U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

BUILDING TECHNOLOGIES PROGRAM

Strategy Guideline: Mitigation of Retrofit Risk Factors

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Alliance for Residential Building Innovation (ARBI)

December 2012

Building America
U.S. Department of Energy

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Prepared for:

The National Renewable Energy Laboratory

On behalf of the U.S. Department of Energy's Building America Program

Office of Energy Efficiency and Renewable Energy

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NREL Contract No. DE-AC36-08GO28308

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Prepared under Subcontract No. KNDJ-0-40340-00

December 2012

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Definitions

ARBI	Alliance for Residential Building Innovation (program team)
CEC	California Energy Commission
CPUC	California Public Utilities Commission
DEG	Davis Energy Group (ARBI team lead)
DOE	U.S. Department of Energy
EGIA	Electric & Gas Industries Association
EUC	Energy Upgrade California, a statewide program
HEA	Home Energy Assessment
HEU	Home Energy Upgrade
LSRP	Large-Scale Residential Retrofit Pilot
PACE	Property Assessed Clean Energy Program
RECS	Residential Energy Consumption Survey
RFQ	Request for Quotation

Executive Summary

The Alliance for Residential Building Innovation (ARBI) is currently developing strategies and measures designed to promote and achieve increased energy savings in the residential building retrofit sector. Through its experience implementing pilot programs for residential energy efficiency retrofits in California, ARBI has developed guidelines focused on promoting and achieving realistic energy savings. Increased understanding of technological, economic, and sociological factors affecting energy savings for residential retrofit projects can help guide successful approaches for retrofit programs. These guidelines are targeted to retrofit program managers, retrofit contractors, policy makers, academic researchers, and non-governmental organizations that work to realize energy savings from home energy upgrades (HEUs).

The guidelines build on identified risk-factors that encompass four key areas: 1) accuracy of energy savings projections, 2) understanding of consumer perceptions for energy savings, 3) measurement of energy savings, and 4) quality control and quality assurance for retrofit installations. The guidelines are designed to assist retrofit programs in addressing key trade-offs for cost and performance, non-energy benefits, and interactions of program infrastructure with other sectors.

Risk factors associated with residential energy retrofits include both technical and programmatic factors. Inaccurate energy modeling, low-quality installations, and lack of market-ready technologies are all technical factors that can impact actual performance of a home after an HEU. Additionally, programmatic factors such as consumer education, contractor participation, supply of qualified contractors, and the possibility of take-back by consumers after an upgrade can degrade retrofit performance.

Specific strategies seek to address the four key areas for attaining energy savings. First, to promote accurate projections of energy savings, implementers should develop more accurate energy modeling. This is facilitated through better pre- and post-installation monitoring, as well as understanding how and when to use models appropriate for particular purposes, such as design or energy use projections. Second, to develop greater understanding of consumer perceptions of savings, industry professionals must understand varied consumer motivations for retrofits. Performance guarantees, which are facilitated through better projections and monitoring, can go far to manage consumer expectations. Third, to measure energy savings, new technologies such as thermostats with networking and monitoring features can assist service providers to monitor consumer behavior. Better measurement also facilitates greater insight into potential changes in consumer behavior after a HEU. Finally, to promote quality control, program managers can facilitate early interactions between contractors and certification managers that reduce conflicts and delays in post-installation certifications. Trade-offs between multiple certification programs can be minimized by ensuring that all participating parties at a local or regional level agree on retrofit and QA/QC procedures.

Through the compilation of such strategies, program managers can facilitate effective interactions between consumers and industry participants that promote residential energy savings.

1 Introduction

The Alliance for Residential Building Innovation (ARBI) is currently developing implementation strategies and measures designed to promote and achieve increased energy savings in the residential building retrofit sector. ARBI is working with public and private sector partners to conduct a series of large-scale residential retrofit program (LSRP) pilots in Stockton, and Los Angeles, Alameda, and Sonoma counties in California. The objective of the pilots is to increase energy efficiency in the residential sector through improved uptake of whole house home energy upgrades (HEUs).

Through its experience in pilot program implementation, ARBI has developed a series of guidelines focused on promoting and achieving realistic energy savings. Through increased understanding of technological, economic, and sociological factors affecting energy savings for residential retrofit projects, ARBI seeks to provide guidelines that describe successful approaches for retrofit programs. The strategies are targeted to retrofit program managers, retrofit contractors, policy makers, academic researchers, and non-governmental organizations that work to realize energy savings from HEUs. On a broader scale, ARBI is also evaluating the success of various business and program models in order to achieve significant program uptake.

1.1 Risk Factors

The ARBI team has focused on promoting and achieving energy savings for residential retrofits as part of its strategies for successful technical and programmatic approaches for the residential energy efficiency sector. Prior to program implementation, ARBI identified a series of risk factors related to technical and economic components of the programs, which were seen as potential impediments to program success if not addressed through proper mitigation strategies. These identified risk factors are listed in Table 1 below.

Table 1. Identified Risk Factors for Residential Retrofit Programs

Programmatic Risks a. **Low uptake**, resulting in failure to achieve economies of scale; b. **Resistance from homeowners** to allow access to key areas of the home; c. **Unattractive business model** for contractors; d. **Inability of contractors to keep up with workload** requirements; e. **Failure by contractors to adhere to program guidelines**.
Technical Risks a. **Low-quality installations** and lack of quality control (QC); b. **High number of callbacks** for service issues; c. **Post-installation technical problems** such as moisture, mold, or combustion, resulting from tightening of a thermal envelope during a home energy upgrade; d. **Failure of upgraded homes to perform to expectations** of homeowners; e. **Failure of upgraded homes to produce energy savings** predicted by modeling.

Controlling these risk factors requires careful planning, coordination, and data collection activities on the part of the ARBI team and its partners working to implement retrofit programs. Using established databases and performance metrics, ARBI collaborates with selected contractors to gather data and assess progress towards mitigating these identified risk factors.

1.2 Strategy Guidelines

In developing strategies to mitigate such risks, ARBI has created a series of guidelines within the overall plan of promoting and achieving energy savings for residential retrofits. These strategy guidelines derive from research and program experience gained by the ARBI team through collaboration across sectors, which has sought to identify industry best practices. Four key components constitute these guidelines, as described below.

