Keys to the House: Unlocking Residential Savings with Program Models for Home Energy Upgrades

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ABSTRACT

After more than 40 years of efforts by efficiency program administrators, the home retrofit market remains challenging to penetrate, especially at levels necessary to address energy savings and emissions reductions goals. Residential retrofit programs have not coalesced around a reliably successful model but still differ widely in their design, implementation and performance. If future programs are to meet their goals, it is essential to understand what program elements are key to acquiring savings as cost effectively as possible. To that end, the U.S. Department of Energy (DOE) sponsored a comprehensive review and analysis of home energy upgrade programs with proven track records, focusing on those with robustly verified savings and constituting good examples for replication. The study team reviewed evaluations for 134 programs that promote multi-measure retrofits or major system upgrades and paid particular attention to useful design and implementation features, costs, and savings for more than 30 programs with rigorous evaluations of performance. This meta-analysis outlines designs for program models and implementation strategies for 1) direct install retrofits; 2) heating, ventilating and air-conditioning (HVAC) replacement and early retirement; and 3) comprehensive, whole-home retrofits.[1] These program models can be useful guides as states consider expanding their strategies for acquiring energy savings as a resource and a path to emissions reductions. We also discuss challenges and strategies for using evaluations to create program models that can be confidently applied in multiple jurisdictions.

Introduction

More than half of the states have mandatory energy savings targets for using efficiency as an energy and environmental resource, and the federal government has made international commitments to significant reductions in greenhouse gas emissions. Since the residential sector accounts for 21% of U.S. carbon dioxide emissions from burning fossil fuels, saving energy in homes is essential to meeting these state and federal policy objectives.

Numerous assessments have offered strategies for driving comprehensive and enduring residential efficiency (see Residential Retrofit Working Group 2015; Neme et al. 2011; Fuller et al. 2010). But with notable exceptions, such as the evaluation of the Better Buildings Neighborhood Program (DOE 2015), there has not been a systematic, uniform validation of

[1] Even though low income programs were the precursors to today's Home Performance with ENERGY STAR retrofit programs, we focus on market-rate programs because low income programs have many other policy drivers and objectives and correspondingly different policies, delivery features, costs, and outcomes.

successful program design and implementation through rigorous evaluations of multiple programs. Such a meta-analysis could highlight successful design and implementation elements that could be replicated with confidence.

DOE engaged the Lawrence Berkeley National Laboratory (LBNL), working with its contractor Energy Futures Group (EFG), to research three widely employed types of residential energy efficiency programs to see if it would be possible to develop replicable "model" program approaches that program administrators (PAs) that are relatively new to energy efficiency or ramping up their efforts could use to meet energy and emissions reductions goals.

DOE sought to develop proven approaches to achieving deep program savings as cost effectively as possible. It was deemed imperative that these model programs were based on the proven successes of actual programs. To this end, the research focused on programs that 1) have a minimum of two to three years of field implementation and 2) have conducted independent, third-party impact evaluations to validate their savings as well as other key indicia of success, such as customer and contractor satisfaction and market penetration. Self-reported success was not considered to be sufficient.

Elements of Program Design

In research for this project, LBNL and EFG focused on identifying those program elements that distinguished more successful programs—the "success factors" that could be isolated for inclusion in model programs. Our review of program evaluations suggests that successful programs meet the following conditions:

1. Market potential for energy savings is sizable.
2. The technology being promoted is reliable.
3. The "right" participants are engaged (the ones for whom the opportunity is sufficient from the program's perspective).
4. The program works financially and "emotionally" for participants (meets their values in some way) and the process is not overly burdensome.
5. The program is in the interests of contractors/vendors/etc.—it either aligns with their business models or, if it is disruptive, the rewards are sufficient to overcome that resistance.
6. The savings are verifiable.

Research Approach

LBNL and EFG looked to multiple sources to identify programs to review and evaluations if available: the LBNL Demand-Side Management Program Database; best-practice program studies conducted by the American Council for an Energy Efficient Economy; the existing homes program guide produced by the Consortium for Energy Efficiency (CEE 2015), and the Regional Energy Efficiency Database (REED) maintained by the Northeast Energy Efficiency Partnerships. LBNL and EFG also contacted numerous industry experts for recommendations on successful programs to consider.

