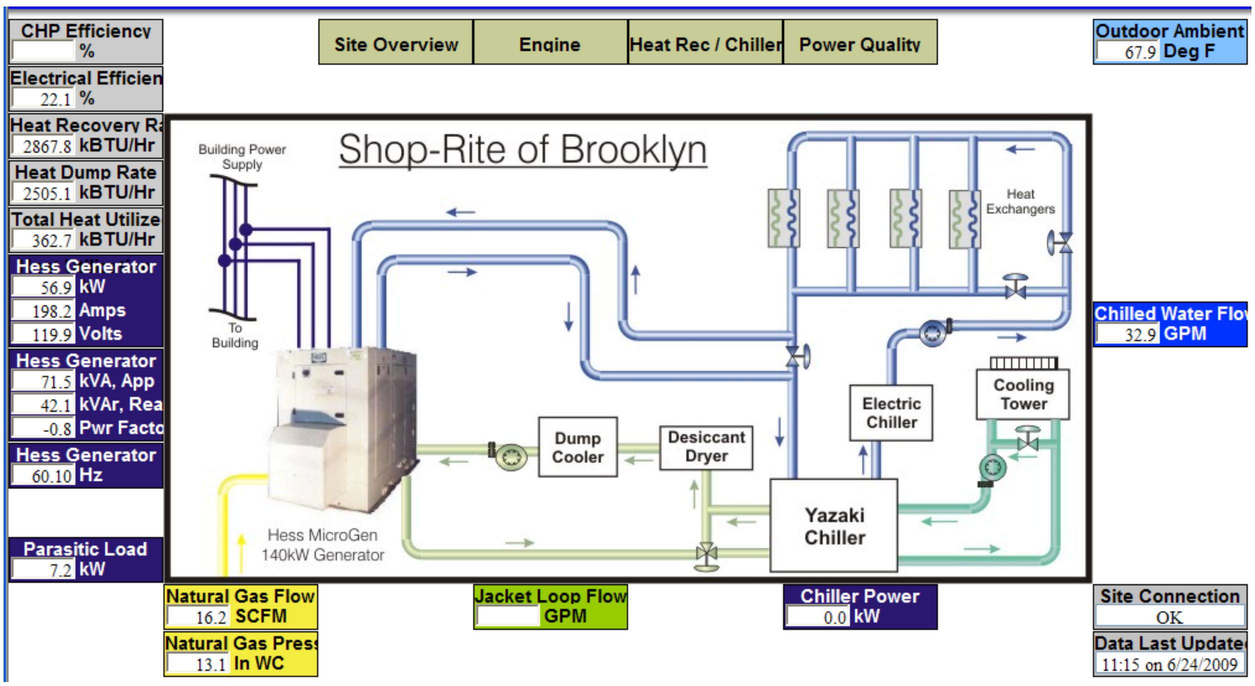


Figure 5 – ShopRite Web-Based Monitoring – Engine-Generator Interface

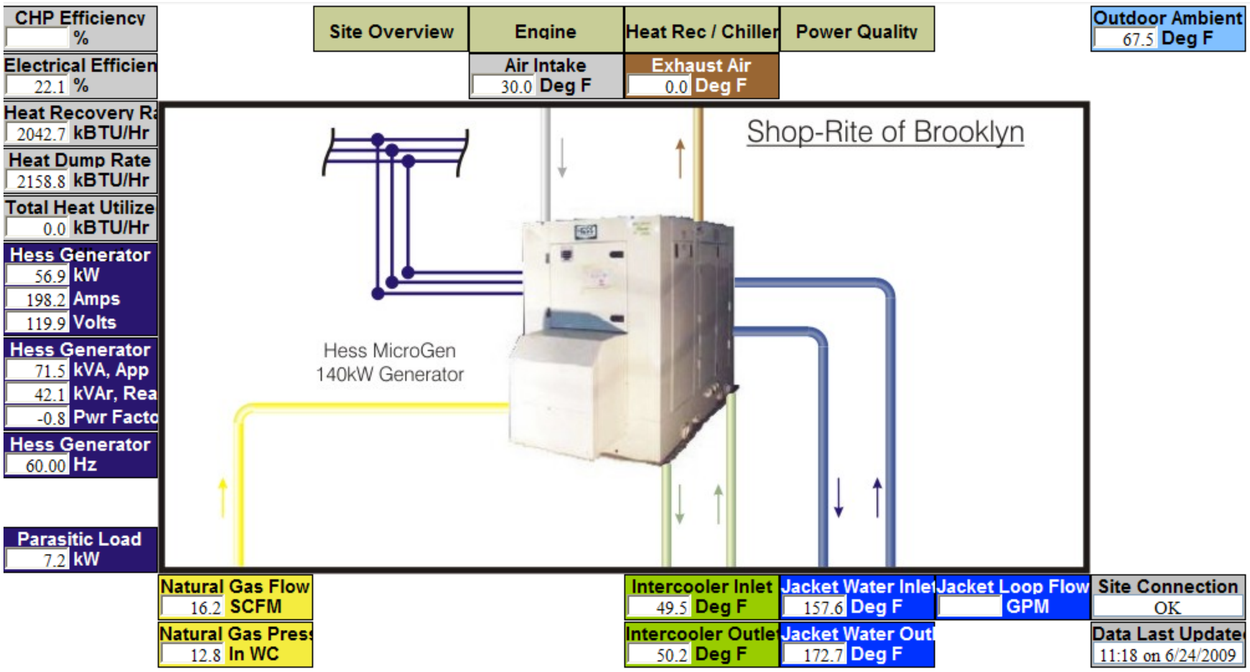


Figure 6 – ShopRite Web-Based Monitoring – Heat Recovery - Chiller Interface

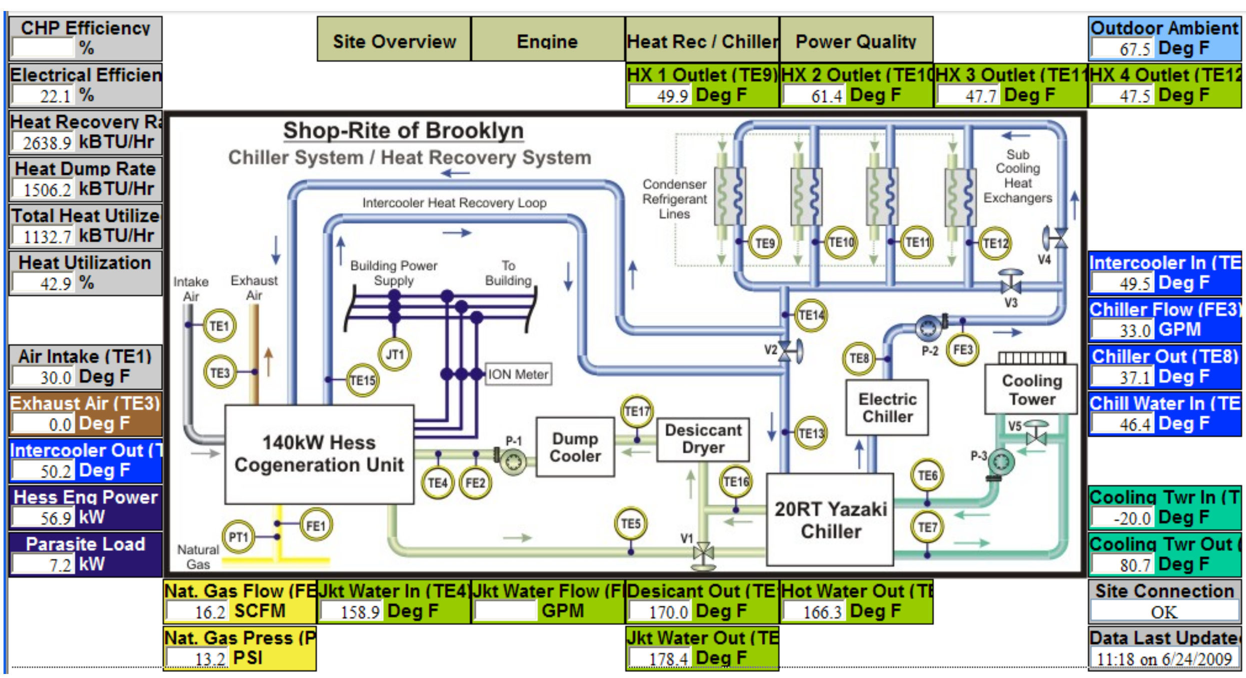
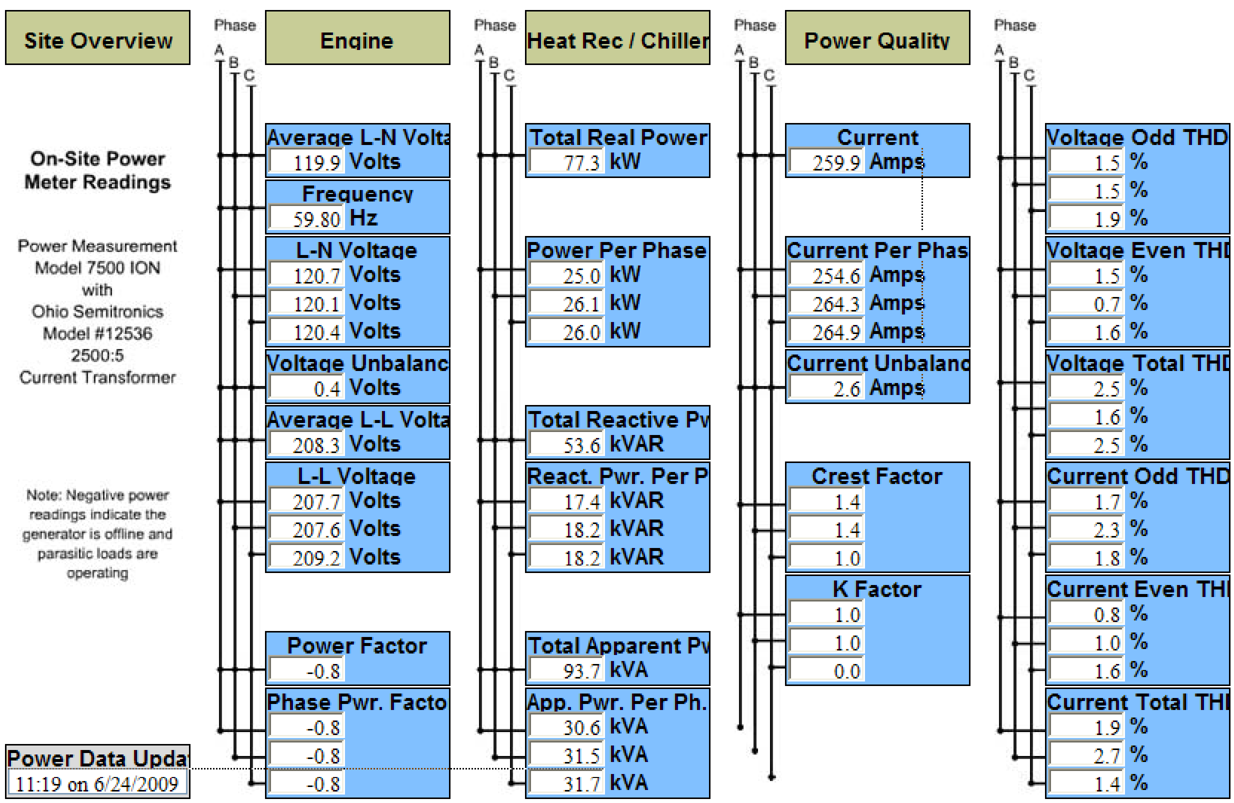


Figure 7 – ShopRite Web-Based Monitoring – Power Quality Interface



The relevant ShopRite system performance data collected by the data acquisition system as well as that being calculated are summarized in Table 1. Table 2 shows additional details related to the system heating loads calculations and following pages 10 and 11 provide supplemental definitions for more important collected and calculated data/parameters.

Table 1 – ShopRite Web-Based Monitoring - Integrated Data Channels

Integrated Data System Channel	Units of Measure	Raw Data Column Descriptions [col][1]	Raw Data Units	Calculation Formula
DG/CHP Generator Output	kWh/int	Generator Total Energy Product [BW]	kWh	$=[BW]$