1) **Accuracy of Energy Savings Projections:** Retrofit program managers and contractors must be able to accurately project energy savings in order to ensure current and future program success. This includes projections both before and after installation activities, which establishes baselines while ensuring that industry participants provide customers with strong yet manageable results. Energy models play a critical role in such activities, but models must be utilized appropriately in order to promote accurate energy projections. Confidence in predictions of energy savings is also critical in mitigating a host of financial, legal, and technical risks in the residential energy efficiency market.
2) **Understanding Consumer Perceptions of Energy Savings:** While technical strategies are necessary to realize retrofit results, industry personnel must also understand how consumer perceptions of energy savings influence program uptake. Knowledge of the variety of consumer motivations can significantly affect program or marketing approaches. Strategies that address consumer perceptions related to expected savings and willingness to pay for installation work can directly address risk factors associated with market uptake.
3) **Measuring Energy Savings:** Beyond projections, industry personnel must develop methods and standards to accurately measure energy savings after completing an upgrade. Methods that utilize new and existing technologies, as well as increased information technology networking capabilities, can assist program managers and industry personnel to measure savings, while also serving to more robust data for energy modeling capabilities. Accurate measurement also addresses consumer perception, market viability, financing, and contractor performance.
4) **Quality Control:** Quality control (QC) and Quality Assurance (QA) guidelines are important for developing effective mechanisms that mitigate risk for the energy retrofit sector. Notably, appropriate use of various industry certification standards and guidelines, such as those from ACI, RESNET, DOE and Building Performance Institute (BPI), can significantly improve achievement in energy savings programs.

The strategy guidelines provide a framework for retrofit programs to address key cost and performance tradeoffs, non-energy benefits, and interactions of program infrastructure with other sectors. They encompass robust and cost-effective procedures that can be implemented on a consistent, prescriptive basis by program managers and qualified contractors in order to assure growth in the energy efficiency retrofit market.

2 Planning and Decision Making Criteria

2.1 Overview

In the residential energy efficiency retrofit market, a host of impediments can prevent effective promotion and achievement of retrofit energy savings. Industry growth relies on successful relationships between service providers and consumers, and challenges arise that can prevent one or both groups from following through with installations. While consumers maintain expectations for energy savings, industry requires reasonable post-installation usage from consumers to meet savings projections. Even as contractors need technical and programmatic capabilities to gather energy data for monitoring and feedback, consumers often seek minimally invasive and cost-effective installations that improve safety and comfort. A host of financial, programmatic, and technical factors can influence decisions and tradeoffs that potentially impede realistic achievement and growth in the residential energy efficiency sector.

2.2 Technical Risk Factors

Technical factors can significantly impede achievement of energy upgrade programs. Underperforming homes (post-upgrade) can result from a variety of factors, including inaccurate projections, poor installation procedures, lack of quality control, or altered homeowner behavior.

New technologies can affect technical risk factors associated with residential building energy retrofits. Energy models that do not accurately predict home performance after an upgrade can significantly impede industry confidence. Increasing the amount of time spent collecting and inputting data to a model can potentially improve performance, but the marginal costs associated with such efforts can be prohibitive when seeking economies of scale. Many current energy models have shown to be inaccurate as a predictor of energy savings for the industry, but not necessarily due to poor modeling tools. Energy models can serve many uses, but inappropriate use of the models can result in unreasonable expectations. Thus, the industry should understand how and when to use energy models for particular purposes. Furthermore, while additional data is needed to use such models more accurately, in many cases, poor installation work degrades home upgrade performance. Thus, although models must be recalibrated after a period of usage, completing installations to a high quality standard is also necessary to ensure performance.

Energy models can serve many uses, but inappropriate use of the models can result in unreasonable expectations.

In addition, though a few contractors in the current marketplace are providing performance guarantees, new technologies that increase data collection and performance modeling can assist industry leaders and policy makers in developing more effective modeling techniques. This, in turn, contributes to the ability of contractors to provide verifiable pre-installation assessments on a broader scale. Developing technologies that can, for instance, address the issue of “take-back,” where consumers alter behavior after an installation, would significantly enhance the ability to offer performance guarantees and mitigate risk factors for low uptake. These new technologies, though, can add costs to the project, which add new layers of complexity to tradeoffs between cost and performance.

While new technologies that reduce energy consumption in other sectors can adversely affect performance, comfort, and health of consumers, within the energy efficiency retrofit sector, upgrades can actually work to improve health and safety. For example, many consumers might complain that driving a more fuel efficient vehicle instead of an SUV impedes their comfort or flexibility; however, improving the energy performance of a home is consistently viewed by residents as increasing their well-being. Even still, some comfort, health and safety risks can ensue from HEUs. Issues such as drafts from air supply registers within the house can bother otherwise satisfied customers. At the same time, failing to properly manage the building envelope along with ventilation can create dangerous back drafting of combustion appliances. Guidelines for quality control can work to mitigate these risks, for a serious accident related to an HEU could have a highly disproportionate effect on this nascent industry. Finally, tightening the building envelope to high standards can potentially increase moisture in the home, which can lead to mold and other health effects. Energy efficiency contractors must control such risks to ensure customer well-being. A strong and knowledgeable industry is, in turn, the responsibility of industry leaders and policy makers who oversee well-trained contractors and crews.

Thus, ensuring performance from a technical perspective encompasses significant cost and market considerations. If consumers expect a certain level of energy savings, the energy efficiency industry can certainly provide this level of service. The challenge ensues in providing this service at an attractive price. The retrofit industry must understand consumer behavior to clarify tradeoffs in up-front costs and long-term performance, working to provide high-quality and proficient technical work at an appropriate price.

2.3 Programmatic Considerations

While technical considerations significantly impact energy upgrade performance, programmatic considerations can also influence progress towards realistic energy savings for residential retrofits. If low numbers of retrofits occur, then economies of scale within a program are not achieved and cost savings are not generated and passed on to customers. Low uptake, though, can be caused by a number of more fundamental risk factors, including: low levels of knowledge and understanding within the marketplace; unrealistic expectations for energy savings from retrofits; and inadequate access to capital for residential sector upgrades.

2.3.1 Consumer Perspectives

For consumers, the largest impediments to HEUs are cost and knowledge. Retrofit costs, financing options, and requirements for up-front payments without guarantees can significantly affect consumer willingness to pursue an HEU. If the performance of an upgraded home was guaranteed, it would both ease consumer worries and improve the attractiveness of the market to outside capital. Thus, cost and performance work together. At the same time, identifying the accurate energy performance and cost savings associated with upfront consumer expenses is critical. Without identifying the commercial "price point" where consumer psychology and capital availability converge to increase sales, residential building energy retrofit programs face significant risk for low uptake.