To assess their applicability to this project, LBNL and EFG assembled a starting list of nearly 400 program years[2] for three types of programs: 1) direct install retrofits; 2) heating, ventilation and air conditioning (HVAC) replacement and early retirement; and 3) comprehensive, whole-home retrofits. More than 100 distinct programs had some type of evaluation that was publicly available and performed over the last four program years. On closer examination, however, only about half of comprehensive programs had recent evaluations, and only a few dozen evaluations combined both robust, independent savings verification with insight into the reasons for success of the programs. Even these evaluations often limited their approach to verifying adherence to Technical Reference Manual (TRM) protocols or an engineering review of the savings calculation methodologies rather than billing analyses.

Though frustrating, the very limited availability of comprehensive evaluations is unsurprising for several reasons:

- Comprehensive evaluations can be complicated and costly, and producing viable billing data is often challenging.
- Though cost-effective, residential direct-install, HVAC, and whole-house programs do not contribute savings to program portfolios at the same level as retail lighting or large commercial efficiency programs. Limited evaluation resources are often focused on those higher-saving programs.
- Evaluations are often narrowly focused on determining compliance with regulatory or statutory obligations. There are significant variations in how these obligations are defined and interpreted. Therefore, there is a corresponding variation in how evaluations are conducted.
- If evaluation contracts are administered by the PA that is being evaluated, critical perspectives may be softened despite the learning opportunities they present.
- PAs may be reluctant to share information critical of performance if doing so could cast a negative light on their program implementation.

We pored through the most relevant evaluations to glean insights into successful program design for each of the three program types. In all, 134 residential energy efficiency direct-install, HVAC, or comprehensive programs were reviewed. Of these, slightly more than 30 programs had recent, publicly available impact evaluations with both robustly verified savings and insight into program design. In the team's view, impact analyses that rely on verifying compliance with deemed values in a TRM, for example, may be useful to confirm that a program is meeting its regulatory obligations but do little to further our fundamental understanding of which program elements are critical in producing savings, whether those savings can be expected to last, and what, if anything, can be done differently to improve results. Evaluations with the necessary insight and rigor are, no doubt, both expensive and time-consuming and are certainly not without limitations due to the availability and reliability of consumption and program data. But they are essential to our understanding of the impacts of these programs and can provide irreplaceable value in guiding more effective program implementation.

[2] A program year (PY) is a year's worth of data for each program.

Model Program Approaches

Enhanced Residential Direct Install

Many PAs have implemented "direct install" programs in which program staff or contractors visit homes to install lower-cost measures such as efficient lighting products, smart strips, and water conservation measures. These programs provide assurance that the measures are installed, therefore savings are typically considered to be reliable. However, the types of low-cost measures that are installed only scratch the surface of the savings opportunities that exist in many homes.

To address this, some PAs have offered direct install programs that seek to provide greater savings through the addition of more comprehensive measures such as air sealing, duct sealing, or insulation. DOE sought to develop a model direct install program along these lines—an "enhanced" program that would result in larger, more persistent savings than those typically achieved in residential direct install programs. Such a program can provide a high level of savings assurance for longer lived measures in addition to the shorter lived, low-cost measures that direct install programs typically focus on.

Because direct install programs specify the measures that they offer, they can be used to obtain savings in targeted end uses that provide specific programmatic benefits. For example, in cooling climates where peak electric use is driven by air conditioning, a direct install program can focus on obtaining cooling savings to reduce peak loads.

Direct install programs are also sometimes thought of as "on-ramps" to engage customers to conduct more comprehensive retrofit projects that may include whole-house insulation and air sealing or HVAC replacements. Most direct install programs include some type of assessment and "kitchen table" conversation with the customer, and these can be used to provide customers with a path to greater efficiency. Indeed, failure to take advantage of this opportunity could make it less likely that participants will pursue subsequent efficiency projects. If the program does not actively try to engage customers to do more, there is a risk that they will "check energy efficiency off of their list" as a task that has been completed.

Direct install programs require significant program incentives to obtain customer participation, making it critical that program costs are managed well in order to maintain cost effectiveness.