DG/CHP Generator Output Demand	KW/int	Generator Power, Total [BX]	kW	$=[BX]$
DG/CHP Generator Gas Input	cuft/int	Natural Gas to Engine Cumul [C]	cuft	$=[C]$
Total Facility Purchased Energy	kWh/int	N/A	N/A	N/A
Total Facility Purchased Demand	KW	N/A	N/A	N/A
Other Facility Gas Use	cuft/int	N/A	N/A	N/A
Total Facility Energy	kWh/int	Calculated		
Total Facility Demand	kW	Calculated		
Useful Heat Recovery	MBtu/int	Total Heat Used Rate [AC]	MBtu/h	$=[AC]*$ 15 minutes/int ÷ 60 minutes/hour
Unused Heat Recovery	MBtu/int	Dump Cooler Heat Dump Rate [AD]	MBtu/h	$=[AD]*$ 15 minutes/int ÷ 60 minutes/hour
Status/Runtime of DG/CHP Generator	Hours/int	Calculated		
Ambient Temperature	°F	Outdoor Ambient Temp [L]	°F	$=[L]$
Total CHP Efficiency	% LHV	Calculated	N/A	
Electrical Efficiency	% LHV	Calculated	N/A	

[1] – The Raw Data Column Description is from the Connected Energy CSV files. The corresponding column id (i.e., A,B,C…) is given in square brackets and shown in the calculation formulas.
Int - interval