Performance guarantees—agreements between contractors and customers that post-installation homes will achieve specified energy savings—can be a critical component in addressing consumer risk factors. Consumers who are driven by fiscal value must believe that money spent on a HEU will result in improved performance. To the extent that a contractor can provide these assurances, risk is transferred from the consumer to the service provider. Subsequently, the contractor must have incentives to both offer performance guarantees and assume this risk through reduction of uncertainty in post-installation performance. Thus, programmatic structures that minimize contractor risk while meeting consumer expectations can go far to increase residential retrofits.

Energy efficient homes have a potential competitive advantage in the real estate marketplace. From the perspective of an educated consumer, a home with verified energy savings would be a more attractive investment, as the lifetime costs would be much less. As of yet, however, the real estate sector does not routinely recognize this value added, for it is a difficult topic for real estate agents to quantify and communicate to consumers. Thus, consumers in a current home face the potential of performing an upgrade that does not enhance market value if they have to sell at some future point. Similarly, consumers purchasing or renting a home face uncertainty about its energy performance.

2.3.2 Contractor Perspectives

While consumers must choose to spend money on an energy efficiency upgrade, service providers must be properly motivated and capable to conduct profitable, quality work that achieves improved energy performance.

A significant risk lies in the ability of contractors to keep up with demand. Growing market sectors across many industries regularly encounter difficult trade-offs related to managing potential future demands in the face of fiscal requirements. If contractors and work crews are not able to keep up with large, sudden growth within energy efficiency retrofit programs, then potential customers may be lost and economies of scale not achieved.

Another risk for contractors who seek to ensure performance is the opportunity for "take-back" in upgraded homes. Some consumers may feel that after an HEU, they can be more lenient with energy usage, leading to activities like turning up the thermostat in the winter or down in the summer. This directly affects home heating costs and home energy performance. When take-back occurs, consumers may perceive that the upgrade did not affect performance, when in fact they are paying the same amount for more comfort through greater efficiency. This risk is directly related to a keen understanding of the marketplace as well as consumer psychology.

> After a home energy upgrade (HEU), some consumers may feel they can be more lenient with energy usage. This can lead to **take-back** activities, such as turning up the thermostat, which directly affects home heating costs and home energy performance.

The ability of contractors to provide accurate projections and deliver quality installations may be impeded by lack of access to key areas of a home. In some instances, consumers are reticent to allow contractors into particular parts of their home, such as bathrooms, bedrooms, or offices. This is often primarily related to security and trust issues between contractors and customers, but may occur even if the customer requested a visit or service. This poses risks to contractors who may not be able to provide verifiable guarantees or waste precious time and resources in such situations.

A major challenge is the current emphasis on "low-bids" within the building industry generally, and the residential retrofit sector specifically. Consumers are more likely to choose less-expensive options, which often results in sub-par work. Furthermore, not all contractors perform the same quality of work. Individual, high-performing contractors may be in a situation where other, lower-bid providers create a dour reputation for the residential retrofit sector, thus depressing overall sales. This relates closely to technical risk factors associated with installation quality and performance guarantees.

2.4 Coordinated Framework for Decision-Making

Strong overlap exists between the programmatic and technical risk factors that can impede rapid market penetration of residential energy efficiency upgrades. Most importantly, cost and performance issues are strongly linked for both consumers and service providers. Consumers may be willing to pay for quality work if verifiable performance guarantees and other assurances are part of regular upgrade services. At the same time, providing such performance guarantees requires quality control, efficient programmatic structures, and, in some cases, new technological capabilities in order to assure accurate modeling. Decisions on cost tradeoffs require both consumers and contractors to be knowledgeable of marketplace opportunities and understand products offered.

Competitive advantages for energy efficiency upgrades have both a short- and long-term perspective. In the short term, contractors face decisions as to specialize in providing energy efficiency upgrades, which can increase their marketplace competitiveness. The residential retrofit marketplace, however, is nascent, and contractors risk low returns on investment if their specialization is too precise for current market needs. When viewed in a longer term, consumers face decisions regarding energy efficiency that could potentially add resale value to a home through verified energy efficiency upgrades. As of yet, however, market appreciation of HEU work is far inferior to other more traditional aspects such as size, number of bedrooms, or kitchen countertop material. Thus, both consumer and contractor confidence in the growing residential retrofit sector rests on assuring that technical, programmatic, and economic risks are effectively mitigated.

3 Technical Description

3.1 Energy Models and Savings Projections

Promoting achievable energy savings is dependent upon appropriate use of energy models. Such models, which assist contractors in assessing the potential for performance upgrades through residential retrofits, are very useful as guides. The usefulness of the models, however, is closely related to the desired purpose and how the models are run.

Energy models can by employed as a tool to assist or provide:

Relative Rankings, which utilities and others create to assess the level of rebates provided to particular homes. Based on the characteristics of a home, including age, construction type, occupancy patterns, and location, utilities use energy models to place a home within a tiered rebate structure based on the potential energy performance as compared to other homes. In such instances, absolute performance is less important than relative performance, as utilities are primarily concerned with creating a relative ranking of homes that guides equitable distribution of allotted rebate dollars based on potential energy savings. The *ECON-2* model shown in Appendix B provides an example of a model used for this purpose. Model projections can be sent to the utility to provide justification for rebates.

Design of energy efficiency upgrades prior to installation. Energy models allow industry professionals the opportunity to comparatively assess various implementations, which influence contractor designs to arrive at a package of installation measures that seek to maximize performance and minimize cost. Energy models used in the design phase may or may not reflect actual energy savings, even as some service providers could be tempted to use them as a benchmark in communicating projected energy savings to consumers. The *EnergyPro* model in Appendix C provides an example of a model used to assess influence design and assess trade-offs of cost and savings.

Energy Use Projections for energy savings for retrofit projects. This application of energy models has significant potential benefits for increasing consumer confidence in energy savings projections, but also retains the greatest level of associated uncertainty. Energy models are reliant on quality data inputs and accuracy in system modeling to predict outcomes. Thus, if input data is inaccurate, or if actual conditions differ from model conditions, the models will not accurately project energy savings. If service providers use them as the primary tool in providing consumers with energy savings projections, the contractor assumes significant risk that actual performance will differ significantly from projections. The *BEopt* model in Appendix D provides an example of a model used to project energy use after an installation.