Factors Related to Success in Direct Install Programs

Evaluations of the following existing direct install programs provide examples of successful implementation practices:

- *Efficiency Maine's ARRA-funded direct install program* reached over 5,100 participants in a one-year period from July 2012 to June 2013. The program provided a $600 incentive for the completion of at least six hours of targeted air sealing and insulation work in conjunction with a home energy assessment.
- The *Connecticut Home Energy Savings Program (HES)* is a state-wide program that offers a $99 home energy assessment and direct-install lighting and air sealing, as well as additional incentives for the installation of more comprehensive measures such as shell

improvements and HVAC upgrades. The program had over 21,000 participants in 2011. A recent evaluation of Connecticut's HES program looked closely at ways to increase per project savings. The report identifies steps the program could take to ensure that air sealing and duct sealing projects capture more of the available savings opportunities while contractors are on site installing measures. Importantly, the evaluation found that missed opportunities could be lessened not only through enhanced quality assurance, but also through structural changes in the program that could improve profitability and more closely align with the business needs of participating contractors.

- *PSE&G's Home Performance Direct Program* is offered to Long Island customers who have central air conditioning. The program provides a free home energy audit and air sealing and/or duct sealing, which is required for homes where site conditions allow it to be done. The program also offered up to 20 free CFL lamps in 2014 and served more than 2,200 customers.
- *Kentucky Power's Modified Energy Fitness Program* served 1,200 customers each year in 2012 and 2013. The program is available to customers that average at least 1,000 kWh per month. The program used an aggressive, targeted marketing approach to attract sufficient interest to meet its participation goals, and in addition to a home energy audit offered water conservation measures, weather stripping and caulking, duct sealing, and efficient lighting products.

The research team developed a program model based on the combined strengths of all of the programs. Where evaluations suggested areas for improvement in program operations we also addressed those in the model program. Characteristics of the resulting model DI program include:

- Capitalizes on significant opportunities for air sealing or duct sealing that could be combined with targeted insulation.
- Premised on one full day per job with air sealing prioritized to avoid leaving obvious opportunities untouched.
- Incentive must be rich enough to entice large numbers of customers to participate.
- Can pay less than 100% incentive if aligned with customer needs but may need to pay 100% if it isn't a customer priority.
- Effectiveness depends on contractors who do this full time, with dedicated crews who specialize in efficient project execution.
- May need to include a pre-visit walk through to screen for health and safety problems.
- Most suited to a heating climate with older homes.
- Second best application is a cooling climate with high presence of central air conditioning.
- Process to engage customers in follow-on projects should have a strategic focus.

Reported Program Costs and Savings

Two of the four programs for which cost and rigorously evaluated savings data were available focused solely on electric savings; a third focused on fossil fuel savings; and the fourth

targeted both electricity and fossil fuel savings. Converting the reported savings to MMBtu for comparison purposes yielded a range of PA costs per MMBtu from $374 to $1,420. Program savings ranged from 842 kWh to 1,222 kWh annually with Connecticut's dual-fuel HES program averaging 1,067 kWh and 58 therms annually. In MMBtu equivalents, the saving ranged from 2.87 to 9.44.

Model Direct Install Program

The central tendency for costs and savings among these direct install programs, when applied to a dual-fuel model, is reflected in **Error! Reference source not found.**. Costs for a single-fuel program would likely vary.

Units	Annual kWh per Unit	Annual Therms per Unit	$ per Unit	Total Annual MWh Saved	Total Annual Therms Saved	Annual Program Cost	$ per Annual MWh Saved	$ per Annual Therm Saved
2,000	800	60	$ 1,094	1,600	120,000	$2,187,600	$ 756	$ 8.15

Table 1: Model Direct Install Program Costs and Savings

Enhanced Residential HVAC

HVAC equipment uses a significant amount of energy in most homes, yet effectively addressing system and operational efficiency has been challenging. The incremental savings that are available from higher efficiency equipment are typically small, and the program administrator often must drive change from standard practice for distributors, contractors, and homeowners. Influencing customers to replace functional equipment before it has reached the end of its useful life can provide greater savings, but this is not an easy task. Adding "quality installation and verification" (QIV) to a system replacement can increase savings, but this is not standard practice for many contractors and can be perceived as an obstacle to profitable business management. There are often opportunities to reduce energy use by improving the ducts used for distribution, but these added services can be challenging to sell to a customer who is already facing an expensive system replacement.