Table 2 – ShopRite Web-Based Monitoring – Heating Loads Calculations

Channel Name [Label][1]	Corroborating Columns [Label][1]	Corroborating Formula	Passed Check
Total Heat Used Rate [AC]	Engine Jacket Water Flow [E], Jacket Water Outlet Temp [P], Desiccant Outlet Temp [AB]	$=([P]-[AB])*0.5*[E]$	Yes
Dump Cooler Heat Dump Rate [AD]	Engine Jacket Water Flow [E], Jacket Water Inlet Temp [O], Desiccant Outlet Temp [AB]	$=([AB]-[O])*0.5*[E]$	Yes
Cogen Heat Recovery Rate [AI]	Engine Jacket Water Flow [E], Jacket Water Inlet Temp [O], Jacket Water Outlet Temp [P]	$=([P]-[O])*0.5*[E]$	Yes
Total Electrical Efficiency [BG][2]	Natural Gas to Engine Cumul [C], Total Heat Used Rate [AC], Generator Total Energy Product [BW]	$=\frac{[BW]*3.413}{[C]*0.930}$	Yes
Total CHP Efficiency [BF][2]	Natural Gas to Engine Cumul [C], Total Heat Used Rate [AC][3], Generator Power – Total [BX]	$=\frac{[BW]*3.413+[AC]/4}{[C]*0.930}$	Yes

[1] – The Raw Data Column Description listed is from the Connected Energy CSV files, the corresponding column label from Excel is in square brackets and used for reference in the calculation formula.
[2] – A Lower Heating Value (LHV) for natural gas of 0.930 Mbtu/scf was assumed for Natural Gas in these calculations.
[3] – The Heat Rate is divided by 4 to calculate the MBtus recovered per interval (see Table 1).

DG/CHP Generator Output (total kWh)

The data for Generator Output comes from a 15-minute accumulator for the power produced by the engine. The column of origin for this data point is labeled “Generator Total Energy Product” in the data files received from Connected Energy. The difference between consecutive records is assigned as the energy produced by the engine for that interval. This 15-minute energy data is then summed into hourly data.

DG/CHP Generator Output Demand (peak kW)

The data for Generator Output comes from a 15-minute average for the generator demand. The column of origin for this data point is labeled “Generator Power, Total” in the data files received from Connected Energy. The maximum for a given hour is assigned to the hourly database.

DG/CHP Generator Gas Input (cubic feet)

The data for Generator Gas Input comes from a 15-minute accumulator for gas flow. The column of origin for this data point is labeled “Natural Gas to Engine Cumulative” in the data files received from Connected Energy. The difference between consecutive records is assigned as the gas consumed by the engine for that interval. This 15-minute gas data is then summed into hourly data.

Total Facility Purchased Energy (total kWh)

Collected directly from facility operator/owner.

Total Facility Purchased Demand (peak kW)

Collected directly from facility operator/owner.

Other Facility Gas Use (cubic feet)

Collected directly from facility operator/owner.

Total Facility Energy (total kWh) and Total Facility Demand (peak kW)

These two data points are the sum of the DG/CHP Generator Output and Total Facility Purchased data points. Since the Total Facility Purchased data points are not available, this channel cannot be calculated.

Unused Heat Recovery (total MBtu/h)

The Unused Heat Recovery comes from the 15-minute average for dump cooler heat rate. The column of origin for this data point is labeled “Dump Cooler Heat Dump Rate” in the data files received from Connected Energy. The rate data is converted to energy, in MBtu, for the interval and then summed into hourly data.

Useful Heat Recovery (total MBtu/h)

The Unused Heat Recovery comes from a 15-minute average for the utilized heat recovery rate. The column of origin for this data point is labeled “Total Heat Used Rate” in the data files received from Connected Energy. The rate data is converted to energy, in MBtu, for the interval and then summed into hourly data.

Status/Runtime of DG/CHP Generator (hrs)

The engine is defined as being fully on for a 15-minute interval if the engine power output is greater than 1 kW for the period (the fully-loaded capacity is approximately 75 kW). The status is given a value of 0.25 if the generator output is above 1 kW and the status is assigned 0.0 if it is below for each of the three generators. These status values are then summed for each 15-minute interval and then summed into hourly data for the online database.

Ambient Temperature (average °F)

The Ambient Temperature comes from a 15-minute average for outdoor temperature. The column of origin for this data point is labeled “Outdoor Ambient Temp” in the data files received from Connected Energy. The 15-minute average temperature is averaged into hourly data for the online database.

Total CHP Efficiency (%)

The Total CHP Efficiency is calculated from the online hourly database as the sum of the Useful Heat Recovery and the DG/CHP Generator Output, converted from kWh to MBtu, divided by the DG/CHP Generator Gas Input. The gas input is converted to MBtu using the Lower Heating Value (LHV) of the fuel which is 0.930 MBtu/cubic foot (Natural Gas).

Electrical Efficiency (%)

The Electrical Efficiency is calculated from the online hourly database as the DG/CHP Generator Output, converted from kWh to MBtu, divided by the DG/CHP Generator Gas Input. The gas input is converted to MBtu using the Lower Heating Value (LHV) of the fuel which is 0.930 MBtu/cubic foot (Natural Gas).

Field Monitoring Results

Field Monitoring Objectives

An on-site CHP monitoring system was developed to measure system operating parameters and calculate the overall mechanical and economical performance of the system in its real-world environment. Specifically, the on-site test objectives were to define, on a monthly basis, the following key parameters:

1. System Performance
2. Cost to Operate
3. Savings from Operation
4. Bottom Line Savings (net savings)

Field Monitoring – System Performance

The following results summarize the six months on-site ShopRite CHP monitoring program and define the overall energy efficiency and economics of the system in its real-world environment. Monthly operating performance details in tabular format are provided in Figures 8 through 13. Summaries of the monthly performance data are provided in Table 3. On average, the ShopRite CHP system was able lower the supermarket monthly electric consumption by 52,000 kWh with monthly reductions ranging from 30,609 kWh to 72,339 kWh. The average overall thermal efficiency of the system was 53% with the monthly values ranging from 42% to 66%. The cumulative CHP system operating cost was $45,513 and the electric utility cost savings were $46,214 for a small savings of $701 recorded over six month of operation. The bottom line savings were strongly affected by spike in natural gas prices which averaged ~$14.0 per MMBtu during the six month testing period.

Table 3 – ShopRite CHP System Performance Monthly Details

System Parameters	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09
Electricity generated kWh	**40,526**	**41,152**	**37,621**	**28,095**	**31,903**	**21,580**
Refrigeration Reduction kWh	**31,813**	**22,977**	**18,722**	**16,491**	**13,615**	**9,029**
Total Grid Load Reduction kWh	**72,339**	**64,129**	**56,343**	**44,586**	**45,518**	**30,609**
Fuel consumption therms	6,202	6,298	6,062	4,660	5,076	4,047
Heat recovered from generator therms	2,701	1,951	1,589	1,762	1,455	965
Power Generation Thermal Efficiency % HHV	**22.3%**	**22.3%**	**21.2%**	**20.6%**	**21.4%**	**18.2%**
CHP System Thermal Overall Efficiency % HHV	**65.8%**	**53.3%**	**47.4%**	**58.4%**	**50.1%**	**42.0%**
Avoided Electric Utility Costs $	10,598	9,395	8,254	6,532	7,267	4,168
Operating Costs $	9,163	9,305	8,956	6,886	6,234	4,969
Bottom line savings $	**1,434.70**	**90.37**	**(701.92)**	**(353.78)**	**1,032.82**	**(801.33)**