Appropriate use of energy models within various stages of home energy assessments and HEU is vital to providing realistic energy savings. While projections are necessary to facilitate consumer buy-in, results are critical to industry performance and reputation. Thus, the interaction of models with the technical and economic influences of the market is vital, and training industry personnel in the appropriate use of such models can significantly improve consumer perception and accuracy of predictions.

3.2 Occupant Behavior

Home energy performance after an upgrade can be drastically affected by the behavior of occupants. Additional residents, new appliances, and changes in temperature set-points can degrade the projected performance, potentially causing issues between contractors and consumers. When a home is modeled, the service provider will ask for reasonable projections as to occupancy and use, while also noting the types of energy-consuming devices found in the house. This data is an input to the model, which assists contractors in providing performance guidelines to customers.

After an upgrade is completed, consumers often expect a particular level of performance, indicated by reductions in energy bills. Often, however, customers change their behavior. Adding new residents or energy-intensive appliances can increase energy consumption and reduce savings. Further complication occurs if utility rates increase. A lifestyle change such as a new stay-at-home parent or change in employment can also increase energy consumption.

Figure 1. Nest Labs thermostat (Source: Nest Labs website; reprinted with permission)

These differentiations are not usually apparent to consumers, as detailed breakdowns of energy use and costs are seldom available. In such instances, consumers may contact the service providers with complaints of unrealized energy savings. At present, service providers seldom have the capability to rigorously analyze customer energy habits, which could possibly show how changes in behavior affected energy use. Some new thermostats available on the market are able to monitor and record temperature set-points, providing a record of consumer behavior to assist in diagnosis. For instance, the new Nest Labs thermostat from former iPod designer Tony Fadell uses algorithms and user input to develop a "schedule" for energy usage that manages heating and air-conditioning to promote savings. The device, which was released in 2011, is available for $249. Other market-ready models, noted in Section 4.3 below, provide various capabilities to record and program thermostat parameters at a wide range of prices.

3.3 Installation of Upgrade

Quality control measures to ensure proper installation of retrofit actions are necessary to ensure energy savings. Retrofit program managers must promote quality control across the suite of potential upgrade actions if actual energy savings are to achieve projections.

The thermal envelope of a home, which separates conditioned (climate-controlled) spaces from non-conditioned spaces, is a key contributor to energy performance. Walls, floors, and ceilings all constitute the thermal envelope. The thermal envelope must be tightened and sealed in order to minimize heating and cooling losses to the outside. Air sealing measures such as weather stripping, caulking, and windows can all improve retention of heating and cooling in the conditioned space. Proper attic insulation at a minimum of R-38 (ideally R-49) can reduce transmission through the building envelope to a non-conditioned attic. Windows should be installed considering environmental conditions, ideally using a model that includes external factors such as building orientation and shading. In window selection, solar heat gain coefficient (SHGC), U value, and frame material must be appropriate for the climate, building orientation and shading conditions.

In addition to the thermal envelope, mechanical systems also contribute significantly to building performance. One of the primary contributors to energy loss is ductwork. Leaky ducts can reduce effective delivery by 30% or more, so measures must be taken to properly seal as much ductwork as possible. Ducts in non-conditioned spaces such as an attic are usually accessible and can be properly sealed. Other ducts, however, are sometimes inaccessible without removing walls or floors, which present trade-offs between cost and performance. Ideally, all accessible ducts within non-conditioned spaces should be sealed. Ducts within conditioned spaces are not as much of a concern since any leakage is within the thermal envelope; however, this can present imbalances in proper air distribution and internal home conditions.

Other parts of mechanical, water, and electrical systems must also be considered. Mechanical systems such as furnaces and air conditioners should be upgraded with appropriately-sized, high efficiency equipment. Water heaters are significant contributors to energy and water use. Installing a water heater blanket, as well as insulation for hot water pipes, can reduce energy losses associated with transmission of hot water. Home electrical systems should be upgraded, including installation of CFL or LED bulbs and ENERGY STAR® rated fixtures for fans and other devices. Plugging devices into power strips that prevent energy losses when turned off can also significantly reduce annual energy bills. Finally, water system components such as low-flow shower heads can improve water heating energy savings and reduce water consumption. Many retrofit programs are including these and other measures (low-flow toilets) to reduce energy and water consumption.

Quality control measures such as those listed below are critical for energy performance:

- Testing should be conducted before and after installation using appropriate test-in and test-out procedures to characterize energy improvements while ensuring proper installation
- Installation crews should receive training from a BPI certified trainer, receive ongoing instruction from specialists in energy efficiency retrofits, and earn BPI certifications
- After installation, contractors should conduct combustion appliance safety tests, examining the combustion appliance zone (CAZ) to measure and ensure carbon monoxide levels comply with established safety standards

4 Implementation

4.1 Accuracy of Energy Savings Projections

The challenge of predicting energy savings is long-standing, but advances in technology and modeling techniques are allowing contractors and energy professionals to more accurately model homes prior to installation. The ARBI team has worked with leading industry professionals to better understand the energy modeling process, especially the appropriate use of models in various scenarios.

A key factor in utilizing models appropriately is to understand the ultimate goal of the modeling process. As energy models can be used for many purposes, knowing how to apply model results in various scenarios mitigates the risk that inappropriate modeling techniques will result in poor model results for the intended purpose. If a model is used as part of the upgrade design process, it can supply useful insights to assist energy professionals in implementing the best combination of measures for a particular house. It may not, however, accurately reflect final performance, depending upon the actual circumstances of the installation process as discussed in Section 3.3. The model may provide accurate projections based on the proposed design, but not the house as-built. Also, upgrades in insulation, mechanical ventilation, and HVAC systems may or may not have been installed as the model assumed. The model performance will be subject to the difference in model assumptions and actual conditions. To correct for this, the model should be rerun using test-out data, reflecting post retrofit conditions.

If a model is used to provide projections for consumers, it should be framed by industry personnel as a guideline that can be refined based on continued monitoring and adjustment, rather than an absolute target. Monitoring allows insights into occupant behavior and may provide feedback about equipment efficiencies if it is configured to measure efficiency. Once occupant behavior is more accurately understood, the model schedules can be adjusted to more accurately reflect actual conditions. At the same time, occupant behavior can be highly variable from provided input, meaning that models may reflect error. Thus, understanding the limitations that models have towards various ends can go far to improve their accuracy.