HVAC programs address potential "lost opportunities" by influencing customers to purchase efficient equipment at the time of replacement, thereby preventing inefficiencies that would persist for 10 to 20 years until the next replacement cycle. HVAC programs also address heating or cooling season demand issues by reducing peak loads. For simplicity, most HVAC programs focus on the nameplate efficiency of the equipment, providing rebates when customers make efficient purchases. QIV program components may be offered on their own or as add-on program requirements to receive a rebate for the more efficient equipment itself. Most commonly, these add-ons include some combination of measuring airflow and refrigerant charge, proper equipment sizing, and duct sealing. In the interest of maximizing cost-effective savings, DOE has focused on HVAC programs that include some or all of these additional components and developed a model program that reflects this preference.

Factors Related to Success in HVAC Programs

Notable examples of success in HVAC program implementation include the following:

- *Focus on QIV.* Public Service Company of Colorado's (PSCo)[3] High Efficiency Air Conditioning program comprehensively addresses both equipment efficiency and QIV at the time of replacement. A thorough process evaluation conducted by Cadmus in 2012 referred to clear contractor participation requirements, including that contractors need to be registered with the program, complete a required certification course, pass an examination, and make a commitment to following the program's QIV guidelines. The evaluation also included a comparison of QIV practices with several other PAs and made recommendations for further improving the Colorado program.
- *Provide incentives to contractors.* Several programs including PSCo's provide incentives to customers for meeting participation criteria as well as to contractors for carrying out the required QIV practices and documentation. Because success in the HVAC program area is highly dependent on contractor participation, administrators of these programs concluded that providing supplemental compensation to the contractors in the form of incentives was required to secure their support and participation.
- *Collaborate across electric and gas utilities.* The Complete System Replacement program is a collaborative program between ComEd and Nicor Gas, Peoples Gas, and Northshore Gas. The program rewarded customers for installing a high efficiency gas furnace and high efficiency central air conditioner at the same time and achieved significant participation—over 11,000 customers in PY2013-14. The program did not address QIV but represents a successful model for dual-fuel collaboration that resulted in large participation numbers, significant customer savings, and benefits for both the gas and electric utilities. This collaboration is particularly notable because the cost-effectiveness of both the electric and gas programs were improved by sharing administrative program costs, eliminating duplication.

While all these programs have a specific focus, such as central air conditioner or heat pump replacement, the success factors—dual-fuel coordination to reduce administrative costs, mandated use of registered contractors with QIV requirements, and financial incentives to contractors to elicit their participation— are broadly applicable.

Reported Program Costs and Savings

Few evaluations incorporating billing analysis are publicly available, and the results of those that are available do not easily transfer to other jurisdictions given the uniqueness of program offerings, climate zones, and local market conditions. This is true both for equipment-only programs and for programs incorporating QIV elements, where savings for three evaluated programs that were reviewed ranged from 319 to 1,274 kWh/yr. Savings also varied depending on whether equipment was being replaced on burnout or retired before the end of its useful life.

[3] A subsidiary of Xcel Energy.

The participation levels and overall costs of these programs also varied considerably, no doubt at least in part because the mix of measures promoted differed from program to program. Some programs only addressed heat pumps while others also addressed central air conditioning, furnace blower fan motors, or thermostats. In some cases, such as with Connecticut's HES program, building shell and HVAC measures are included within one program budget, making it difficult to dissect the costs and benefits related only to the HVAC component. Similarly, a significant portion of spending on South Carolina Electric and Gas' Heating and Cooling and Water Heating program is devoted to water heaters. Among the limited set of programs where data were available, the costs and savings were very different, with program costs per participant ranging from $247 to $1,514. Program administrators and evaluators also differed in reporting savings as net or gross, both in annual reporting and in evaluations. These variations in reporting protocols and the mix of promoted measures make savings per participant, as a metric, less helpful than desired.

Given these data constraints, we simplified our projections for a model program by choosing conservative values from the impact evaluation data. Analysis of savings potential for programs similar to the HVAC model program presented here would need to be conducted to reflect local conditions in order to estimate the potential benefits.