Figure 8 - November 2008 BCHP Operating Performance Details

ShopRite of Brooklyn
Energy Savings For November 2008

ENERGY DELIVERED		From	**Nov 1**	to	**Nov 30**				
ELECTRIC					**THERMAL**				
Energy	40,526.2	kWh			270,056.0	kBtu			
Power (Avg.)	56.2	kW			2,700.6	therms			
ENERGY CONSUMED		From	**Nov 1**	to	**Nov 30**				
GAS					Therm Factor				
	602,300.0	scf		X	1.0297		=	**6,201.9**	therms
AVOIDED ENERGY COSTS									
DELIVERY - Con Ed Service Classification RA9 Rider J1 General Large Bus. Incentive Meter # 51545									
Generation Delivery Reduction					$/kWH			Costs	
40,526.2	kWh	X			0.0385			1,560.26	
Subcooling Delivery Reduction									
31,813.0	kWh	X			0.0385			1,224.80	
COMMODITY - Con Ed Solutions Meter # 5154529									
Generation Commodity Reduction					$/kWH				
40,526.2	kWh	X			0.108004			4,376.99	
Subcooling Commodity Reduction									
31,813.0	kWh				0.108004			3,435.93	
				Avoided Electric Charges				**10,597.98**	
Demand Reduction					$/kW				
0	kW								
				Avoided Demand Charges				0.00	
						Total	=	**$10,597.98**	
THERMAL - NGrid Rate T2-2 - Tran General									
Gas Displaced									
0.0	th. =	therms							
75% Eff.									
OPERATING ENERGY COST - NGrid Rate 4A - High Load Factor (Over 1,000 therms)									
Gas Consumed		From	**Nov 1**	to	**Nov 30**	Bill Date:			
6,201.9	therms	X	$1.4775	/therm			=	**$9,163.28**	
NET SAVINGS			**PERFORMANCE**						
Avoided Elect. Cost	10,597.98		Elect. Eff. =	22.3	% HHV				
Gas Displaced	0.00		Elect. Eff. =	24.8	% LHV				
Total Avoided Costs	10,597.98		CHP Eff. =	65.8	% HHV				
Less Operating Cos	9,163.28		CHP Eff. =	73.2	% LHV				
Net Savings	**$1,434.70**								

Figure 9 - December 2008 BCHP Operating Performance Details

ShopRite of Brooklyn
Energy Savings For December 2008

ENERGY DELIVERED		From	**Dec 1**	to	**Dec 31**			
ELECTRIC					**THERMAL**			
Energy	41,151.9	kWh			195,051.0	kBtu		
Power (Avg.)	55.3	kW			1,950.5	therms		

ENERGY CONSUMED		From	**Dec 1**	to	**Dec 31**				
GAS					Therm Factor				
	611,600.0	scf		X	10297		=	**6,297.6**	therms

AVOIDED ENERGY COSTS

DELIVERY - Con Ed Service Classification RA9 Rider J1 General Large Bus. Incentive Meter # 5154

Generation Delivery Reduction			$/kWH		Costs
41,151.9	kWh	X	0.0385		1,584.35
Subcooling Delivery Reduction					
22,977.0	kWh	X	0.0385		884.61

COMMODITY - Con Ed Solutions Meter # 5154529

Generation Commodity Reduction			$/kWH		
41,151.9	kWh	X	0.108004		4,444.57
Subcooling Commodity Reduction					
22,977.0	kWh		0.108004		2,481.61
				Avoided Electric Charges	**9,395.14**
Demand Reduction			$/kW		
0	kW				
				Avoided Demand Charges	0.00
				Total =	**$9,395.14**

THERMAL - NGrid Rate T2-2 - Tran General

Gas Displaced			
0.0	th.	=	therms
75% Eff.			

OPERATING ENERGY COST - NGrid Rate 4A - High Load Factor (Over 1,000 therms)

Gas Consumed		From	**Dec 1**	to	**Dec 31**	Bill Date:		
6,297.6	therms	X	$1.4775	/therm			=	**$9,304.77**

NET SAVINGS		**PERFORMANCE**		
Avoided Elect. Cost	9,395.14	Elect. Eff. =	22.3	% HHV
Gas Displaced	0.00	Elect. Eff. =	24.8	% LHV
Total Avoided Costs	9,395.14	CHP Eff. =	53.3	% HHV
Less Operating Cos	9,304.77	CHP Eff. =	59.2	% LHV
Net Savings	**$90.37**			

Figure 10 - January 2009 BCHP Operating Performance Details

ShopRite of Brooklyn
Energy Savings For January 2009

ENERGY DELIVERED			From		**Jan 1**	to	**Jan 31**				
ELECTRIC							**THERMAL**				
Energy		37,620.9	kWh				158,931.0	kBtu			
Power (Avg.)		50.6	kW				1,589.3	therms			
ENERGY CONSUMED			From		**Jan 1**	to	**Jan 31**				
GAS							Therm Factor				
		588,700.0	scf			X	1.0297		=	**6,061.8**	therms
AVOIDED ENERGY COSTS											
DELIVERY - Con Ed Service Clas.RA9 Rider J1 General Large Bus. Incentive Meter # 5154529											
Generation Delivery Reduction							$/kWH			Costs	
37,620.9	kWh			X			0.0385			1,448.40	
Subcooling Delivery Reduction											
18,722.0	kWh			X			0.0385			720.80	
COMMODITY - Con Ed Solutions Meter # 5154529											
Generation Commodity Reduction							$/kWH				
37,620.9	kWh			X			0.108004			4,063.20	
Subcooling Commodity Reduction											
18,722.0	kWh						0.108004			2,022.05	
						Avoided Electric Charges				**8,254.45**	
Demand Reduction							$/kW				
0	kW										
						Avoided Demand Charges				0.00	
								Total	=	**$8,254.45**	
THERMAL - NGrid Rate T2-2 - Tran General											
Gas Displaced											
0.0	th. =		therms								
75% Eff.											
OPERATING ENERGY COST - NGrid Rate 4A - High Load Factor (Over 1,000 therms)											
Gas Consumed			From		**Jan 1**	to	**Jan 31**	Bill Date:			
6,061.8	therms			X	$1.4775	/therm			=	**$8,956.37**	
NET SAVINGS					**PERFORMANCE**						
Avoided Elect. Cost		8,254.45			Elect. Eff. =	21.2	% HHV				
Gas Displaced		0.00			Elect. Eff. =	23.5	% LHV				
Total Avoided Costs		8,254.45			CHP Eff. =	47.4	% HHV				
Less Operating Cos		8,956.37			CHP Eff. =	52.7	% LHV				
Net Savings		**($701.92)**									

Figure 11 - February 2009 BCHP Operating Performance Details

ShopRite of Brooklyn
Energy Savings For February 2009

ENERGY DELIVERED		From	**Feb 1**	to	**Feb 28**		
ELECTRIC					**THERMAL**		
Energy	28,094.8	kWh			176,230.0	kBtu	
Power (Avg.)	41.8	kW			1,762.3	therms	
ENERGY CONSUMED		From	**Feb 1**	to	**Feb 28**		
GAS					Therm Factor		
	452,600.0	scf		X	1.0297	=	**4,660.4** therms

AVOIDED ENERGY COSTS

DELIVERY - Con Ed Service Clas.RA9 Rider J1 General Large Bus. Incentive Meter # 5154529					
Generation Delivery Reduction			$/kWH		Costs
28,094.8	kWh	X	0.0385		1,081.65
Subcooling Delivery Reduction					
16,491.0	kWh	X	0.0385		634.90
COMMODITY - Con Ed Solutions Meter # 5154529					
Generation Commodity Reduction			$/kWH		
28,094.8	kWh	X	0.108004		3,034.35
Subcooling Commodity Reduction					
16,491.0	kWh		0.108004		1,781.09
			Avoided Electric Charges		**6,532.00**
Demand Reduction			$/kW		
0	kW				
			Avoided Demand Charges		0.00
			Total	=	**$6,532.00**
THERMAL - NGrid Rate T2-2 - Tran General					
Gas Displaced					
0.0	th. =	therms			
75% Eff.					