> **Pre- and post-installation monitoring** in a sampling of houses is a critical component of accurate energy savings projections. Conducting tests both before and after installations and inputting that data appropriately can work to provide better modeling predictions of energy use for similar house types.

Pre- and post-installation monitoring is a critical component of accurate energy savings projections. Data drives both better modeling and more accurate predictions. Models with more data are likely to be more robust. At the same time, the process of obtaining that data allows energy professionals to assess actual performance of upgrades. Conducting tests both before and after installations and inputting that data appropriately can work to provide better predictions of models.

Over time, modeling may not be necessary for every house pre-retrofit. The ARBI team is currently working to apply energy models to broader scales, including at the neighborhood or regional level. If an area is comprised of similar homes built in the same era, then energy models can be applied more broadly, thus reducing time and effort required to project energy savings. Applying models too broadly, however, can result in poor model performance. The number of occupants in a home, details regarding construction, and types of appliances are all important inputs to energy models that can be overlooked if working at too broad of a scale. Thus, industry professionals must balance economies of scale with need for detail in using energy models within both the design and use projection scenarios.

4.2 Understanding Consumer Perceptions of Energy Savings

Consumers typically have an expectation to receive certain energy savings for their investments in energy efficiency retrofits. This expectation, however, is shaped by public perception, education, and interactions with energy efficiency professionals. Managing such perceptions, so that they are both realistic and beneficial, lies at the heart of effective understanding of the marketplace and consumer behavior.

Industry professionals must work to better understand the multiple motivations consumers may have for pursuing energy efficiency retrofits. A first question to ask is: what does a potential customer care about? For some customers, realized savings may be the most important motivation. In these instances, contractors should emphasize appropriate savings predictions, including making consumers aware that 1) model predictions are not absolute, 2) consumer behavior after an upgrade can significantly affect results, 3) electricity rates can change, which can affect utility cost savings, and 4) weather patterns can have a significant effect on home performance. For other customers, savings may be less important than concerns of health or comfort. Contractors should work to understand what factors are of greatest concern to customers, and be sure to incorporate measures that mitigate these concerns into the HEU.

Presentations to various consumers must be adapted based on consumer motivations in order to most accurately and effectively present opportunities for energy savings in a home.

Contractors must work to cultivate a long-term relationship with consumers, helping to guide them through the process of understanding energy predictions, opportunities, and savings. For instance, many consumers will not have time or interest in understanding the nuances of energy predictions provided through common industry tools such as *EnergyPro*, *BEopt* or *Recurve* reports. Rather than inundate customers with too much information, the contractor must help the consumer work through a complex findings report in order to identify the most useful results that will sell the upgrade to a consumer.

Performance guarantees provide security for consumers and a competitive advantage for contractors. While other related industries have successfully implemented performance guarantees, the residential energy efficiency sector has not widely explored these options. Applying effective performance guarantee models to the residential energy efficiency sector requires collaboration within the energy efficiency industry, while working with partners in other industries to adapt successful business models.

In other industries, performance guarantees have shown to be critical components to managing consumer expectations. For the energy efficiency sector, they present significant challenges. If consumer expectations are too low, they may not decide to move forward with an HEU. At the same time, if performance guarantees do not justify initial consumer expenditures, customers will be reticent to spend large sums for an HEU. The guarantee as part of a well-priced and well-marketed package is a strong tool to combat lack of education and consumer complacency in the energy efficiency marketplace. It can work to mitigate several of the previously identified risks, such as model prediction of energy use, consumer uncertainty over results, or hesitancy about the contractor.

Warranty programs for retrofits similar to those offered in other home and consumer sectors can facilitate long-term relationships between customers and contractors, while also increasing the economic attractiveness of retrofit work for contractors through the inclusion of maintenance agreements.

Finally, consumer perception is also addressed through program strategies that ensure quality work. Assuring strong, ethical work amongst industry professionals can help to build trust in the nascent energy efficiency industry. Testimonials from prior customers also go far to assure potential customers of contractor trustworthiness.

4.3 Measuring Energy Savings

The measurement and assessment of energy savings after HEU installations can provide robust data useful in future work, as well as insights into quality control needs and consumer satisfaction. Incorporating these into regular operations of retrofit programs is critical to gaining useful information throughout the pilot operations.

In recent years, a number of innovations and services have created greater opportunities to measure energy savings in residential homes. Innovative home energy management systems that differentiate home heating and cooling energy use from other energy uses provide greater resolution for homeowners and energy managers. Networking that links data gathering capabilities with residential energy use data through automatic retrieval provide increased analysis and remote monitoring capabilities. Online platforms such as *MyEnergy (www.myenergy.com)* offer residents the opportunity to view detailed descriptions of their energy consumption and compare consumption across various time periods. Retrofit programs can incorporate screenshots from the *MyEnergy* platform into customer communications and management activities, while also facilitating analysis by program managers. The cost of capturing this data is dropping dramatically, as well, making it affordable to incorporate such capabilities into regular retrofit program operations. The ARBI team is now researching the efficacy and accuracy of this portal and data collection technique.

New technologies also provide opportunities for better monitoring. Devices that differentiate between consumptive uses provide greater resolution into residential energy patterns, which assists homeowners in analyzing areas for potential improvement. Additionally, such technologies allow program managers to more readily track energy usage of upgraded homes, allowing for greater analysis capabilities that can assist in customer management. Another relatively new technology can shed light on occupant behaviors that drive energy use—thermostats that monitor and retain heating and cooling setpoints over time. Such thermostats are becoming increasingly available at market prices. For instance, the previously mentioned Nest Labs thermostat, which seeks to combine design and technical capabilities, retails for $249. The Ecobee thermostat, which retails for $350, monitors sets as well as indoor and outdoor temperature, while also connecting to local WiFi networks for remote control. The EnergyHub device, which retails for $300, has similar capabilities, except for monitoring outdoor air temperature. Generally, such communicating thermostats provide additional opportunities to connect available data with ready platforms, including smart phones and the *MyEnergy* portal. When homeowners and program managers have access to more robust data on energy usage, it can help to answer questions and alleviate conflicts in a more efficient manner, thus saving all parties time and energy.