Model HVAC Program

Building on the success factors outlined above and on the savings that were documented through the impact evaluations, we propose the following characteristics for an HVAC program model:

- *Consider early equipment retirement to increase savings.* The program is premised on increasing the efficiency of replace-on-burnout equipment purchases, as this approach will be most widely applicable. But the same platform can be used to engage customers who may be well served by early retirement of existing equipment. Connecticut's HES program and Colorado's High Efficiency Air Conditioning program, among others, offer an additional incentive to motivate customers to "retire" equipment that is still functioning.
- *Provide on-ramps for less experienced markets.* The equipment efficiency may be tiered or set at the highest efficiency level that is reliable and widely available depending on the maturity of the market, the range of efficiencies available for specific equipment, and the cost effectiveness of the different equipment options. In general, it makes sense to promote the highest efficiency that is cost-effective, but in markets that are less experienced with energy efficiency it can make sense to offer an "on-ramp" to the program by promoting cost-effective equipment efficiencies that are not at the absolute highest levels. For example, Dayton Power and Light offered one rebate level for central air conditioning equipment with a SEER of 14-15 and a higher rebate for equipment with a SEER of 16+.
- *Contractors meet quality installation and verification requirements.* QIV should be required, and incentives available only to participants who use a registered contractor who has committed to meeting the required installation protocols. By adhering to installation standards and offering incentives for quality installation, energy efficiency

programs can play a role in leveling the playing field for quality-minded contractors so that they are not forced to compete on price alone. PSCo has clear eligibility requirements for contractors to ensure that equipment is installed to deliver the efficiency that the nominal ratings suggest. Note also the importance of regularly performing quality control to assure that contractors are adhering to program requirements, and both working with them to improve quality where it is deficient— and if it is not possible for them to meet program requirements, ultimately rescinding their right to offer program services.

- *Train contractors in required installation practices.* The program will provide or support training as required to assure that contractors have the information they need to meet the requirements. Energy efficiency programs that support the development of a regional trade ally network can benefit both from near term increases in program participation and from long term transformation to more efficiency in standard installation and maintenance practices. The PSCo program, with its rigorous participation requirements, serves as a strong example among the programs we reviewed. A 2012 evaluation of the program conducted trade ally surveys and found that "…two-thirds of participating trade allies reported that they changed their standard CAC installation practices based on what they learned from the QI training required for becoming an Xcel Energy registered program contractor." (Cadmus 2012)

The values in **Error! Reference source not found.** represent the central tendency of the enhanced HVAC programs that focused on central air conditioning as the primary measure and robustly verified savings.

Units	Annual kWh per Unit	Annual Therms per Unit	$ per Unit	Total Annual MWh Saved	Total Annual Therms Saved	Annual Program Cost	$ per Annual MWh Saved	$ per Annual Therm Saved
2,000	1,150	-	$ 1,070	2,300	-	$2,139,000	$ 930	$ -

Table 2: Model Enhanced HVAC Program Costs and Savings

Residential Comprehensive Energy Upgrade

Comprehensive energy upgrade programs for the residential sector have been implemented by PAs across North America. Also commonly known as "whole-house" retrofit programs, they seek to maximize the installation of energy efficiency measures in existing homes while also assuring that building durability and occupant health and safety are fully addressed. Many of these programs have been based on the DOE's Home Performance with ENERGYSTAR program model, which provides guidelines for comprehensiveness, technical performance, and quality assurance. Other programs were developed to best suit the regulatory structures within which the respective PAs work. DOE sought to identify successful programs that achieve these goals in a single engagement with the customer or by engaging with customers in a sustained manner that allows for comprehensive retrofits to be staged over a period of years. In either case, the program goal is to maximize the adoption of cost-effective energy efficiency in each participating home, across all end uses and fuels.

Unfortunately, the study team was unable to find many impact evaluations of comprehensive energy upgrade programs that employ billing analysis to determine the energy saving impacts of these programs. That paucity of data sharply limits confidence in the savings and identification of design elements associated with those impacts.

Reported Program Costs and Savings

We focused on identifying programs that had undergone impact evaluations to verify participants' energy savings, but because there were several different methods that evaluators used to verify savings based on the availability of data, needs of the regulatory jurisdiction, and budgets, it was difficult to correlate results across programs. This made it challenging to use these results as predictors of what other programs might be able to achieve. For instance, per unit savings ranged from just over 100 kWh to nearly 3,000 kWh annually, at a cost to the PA ranging from $0.34/kWh to $1.88/kWh. The findings were often limited by the data that were available to the evaluators. Despite our best efforts, it was therefore difficult to piece together evaluated savings, participation, and costs for consistent time frames, even for individual programs. We strove to identify average savings by project for each program where data were sufficient, as well as provide average costs for those projects and, by extension, the average cost per kWh, therm, or MMBtu saved. Due to limitations in the available data we had mixed success.