OPERATING ENERGY COST - NGrid Rate 4A - High Load Factor (Over 1,000 therms)

Gas Consumed			From	**Feb 1**	to	**Feb 28**	Bill Date:	
4,660.4	therms	X	$1.4775	/therm			=	**$6,885.77**

NET SAVINGS		**PERFORMANCE**		
Avoided Elect. Cost	6,532.00	Elect. Eff. =	20.6	% HHV
Gas Displaced	0.00	Elect. Eff. =	22.9	% LHV
Total Avoided Costs	6,532.00	CHP Eff. =	58.4	% HHV
Less Operating Cos	6,885.77	CHP Eff. =	64.9	% LHV
Net Savings	**($353.78)**			

Figure 12 - March 2009 BCHP Operating Performance Details

ShopRite of Brooklyn
Energy Savings For March 2009

ENERGY DELIVERED		From	Mar 1	to	Mar 31			
ELECTRIC					**THERMAL**			
Energy	31,903.4	kWh			145,494.0	kBtu		
Power (Avg.)	41.8	kW			1,454.9	therms		
ENERGY CONSUMED		From	Mar 1	to	Mar 31			
GAS					Therm Factor			
	493,000.0	scf		X	1.0297	=	**5,076.4**	therms

AVOIDED ENERGY COSTS

DELIVERY - Con Ed Service Classification RA9 Rider J1 General Large Bus. Incentive Meter # 5154

Generation Delivery Reduction			$/kWH		Costs
31,903.4	kWh	X	0.0434		1,384.61
Subcooling Delivery Reduction					
16,491.0	kWh	X	0.0434		715.71
COMMODITY - Con Ed Solutions Meter # 5154529					
Generation Commodity Reduction			$/kWH		
31,903.4	kWh	X	0.113500		3,621.04
Subcooling Commodity Reduction					
13,615.0	kWh		0.113500		1,545.30
			Avoided Electric Charges		**7,266.66**
Demand Reduction			$/kW		
0	kW				
			Avoided Demand Charges		0.00
			Total	=	**$7,266.66**

THERMAL - NGrid Rate T2-2 - Tran General

Gas Displaced			
0.0	th. =		therms
75% Eff.			

OPERATING ENERGY COST - NGrid Rate 4A - High Load Factor (Over 1,000 therms)

Gas Consumed		From	Mar 1	to	Mar 31	Bill Date:		
5,076.4	therms	X	$1.2280	/therm			=	**$6,233.84**

NET SAVINGS		**PERFORMANCE**		
Avoided Elect. Cost	7,266.66	Elect. Eff. =	21.4	% HHV
Gas Displaced	0.00	Elect. Eff. =	23.8	% LHV
Total Avoided Costs	7,266.66	CHP Eff. =	50.1	% HHV
Less Operating Cos	6,233.84	CHP Eff. =	55.7	% LHV
Net Savings	**$1,032.82**			

Figure 13 - April 2009 BCHP Operating Performance Details

ShopRite of Brooklyn
Energy Savings For April 2009

ENERGY DELIVERED			From		**Apr 1**	to	**Apr 30**				
ELECTRIC							**THERMAL**				
Energy		21,580.1	kWh					96,489.0	kBtu		
Power (Avg.)		41.8	kW					964.9	therms		
ENERGY CONSUMED			From		**Apr 1**	to	**Apr 30**				
GAS							Therm Factor				
		393,000.0	scf			X	1.0297		=	**4,046.7**	therms
AVOIDED ENERGY COSTS											
DELIVERY - Con Ed Service Clas.RA9 Rider J1 General Large Bus. Incentive Meter # 5154529											
Generation Delivery Reduction							$/kWH			Costs	
21,580.1	kWh			X			0.0434			936.58	
Subcooling Delivery Reduction											
9,029.0	kWh			X			0.0434			391.86	
COMMODITY - Con Ed Solutions Meter # 5154529											
Generation Commodity Reduction							$/kWH				
21,580.1	kWh			X			0.092770			2,001.99	
Subcooling Commodity Reduction											
9,029.0	kWh						0.092770			837.62	
						Avoided Electric Charges				**4,168.04**	
Demand Reduction							$/kW				
0	kW										
						Avoided Demand Charges				0.00	
								Total	=	**$4,168.04**	
THERMAL - NGrid Rate T2-2 - Tran General											
Gas Displaced											
0.0	th. =		therms								
75% Eff.											
OPERATING ENERGY COST - NGrid Rate 4A - High Load Factor (Over 1,000 therms)											
Gas Consumed			From		**Apr 1**	to	**Apr 30**	Bill Date:			
4,046.7	therms			X	$1.2280	/therm			=	**$4,969.37**	
NET SAVINGS					**PERFORMANCE**						
Avoided Elect. Cost		4,168.04			Elect. Eff. =	18.2	% HHV				
Gas Displaced		0.00			Elect. Eff. =	20.2	% LHV				
Total Avoided Costs		4,168.04			CHP Eff. =	42.0	% HHV				
Less Operating Cos		4,969.37			CHP Eff. =	46.7	% LHV				
Net Savings		**($801.33)**									

Conclusions

Summary and Conclusions

A unique Integrated Energy System was designed and successfully installed in CHP configuration at the ShopRite Supermarket on McDonald Avenue in Brooklyn, NY. This CHP system is unique in that it uses engine waste heat to drive a 20 RT absorption chiller that provides subcooling to the low and medium refrigeration racks at the store. Such configuration proved to achieve additional reduction in grid provided electricity by reducing refrigeration compressors power consumption

The six months on-site CHP monitoring program confirmed that the system overall thermal efficiency can reach as high as 66%. With a 60% or higher efficiency being typical target for CHP systems it is important that monthly operations of the ShopRite system are optimized to achieve higher average that the current 53%.

The major efficiency and performance indicators as well are economics of monthly operation are listed below and detailed in tabular format.

- Almost On average, the ShopRite CHP system was able lower the supermarket monthly electric consumption by 52,000 kWh with monthly reductions ranging from 30,609 kWh to 72,339 kWh
- The average overall thermal efficiency of the system was 53% with the monthly values ranging from 42% to 66%.
- The cumulative CHP system operating cost was $45,513 and the electric utility cost savings were $46,214 for a small savings of $701 recorded over six month of operation. At least 75% of the resort's domestic hot water heating load
- The bottom line savings were strongly affected by spike in natural gas prices which averaged ~$14.0 per MMBtu during the six month testing period.