Figure 2. Ecobee thermostat (Source: Ecobee website; reprinted with permission)

At the same time, such capabilities run the risk of becoming one more electronic-based procedure in the already busy world of consumers. Strategies must take into account how to effectively incorporate new robust data capabilities into products focused on consumer uptake. Customers can become quickly overloaded by too much data, to the point that they tune out and program goals are diluted. Therefore, implementations must minimize burdens for consumers, relying on strong relationships to pinpoint the level of engagement that customers are willing to undertake in long-term energy monitoring. If done effectively, such measures can assist in long-term monitoring efforts, performance guarantees, customer retention, and uptake of HEUs in the market.

Finally, home performance for retrofits may tend to degrade over time following an installation. Simple measures such as replacing air filters, however, can work to maintain high levels of performance. Ensuring that such maintenance occurs can significantly increase longevity of performance, but accomplishing this must make economic sense to all parties involved. This could include homeowners regularly servicing their HVAC systems or keeping their pool cleaned so the pump doesn't have to expend additional energy to keep the filter clean. As noted previously, contractors can manage consumer expectations for future performance through warranty programs, which serve the dual purpose of maintaining home performance while building long-term contractor-customer relationships. Through such methods, assessment of energy upgrade performance can also assist program managers to better understand the long-term dynamics of technical and market factors.

4.4 Quality Control Measures

Quality control and quality assurance measures are critical in providing performance guarantees, building consumer confidence in energy efficiency retrofits, and assuring customer safety and health. While strong training and certification programs exist that certify contracting professionals in proper energy efficiency installation techniques (such as those offered by BPI), effective implementation of such techniques may vary. In some cases, subcontractors hired by certified contractors may not have proper training and conduct sub-par work.

More often, however, breakdowns in communication among industry professionals impede the certification process. The ARBI team has seen that facilitating this communication early in the HEU process can alleviate complications in certification program mandates. By involving contractor certification program representatives in the selection process for neighborhood-level performance parameters, retrofit program managers can facilitate smooth quality control processes as contractors upgrade homes. For instance, if a contractor seeks to start an upgrade program in a neighborhood, retrofit program managers can facilitate a site visit between quality control representatives, contractors, and program managers. During such sessions, issues of inspections and tradeoffs can be worked out, so that contractors have a clear agenda provided by program representatives for installation upgrades. This has been shown to significantly alleviate subsequent delay and uncertainty in certification of upgraded homes. These meetings foster agreements among the involved parties, which then provide a roadmap that, if followed, will result in a certification. Even if a home is subject to multiple certification standards, ARBI collaborators have found that these pre-installation site visits are critical to mitigating later certification delays. By recognizing that certification programs are a vital part of the retrofit industry, these early collaboration procedures can work to alleviate the most pressing risks related to lack of information transfer.

> Program managers can develop installation guidelines and integrated QA/QC procedures tailored to specific regions and programs, to minimize added costs to participating contractors.

Certification programs vary across the industry, which can complicate the certification process. Various public and private upgrade programs may use different and multiple certification regimes, complicating the process of certification for contractors and homeowners. Consumers and contractors can be burdened when multiple annual audits are required for rebate dispersal. In extreme circumstances, contractors may even refuse to work with rebate programs that have onerous certification requirements. To mitigate this risk, actions must be taken to streamline, synthesize and homogenize various certification requirements and eliminate overlapping program requirements within upgrade programs.

Quality assurance programs can address issues both before and after installations. Robust education and training programs for participating contractors and crews can work to ensure that contractors are conducting good work. At the same time, program managers for state and federally managed upgrade programs can conduct post-installation verifications to assess work from participating contractors. This combination of program measures can ensure that contractors are providing quality installations, maintaining program reputation and consumer satisfaction. Industry leaders and program managers can also develop documentation and materials that facilitate knowledge transfer. This knowledge transfer would allow new program designers and managers to have a framework and benchmarks to start building their own programs.

Overall, key performance indicators for the strategy guidelines include number of home energy assessments and HEUs, number of post-installation claims and complaints, and level of expected and actual savings. Clear actions that increase technological and programmatic innovations are necessary to ensure greater financing potential for residential energy efficiency upgrades. Residential energy efficiency retrofits must seek competitive market advantages, including both short- and long-term perspectives.

5 Conclusions

Strategy guidelines are important to promoting and attaining realistic energy savings for residential retrofits. Relationships between program managers, contractors, quality assurance personnel, and consumers are influenced by technical and administrative factors, and can be facilitated through early integrated communication. The ARBI team has sought to develop guidelines across several categories. First, accurate projections of energy savings provide consumers with reasonable expectations while offering service providers the opportunity to mitigate risks. More accurate energy modeling, facilitated through new technologies and pre- and post-installation monitoring, can improve current practices. Models must also be used for appropriate purposes in particular situations, including as tools for projections or design. Second, developing greater understanding of consumer perceptions of savings can assist service providers in managing expectations and market offerings. Industry professionals must understand the varied consumer motivations for retrofits. Performance guarantees, which are facilitated through better projections and monitoring, can go far to manage consumer expectations. Third, more effective strategies to measure energy savings are critical for retrofit industry growth. New technologies such as thermostats with networking and monitoring features can assist service providers to monitor consumer behavior. Better measurement also facilitates greater insight into potential changes in consumer behavior after a HEU. Finally, effective procedures for quality control measures can ensure standardized work. Program managers can work to facilitate early interactions between contractors, quality assurance personnel and certification managers to reduce conflicts and delays in post-installation certifications. Trade-offs between multiple quality assurance and/or certification programs can be minimized by ensuring that all participating parties at a local or regional level agree on retrofit, quality assurance, and certification procedures. The combination of such implementations across the four categories can go far to mitigate risks associated with low uptake of energy efficiency retrofits.