Factors Related to Success in Comprehensive Energy Upgrade Programs

Notable examples of success in Comprehensive Energy Upgrade program implementation include the following:

- *Provide high levels of customer support.* The evaluators for Eversource Energy's Home Performance with ENERGY STAR program in New Hampshire commented that the significant levels of customer support provided by the program through the upgrade process contributed to program success. This practice is similar to the support provided by Home Energy Advisors under the Better Buildings Neighborhood Program (Billingsley 2016). New Hampshire's program also reported unusually high conversion rates for Eversource in New Hampshire and for Unitil—on the order of 80% to 95%. This is attributed to a "Home Heating Index" screening process to pre-qualify candidates who are higher energy consumers and thus likely to have savings opportunities. Entergy Arkansas also incorporated program elements into its program design to increase the focus on homes with higher savings potential beginning in 2014, providing a larger incentive for assessments for larger homes and adding a tiered bonus incentive structure that increases as more measures are installed.
- *Go beyond single-fuel measures.* Programs addressing multiple fuels, such as those administered by Efficiency Vermont and Ameren Illinois, seem to save more energy overall than do programs that are limited to single-fuel measures. This makes sense, as programs that take advantage of all savings opportunities have more potential savings to capture. It would also make sense for these programs to have lower transaction costs per unit of savings, though it was not possible to determine if this was the case based on the available data.

- *Engage customers at the start and capture immediate savings.* Numerous programs provide opportunities for vendors who conduct assessments to directly install lighting and hot water conservation measures at no cost to customers. This approach can engage the customer by providing immediate energy savings and provide programs with the ability to claim savings for measures in homes that receive assessments regardless of whether those customers eventually install comprehensive retrofit measures. However, it is critical that vendors not leave customers with the impression that by accepting the direct install measures, they can check energy efficiency off their list of priorities. Among the programs the study team reviewed that provide no-cost, direct install measures are Entergy Arkansas, Energize Connecticut, Commonwealth Edison, Efficiency Vermont, Ameren Illinois, MassSave, and EmPOWER Maryland.
- *Give a bonus for going deeper*. Numerous PAs offer tiered or bonus incentive structures that provide greater rewards for projects that save more energy. For example, Wisconsin's 2013 Focus on Energy Home Performance with ENERGY STAR program provided incentives of 33% of the measure cost, up to $1,250, but also offered a $250 bonus incentive for projects that achieved 25% or greater energy savings. Austin Energy also offered a "Home Performance Bonus Rebate" of between $250-$500 to customers who install a qualifying new air conditioner or heat pump and also install certain weatherization measures. Efficiency Vermont offered a $250 "Comprehensive Retrofit Bonus Package" to customers who achieved at least a 35% air leakage reduction and installed insulation such that the total area of insulation installed is equal to or greater than 75% of the home's finished floor area (e.g., a 2,000 square foot home would need to install at least 1,500 square feet of insulation in walls or ceilings).
- *Upgrade or replace HVAC systems.* Significant savings opportunities may also exist for cost-effective HVAC improvements and replacements within home upgrade programs. Austin Energy achieved an average of 22% savings per home in its Home Performance with Energy Star program in which 56% of participants installed HVAC measures. Heat pump installations was one of the predominant measures in BC Hydro's 2009-2011 program that saved electricity at a cost of $0.34 per first-year kWh.

Model Comprehensive Energy Upgrade Program

Based on the observations above, we propose these key facets of a model comprehensive upgrade program:

- Pre-screening eligible homes for high energy use and thus high savings potential.
- Packaging audits with direct installations of no-cost lighting and hot-water measures for immediate savings that can be counted even if the customer does not opt for more.
- Aligning the program with contractor business needs by optimizing contractor time and payment.
- Awarding of tiered or bonus incentives, scaling with more measures or a bonus for certain savings thresholds (e.g., $250 more if >20%).
- Improved audit-to-retrofit conversion rates through high levels of customer support during lags between energy assessment and installation.

- Enhanced quality assurance *while contractor is on site* to ensure no missed opportunities (e.g., complete, high-quality duct and air sealing).
- Take advantage of all cost-effective savings opportunities and target multiple-fuel savings to lower the transaction cost per unit of savings.
- Go beyond shell, lighting and appliance measures to make HVAC improvements and replacements a priority.