The on-site BCHP monitoring program measured the overall mechanical and economical performance of the system in its real-world environment for one year. The following tables summarize the monthly BCHP system performance.

System Parameters	Nov-08	Dec-08	Jan-09	Feb-09	Mar-09	Apr-09
Total Grid Load Reduction kWh	72,339	64,129	56,343	44,586	45,518	30,609
CHP System Thermal Overall Efficiency % HHV	65.8%	53.3%	47.4%	58.4%	50.1%	42.0%
Bottom Line Savings $	1,434.70	90.37	(701.92)	(353.78)	1,032.82	(801.33)

Appendix A – IES System Installation Pictures

Equipment Installation

Hess Microgen 140 Engine-Generator and Yazaki 20 RT Absorption Chiller Installed

Microgen 140 Generator Electric Distribution/Control Panel and Refrigerated Cases Subcooling Heat Exchanger

Appendix B – IES System Equipment Specification Sheets

Hess Microgen 140 Engine-Generator

SPECIFICATION	HESS 140 SYSTEM [a]	
Frequency	60 Hz	50 Hz
Continuous Electric Output at unity power factor (kW)	140	120
Mechanical Power (bhp)	197	168
Rotating Speed (rpm)	1,800	1,500
Heat Rate (BTU per kWh) [b]	10,220	10,220
Combined Efficiency	84%	84%
Electrical Efficiency	36%	33%
Thermal Efficiency	50%	50%
Fuel Consumption (SCFM) [c]	26.4	22.6
Fuel Consumption (Therms per Hour) [c]	14.3	12.2
Total Thermal Energy Output (BTU per Hour)	721,921	614,115
Heat from Water Jacket (BTU per Hour)	424,794	363,656
Heat from Exhaust (BTU per Hour)	297,127	250,459
Cooling Tons [d] (tons of absorption chilling)	TBD	TBD
Steam Output 15 psi (lbs per hour) [e]	170	143
Steam Output 125 psi (lbs per hour) [e]	TBD	TBD
Exhaust Temperature (°F) (Engine Out)	1,069	1,056
Exhaust Temperature (°F) (Module Out)	248	248
Exhaust Flow (lbs/hr)	1,200	1,000
Minimum Water Flow	63	53
Maximum Water Temperature (°F) (Module Out)	205	205
Cogen Return Temperature (°F) (Nominal)	175	175
Generator Electrical Output		
Voltage [f]	120/208, 120/240, or 277/480, 3-phase	219/380, 3 phase
Type	Single bearing, Direct coupled, Continuous	
Power Factor	Synchronous: Variable from 0.8 lagging to 0.8 leading; Inductive 0.83 FL	
Options	Synchronous or Inductive	
Operating Modes	Grid Independent, Standby, or In Parallel with Utility Grid	
Environmental [a]		
NOx	< 0.15 g/bhp·hr	
CO	< 0.60 g/bhp·hr	
VOC	< 0.15 g/bhp·hr	
HRC	< 0.15 g/bhp·hr	
Noise	< 69 dBA at 3 meters	
Fuel		
Type [g]	Natural Gas	
Standard	905 BTU/SCF LHV	
Minimum Gas Pressure [h] [i]	14 inches H_2O	
Maximum Gas Pressure [h] [i]	21 inches H_2O	
Package Size		
Dimensions (L x W x H)	11' 8" x 4' x 5' 10" (3.6m x 1.2m x 1.8m)	
Weight [j]	5,800 lbs (2,630 kg)	
Compliance Standards	UL 2200 Listed (generating system) UL 1741 Type Tested (control system) UL 508 Listed (industrial control equipment - NEXGEN) IEEE 1547 compliant	

Notes

(a) All specifications are based on rich burn configuration using optional SCAQMD compliant emission technology

(b) Heat rate assumes maximum exhaust back pressure of 23.6 inches H_2O

(c) Using 905 BTU/SCF LHV natural gas

(d) Depending on local conditions

(e) Assuming 78% boiler efficiency

(f) 600 V available upon request

(g) Other fuel options available including propane, biogas (methane), and diesel

(h) Gas pressure as measured at full load operating flow rate at internal engine regulator entrance

(i) Gas pressure variation must be within ± 1" WC

(j) Weight includes catalytic converter and sound attenuated cabinet

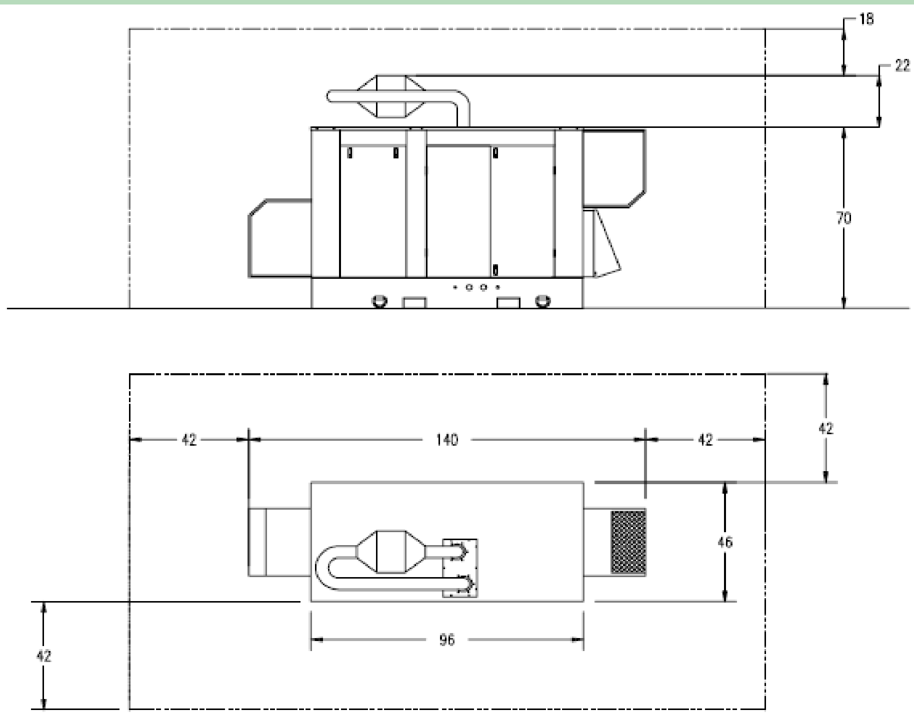
DESIGN PARAMETER	HESS 140 SYSTEM		
	Minimum	Design	Maximum
Ambient Temperature (°F)	32 [b]	95	110 [c]
Combustion Air Temperature (°F)	NA	90	104
Intercooler Supply Temperature (°F)	NA	45	NA
Intercooler Temperature Rise on water side (°F)	NA	5.0	NA
Intercooler Flow Rate (gpm)	NA	20	NA
Engine Flow Rate (gpm) [d]	NA	64	NA
Engine Temperature Send (°F) [d]	NA	185	210
Engine Temperature Return (°F) [d]	NA	175	195
Engine Jacket Water Pressure (psi)	NA	12.8	16
Natural Gas Heat Content (BTU/SCF LHV) [e]	500	905	1,100
Fuel Flow Rate (SCFM) [f] [g]	NA	26.4	NA
Fuel Flow Rate (therms/hr) [g]	NA	14.3	NA
Operating Gas Pressure (inches of water column) [h]	7 [i]	14	28
Gross Electrical Output (kVA) [j]	35 [k]	140	140
Heat Rate (BTU/kWh)	NA	10,220	NA
Power Factor (±%)	0.8	1.0	0.8
Voltage (V)	NA	208 or 480, 3-phase	NA
Amperage (A) / kW	97 @ 208V, 42 @ 480V[k]	389 @ 208, 169 @ 480V	NA
Exhaust O_2 (% exhaust volume)	NA	0	0.8
Exhaust Back Pressure @ Turbo Outlet (inches H_20/psig)	NA	24	26