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Appendix A: Background on LSRP Programs

The ARBI team is currently working to implement a series of large-scale residential retrofit program (LSRP) pilots in Stockton, and Los Angeles, Alameda, and Sonoma counties in California. The LSRP pilots aim to develop a market for energy efficiency retrofits through increased consumer outreach and education, incorporation of market efficiencies, and creation of economies of scale. In enacting the pilots, the team has developed and is continuously refining several novel strategies, including:

- Design of bulk purchasing strategies based on an assessment of existing approaches. This includes understanding dynamics of local and national equipment sources.
- Design of methods for addressing various logistical challenges, particularly those related to storage of equipment and delivery to multiple job sites.
- Design of contractor participation guidelines. These guidelines were designed to ensure that contractors hold suitable qualifications, would adhere to quality specifications, and would maintain high standards of workmanship. It is critical that contractors approach and work with homeowners in a way that is consistent with the overall goals of the pilot LSRPs.
- Identification of key values to be tracked and beta testing of tracking systems.
- Evaluation of delivery infrastructure, which includes determining effective customer relations strategies as well as efficient higher-level bureaucratic organization.
- Evaluation of various marketing strategies, including door-to-door outreach, neighborhood-level targeting, early adoption incentives, sales infrastructure, publicity campaigns, and communications efforts such as websites and call centers.
- Evaluation of varying sales infrastructures, including use of professional contractors and installers as sales personnel, as opposed to the use of professional sales personnel with experience in other related industries.

The objective of the pilots is to increase energy efficiency in the residential sector through improved uptake of whole house home energy upgrades (HEUs). The three pilots contain similar core elements, while employing tailored marketing and outreach strategies based on the specifics of the target regions. This allows ARBI to compare and contrast various strategies. The ARBI team has responded to early results by implementing targeted modifications in pilot structure based on data and feedback from participants.

Appendix B: *ECON-2* Model Results Used for Utility Justification

As described in Section 3.1, the *ECON-2* model output below provides an example of information used by utilities to assess rebate levels for particular HEUs.

Energy Upgrade Recommendations — **ECON-2**

Project Name	Documentation Author
Project Address	Author Address

Recommended Improvements	Description	Annual Savings	Est. Cost to Install	Savings Site	Savings TDV
Roof Insulation	Type = R-38 Roof Attic Cavity Insulation = 38.0 R-Value Interior Insulation = 0.0 R-Value Exterior Insulation = 0.0 R-Value	$138	$0	0.8 %	1.2 %
Windows	Type = New Double Vinyl LoE U-Factor = 0.300 SHGC = 0.3	$2,135	$0	13.4 %	21.9 %
Building Leakage	Building Leakage = 3.6 SLA Leakage Rate at 50 Pascals = 1285 cfm	$2,143	$0	13.5 %	22.0 %
HVAC Duct Leakage	Leakage = 6 % Leakage Rate at 25 Pascals = 55 cfm	$2,747	$0	22.6 %	30.9 %
HVAC Duct Insulation	Duct Insulation = 6.0 R-Value	$2,910	$0	25.4 %	33.4 %
HVAC System	Name = New 80/16 Split System Type = Split DX Heating = Central Furnace Efficiency = 0.80 AFUE Cooling = Split Air Conditioner SEER = 16.00 EER = 13.00	$3,373	$0	26.8 %	38.3 %

Annual Results End Use	Energy Cost Existing	Energy Cost Improved	Energy Cost Savings	Electricity (kWh) Existing	Electricity (kWh) Improved	Electricity (kWh) Savings	Fossil Fuel (therms) Existing	Fossil Fuel (therms) Improved	Fossil Fuel (therms) Savings
Space Heating	$426	$253	$173	0	0	0	401	248	153
Space Cooling	$3,151	$634	$2,517	2,569	519	2,050	0	0	0
Fans	$1,383	$736	$647	1,128	603	524	0	0	0
Pumps	$0	$0	$0	0	0	0	0	0	0
Domestic Hot Water	$222	$213	$9	0	0	0	209	209	0
Indoor Lighting	$1,272	$1,266	$6	1,038	1,038	0	0	0	0
Outdoor Lighting	$156	$156	$1	128	128	0	0	0	0
Appliances/Plug Loads	$4,344	$4,322	$21	3,542	3,542	0	0	0	0
Ancillary	$0	$0	$0	0	0	0	0	0	0
Renewables	$0	$0	$0	0	0	0	0	0	0
TOTAL	$10,954	$7,581	$3,373	8,404	5,829	2,574	610	457	153

CO_2 (lbs/year)	Existing	Improved	Savings
Electricity	97,901	67,913	29,989
Fossil Fuel	7,110	5,328	1,783
TOTAL	105,012	73,240	31,771
Average Demand (kW)	8.20	2.91	5.29
TDV Energy ($kBtu/ft^2$-yr)	196.77	121.38	75.39

Climate Zone:	12
Electric Rate:	PG&E G1 S
Gas Rate:	PG&E G1 S
Floor Area:	1,372
Type:	Single Family

Improvements above shown with cumulative savings benefit for combined measures

The estimated operating costs shown in this report are dependent upon many factors. The construction and conservation features of the project clearly are important. Equally important is the thermostat setting. How the thermostat is used, appliance use, and occupant interaction all influence the annual operating cost. The estimates provided in this report are based on typical conditions; your actual usage will vary.