The values in **Error! Reference source not found.** represent the central tendency of the cost and savings values for programs that we reviewed with robustly verified savings, assuming a dual-fuel approach.

Units	Annual kWh per Unit	Annual Therms per Unit	$ per Unit	Total Annual MWh Saved	Total Annual Therms Saved	Annual Program Cost	$ per Annual MWh Saved	$ per Annual Therm Saved
2,000	1,424	96	$ 2,418	2,848	192,000	$4,835,840	$ 1,100.00	$ 8.87

Table 3: Model Comprehensive Home Energy Upgrade Program Savings and Costs

Limitations

When it comes to residential efficiency programs, one size – or design – does not fit all. No program model can be applied universally. Every territory has its own unique housing, end-use and equipment stocks, as well as other market and economic conditions.

The program models offered here also are grounded in and derived from evaluations of programs in earlier years and therefore are backward looking. Innovative new program models are expanding the menu of successful design options and may hold promise. Some "programs" such as pay-for-performance solicitations[4] are not really programs in the traditional sense but narrower transactional venues for resource acquisition that offer a price for avoided energy and capacity and let market actors define their own means of delivering savings.

We should also note that the program models offered here do not have to be sharply defined from one another and often are not. In many territories, whole home and direct install programs and sometimes enhanced HVAC programs are parts of a continuum of services offered under the umbrella of a single program: A contractor installs simple low-cost measures while conducting an audit to identify larger savings opportunities, of which the customer may choose a system replacement or a broader array of measures spanning the entire home. The challenge for the program administrator is orchestrating and coordinating these offerings and enabling contractors to present them to the customer in a simple, coherent fashion.

Lastly, many programs that were not part of this research could also provide great insights into program success and development of a program model. We chose to base our program models on existing programs for which we could obtain third-party evaluations that coupled a high degree of rigor in savings verification with insight into program design and implementation. The paucity of evaluations meeting these conditions sharply constrains the

[4] See, e.g., stakeholder proposals for such a program in California (CPUC Rulemaking 13-11-005), more recently taken up by Pacific Gas & Electric for a multi-year pilot.

ability of researchers, program administrators and other market actors to assess what works and what doesn't with confidence. For real understanding of the dynamics between program design and impacts, the scope of evaluations will need to expand, with a shift in emphasis from validating first-year savings or compliance with deemed savings values to more rigorous verifications and explorations of program design.

Summary

A high-quality meta-analysis of residential energy upgrade programs is difficult for several reasons. First, only about half of comprehensive programs have current evaluations. Second, evaluations differ widely in the methodology and rigor employed in verifying savings and providing insight into program design and its relationship to savings. Inconsistencies and low specificity frustrate the confident correlation of "success" with specific design elements. Lastly, more often than not, evaluations lack meaningful contributions to broader industry understanding of what works in comprehensive residential energy upgrade programs and what doesn't. This is not surprising, given the regulatory environment in which programs operate and the risks that program administrators face. In many cases, evaluations are geared to answering questions on short-term regulatory requirements rather than serving the larger, longer term interest in the ingredients of success and development of replicable models.

It is possible nonetheless to draw out some key, largely common-sense themes:

- Participants and contractors need programs to work for them—quickly, with minimal effort—and be either aligned with their interests or counterbalanced with incentives.
- Perceptions about incentives—"getting a good deal"—may matter as much or more as the role of incentives in reducing customer costs.
- Tiered or bonus incentives can drive greater savings per project.
- Changing market practices requires sustained investments and supportive program policies, such as quality installation verification.
- Program requirements need to reflect practical work management needs of contractors.
- Timing matters: If customers can't do make the recommended improvements all at once, use multiple touches and phases.
- Bundle measures to improve cost-effectiveness.
- Go after improvements in the building shell, lighting and appliances, but also target savings in HVAC, hot water and behavioral changes.
- Work on closing the gap in understanding in how to convert direct install approaches into more comprehensive projects and sustained engagement.
- Tailoring messages to the target market matters. Use broad appeal or targeted outreach depending on what you want to achieve.
- Quality controls have a cost, yet they protect multiple interests and ensure savings.
- "Participating contractor" requirements provide concrete expectations for both customers and contractors.

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