Siting Requirements

3,500 PSI reinforced, 6" thick (min), subgrade compacted to 90% relative density

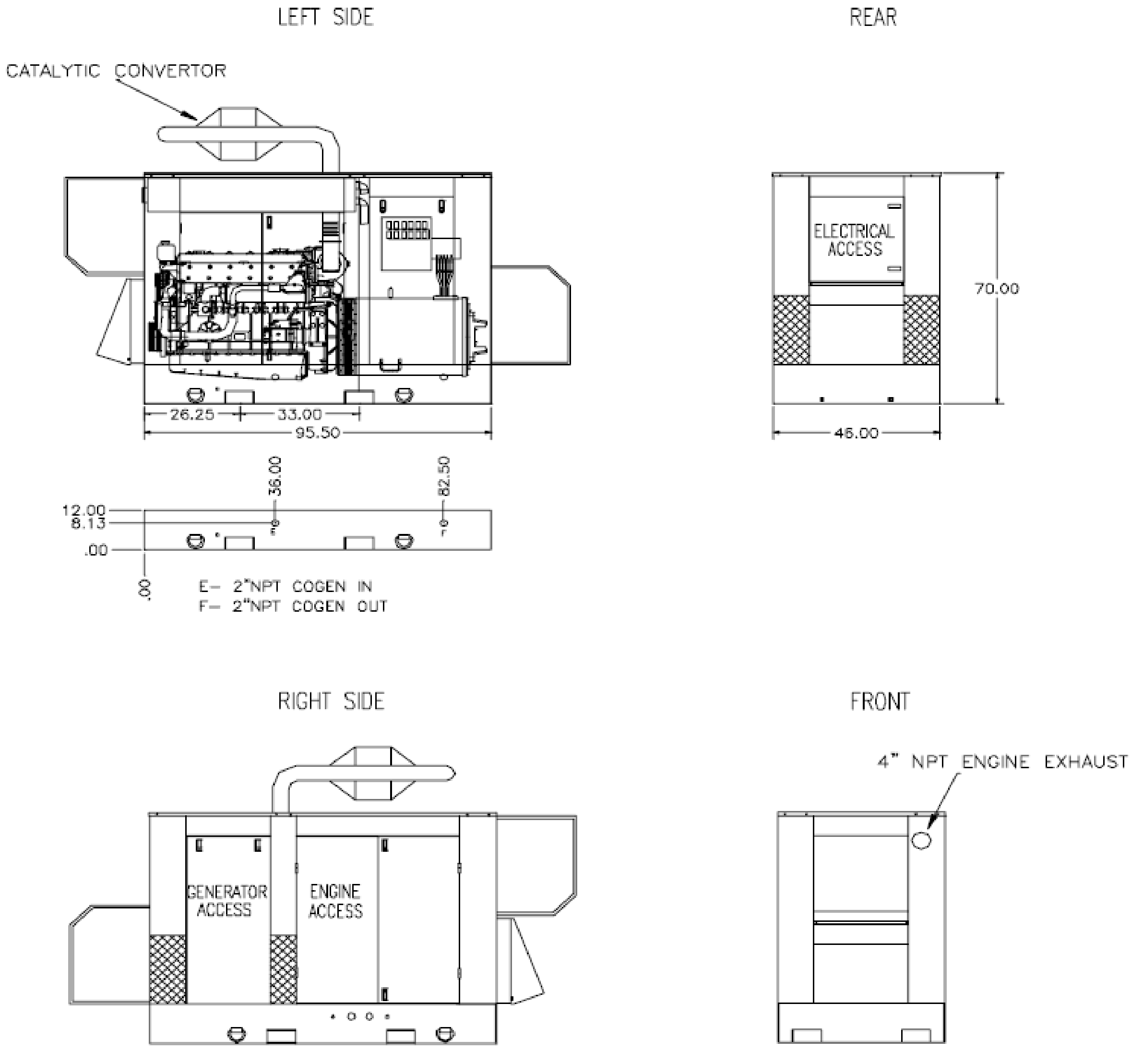
500 CFM of combustion make-up air and 2,500 CFM of cabinet ventilation air

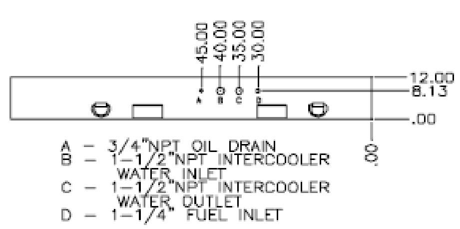
Minimum Service and Safety Clearances (inches)



Notes:

(a) Design Specifications based on a rich burn configuration with catalyst
(b) Operation at temperatures < 32°F requires engine block heater
(c) Operation at temperatures > 110°F may cause damage to sensitive controls and will void warranty if internal component temperatures are measured over 130°F. Supplemental cooling may be required
(d) Engine coolant must include a minimum of 20% propylene or ethylene glycol for freeze/boil/corrosion protection. Higher concentrations may be required for certain site conditions.
(e) Natural gas other than utility grade must be tested and approved by Hess Microgen.
(f) Site design should allow for a fuel flow rate 15% greater than design specification.
(g) SCFM requirements at indicated operating gas pressure
(h) Required gas pressure to external regulator = 5 psi.
(i) 7" through special order only. Additional engineering may be required for multiple units.
(j) 1 kVA = 1 kW at Power Factor = 1.0.
(k) 25% rated continuous load.





PERMISSIBLE LOCATIONS FOR CONDUIT INSTALLATION

NOTES:
1. ALL MEASUREMENTS ARE IN INCHES.
2. CONDUIT TO BE LOCATED IN SHADED AREAS SHOWN.
3. TAKE CARE WHEN MAKING CONDUIT HOLES TO PREVENT DAMAGE TO WIRES, CONDUITS, OR OTHER INTERNAL COMPONENTS.
4. CONDUIT SIZE AND TYPE TO COMPLY WITH LOCAL CODES AND JOB DRAWINGS AND SPECIFICATIONS.