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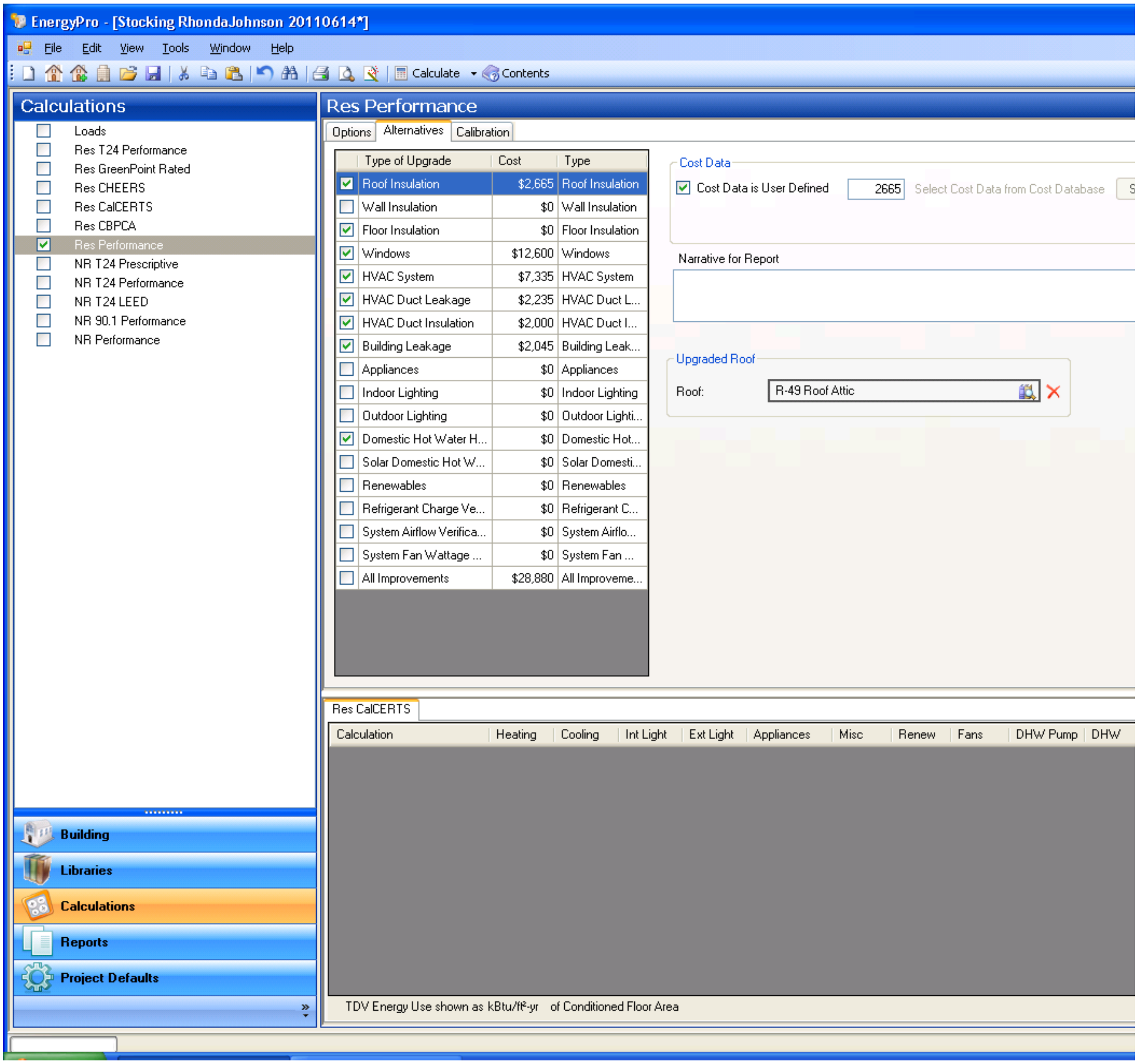
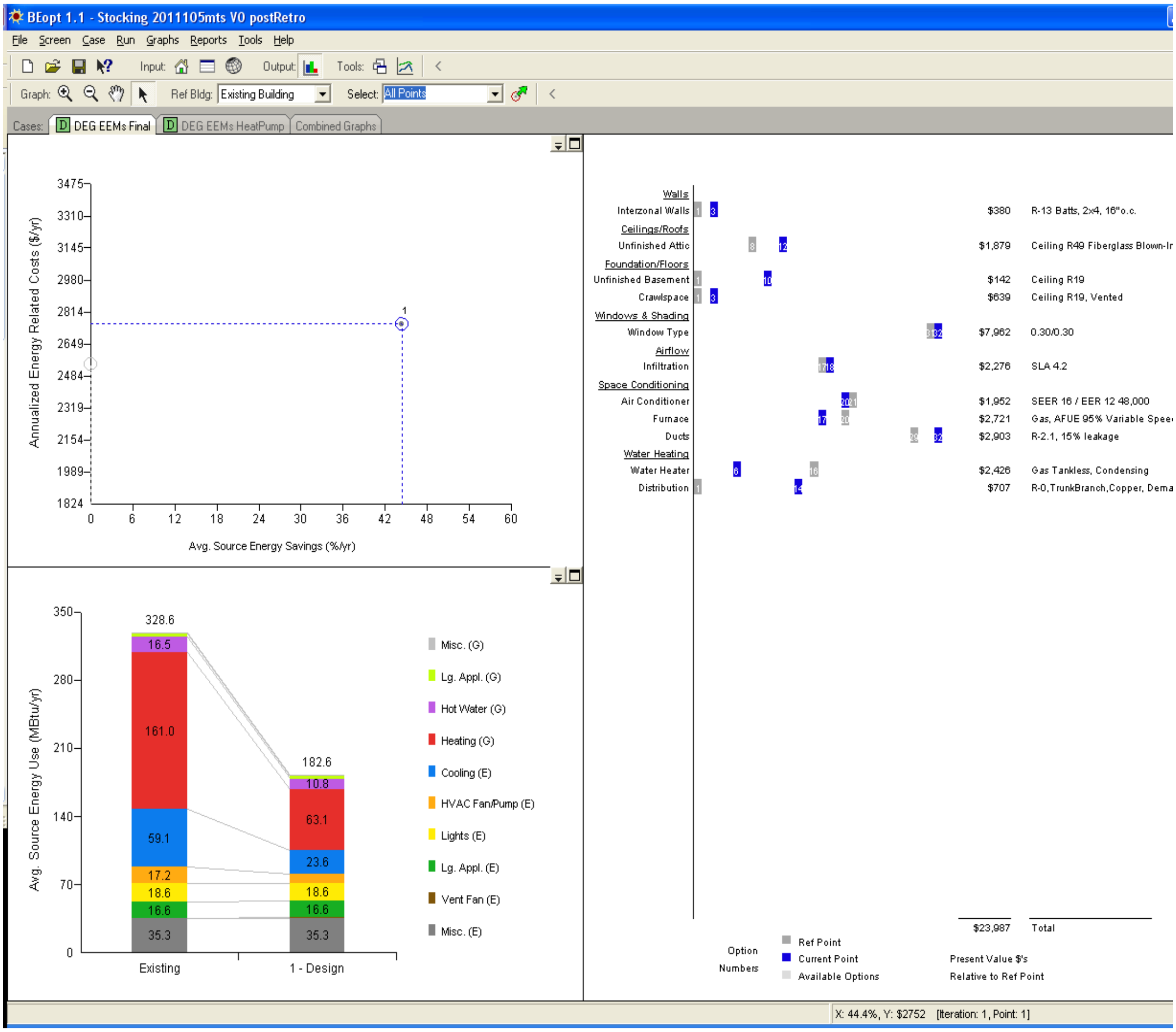
Appendix C: *EnergyPro* Model Results Used for Design Purposes

The figure below shows a screen shot of an *EnergyPro* model with various alternatives used in developing a cost-effective package of measures.



Appendix D: *BEopt* Model Used for Post-Installation Projections

The figure below shows a screen shot of a *BEopt* model with various alternatives used for simulating pre- and post-installation energy use.



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