Yazaki WFC-SC20 Absorption Chiller

YAZAKI

WFC-SC20 & -SH-20

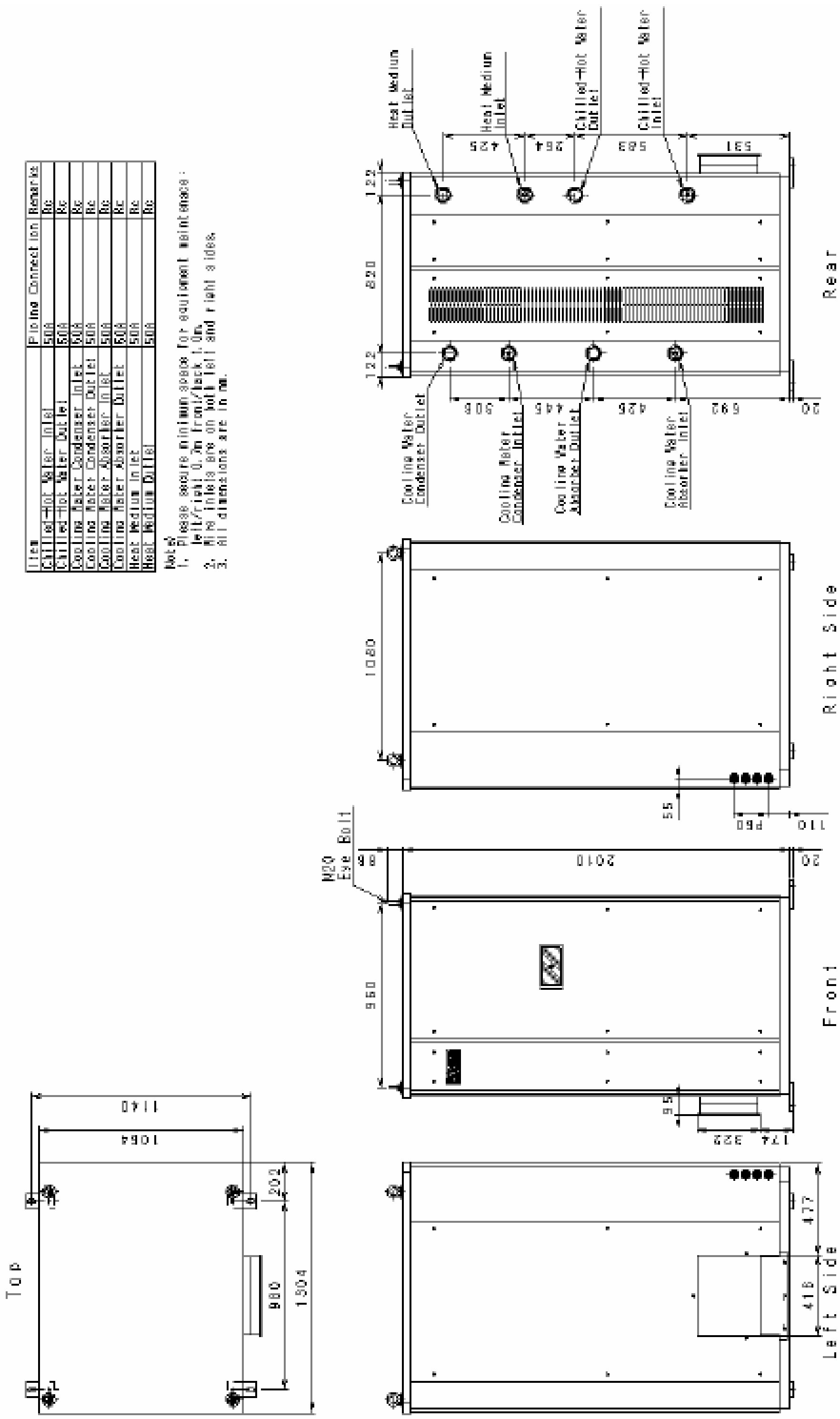
Specifications:

Water Fired Chiller absorption type with H_2O/LiBr
System functionality provides cooling
Heating with an automatic change over control mode (SH model only)
Utilizing Hot Water

Model	Production
WFC-SC20	Chilled Water
WFC-SH20	Chilled & Heating Water

ITEM		MODEL		WFC-SH20	WFC-SC20
Cooling Capacity			kW	70.3	
Heating Capacity			kW	97.5	-
Chilled Water and Hot Water	Chilled Water Temperature	Inlet	℃	12.5	
		Outlet	℃	7.0	
	Hot Water Temperature	Inlet	℃	47.4	-
		Outlet	℃	55.0	-
	Evaporator Pressure Loss(Max) *3		kPa	65.8	
	Max Operating Pressure		kPa	588	
	Rated Water Flow		L/sec	3.05	
			m^3/hr	11.0	
	Water Retention Volume		L	47	
Cooling Water	Heat Rejection		kW	170.8	
	Cooling Water Temperature	Inlet	℃	31.0	
		Outlet	℃	35.0	
	Abs.&Cond.Pressure Loss(Max) *3		kPa	45.3	
	Max Operating Pressure		kPa	588	
	Rated Water Flow		L/sec	10.2	
			m^3/hr	36.7	
	Water Retention Volume		L	125	
Heat Medium	Heat Input		kW	100	
	Heat Medium Temperature	Inlet	℃	88	
		Outlet	℃	83	
		Inlet Limit	℃	70 - 95	
	Generator. Pressure Loss(Max) *3		kPa	46.4	
	Max Operating Pressure		kPa	588	
	Rated Water Flow		L/sec	4.8	
			m^3/hr	17.3	
	Water Retention Volume		L	54	
Electrical	Power Source			400V 50Hz 3ph.	
	Consumption *1		W	260	
Control				On—Off	
Dimension	Width		mm	1,064 (1,159)	
	Depth		mm	1,304	
	Height *2		mm	2,010 (2,116)	
Piping	Chilled Water		A	50	
	Cooling Water		A	50	
	Heat Medium		A	50	
Weight	Dry Weight		kg	930	
	Operating Weight		kg	1,155	

*1. Power consumption of Chiller Only.(excluding recirculating pumps and cooling tower fan)
*2. Dimension in( ) include fixed plate and eye bolt.
*3. Specification are subject to change without prior notice.
*. The table shows standard operating condition (i.e. 88 ℃ heat medium inlet temperature)


Item / Piping Connection / Remarks
Chilled-Hot Water Inlet 50A Rc
Chilled-Hot Water Outlet 50A Rc
Cooling Water Condenser Inlet 50A Rc
Cooling Water Condenser Outlet 50A Rc
Cooling Water Absorber Inlet 50A Rc
Cooling Water Absorber Outlet 50A Rc
Heat Medium Inlet 50A Rc
Heat Medium Outlet 50A Rc
Notes
1. Please secure minimum space for equipment maintenance: left/right 0.3m front/back 1.0m.
2. Pipe inlets are on both left and right sides.
3. All dimensions are in mm.
Heat Medium Outlet
Heat Medium Inlet
Chilled-Hot Water Outlet
Chilled-Hot Water Inlet
Cooling Water Condenser Outlet
Cooling Water Condenser Inlet
Cooling Water Absorber Outlet
Cooling Water Absorber Inlet
M20 Eye Bolt
Rear
Right Side
Front
Top
Left Side