Scaling Up Participation and Savings in Residential Retrofit Programs

Rachel Cluett and Jennifer Amann

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529 14th Street NW, Suite 600, Washington, DC 20045

Phone: (202) 507-4000 • Twitter: @ACEEEDC

Facebook.com/myACEEE • aceee.org

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About the Authors

Rachel Cluett conducted research for ACEEE from 2012 to 2016. Her research focused on residential sector energy efficiency, including labeling and energy use disclosure, efficiency program design, and product standards and labeling. She is a BPI-certified building analyst and envelope professional and a certified Home Energy Rating System (HERS) rater. Rachel earned a bachelor of science in natural resources from Cornell University. She is now pursuing a master of public health at Harvard University, where she will focus her studies on the health impacts of energy efficiency improvements in homes.

Jennifer Thorne Amann promotes residential and commercial whole building performance improvements, explores behavioral approaches to improving energy efficiency, and analyzes the impacts of stronger appliance efficiency standards. She has authored dozens of publications and articles on appliances, lighting, consumer electronics, equipment installation practices, emerging residential and commercial building technologies, and the progress of market transformation initiatives. She joined ACEEE in 1997. Jennifer earned a master of environmental studies from the Yale School of Forestry and Environmental Studies and a bachelor of arts in environmental studies from Trinity University.

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Executive Summary

Whole home retrofit activity, which aims to systematically address the biggest energy issues in a home as identified on a house-by-house basis, has grown in recent years. Contractor and program experience have continued to develop as well. However demand for home performance services and program participation rates have yet to experience significant levels of growth, and many programs fail to capture the full range of available savings. This report explores opportunities for residential retrofit programs to grow participation and realize the anticipated energy savings. We begin with a discussion of program challenges, followed by strategies to address those challenges and examples of current programs employing these strategies.

CHALLENGES

Programs face challenges in three general areas: (1) calculating accurate project-level savings estimates, (2) ensuring that upgrades are installed and perform as expected, and (3) encouraging public buy-in and participation in programs. All of these factors affect a program's ability to realize savings.

OPPORTUNITIES

Current Practice

A number of strategies are already being implemented in retrofit programs to improve project-level realization rates.

Home performance data standardization. To improve energy modeling outcomes, programs can embrace efforts to standardize data collection within the home performance industry. Programs can make administration easier and less time intensive for participating contractors by adhering to Building Performance Institute (BPI) standards for data collection and transfer (sometimes referred to as HPXML within the industry). This allows contractors to transfer necessary project data to program administrators without having to use a specified modeling tool or software that they may not be familiar with. HPXML standards have been adopted to streamline administration and delivery by a number of programs, including the Arizona Public Service Home Performance program, the California investor-owned utilities (IOUs) whole home programs, and the home performance program of the New York State Research and Development Authority (NYSERDA).

Access to energy use data. Research by Performance Systems Development on NYSERDA's home performance programs found that calibrating energy models to actual energy use can improve the accuracy of modeled savings estimates. The ANSI/BPI-2400 standard lays out a process for contractors to use actual energy consumption data to calibrate energy models. In order to complete the process more easily, and on a larger scale, third-party assessors and contractors need better access to quality energy use data than most have today. The Green Button Connect My Data functionality, which can be enabled by utilities, allows customers to authorize automatic, ongoing transfer of usage data to assessors who need it to improve the home's energy performance. Some utilities have adopted Green Button, but many have yet to do so. Some states, including California, Illinois, New York, and Colorado, are taking action to develop data access policies enabling customers to readily access and share their own energy use data.

Evaluating programs in real time. Better data protocols on home performance measures and projects, better access to energy usage data, and new software tools are making it possible for programs to track results more thoroughly during the program cycle. New software tools and practices can help administrators understand how individual projects and contractors are performing and contributing to overall program goals in real time, so if there are issues they can be diagnosed and addressed while the program is in progress. A number of programs are improving overall results and realization of energy savings through real-time evaluation of project performance using emerging software tools.

Emerging Opportunities

There are a number of emerging practices in the field, as well as pilot program concepts, incorporating measured performance techniques and energy use measurement into programs to achieve higher energy savings realization rates.

Home energy management systems. Home energy management systems (HEMS) such as smart thermostats are increasingly being implemented by utilities for demand response and energy efficiency programs. These systems could also be used by contractors as data collection and measurement tools in residential retrofit programs, allowing them to assess and understand pre-retrofit housing conditions and to ensure that measures have been installed and are operating as intended.

HVAC system measurement and verification. Retrofit programs should consider going after the savings that result from proper design and quality installation of HVAC systems. Particularly in homes with electric heat pumps or air-conditioning systems, losses from improper refrigerant level, air flow, equipment sizing, and duct leakage account for almost 30% of the energy an average system consumes. System efficiency can be improved considerably with proper tools, training, and protocols for measuring system performance.

Pay-for-performance pilot programs. The pay-for-performance approach is structured around utilities paying aggregators for energy savings measured through metered energy usage data. Pacific Gas and Electric in California is in the process of launching a residential pay-for-performance pilot program to test whether a market-based solution can scale the market for residential energy efficiency. This will be the first pay-for-performance utility pilot targeted to residential customers in the age of access to high-quality energy usage data. Aggregators will work directly with residential customers to reduce energy use in any way they choose. The program puts emphasis on aggregators' having a successful strategy in place for predicting and realizing actual energy savings. It is not clear the degree to which whole home retrofits will be a part of this pilot program.

Increasing Participation in Deeper Retrofits

Increasing participation in programs and getting participants to take on more comprehensive energy-saving projects are necessary to fully realize the savings potential in the residential building sector. Marketing and outreach efforts intensively focused on a particular geographic area or community have worked to reach higher-than-average levels of participation in retrofit programs in states such as Oregon, Washington, and Vermont. In addition, multiple strategies for encouraging homeowners to reach deeper savings are being developed and tested; these include major renovation and deep retrofit pilot programs, road maps for retrofitting homes over time to reach maximum potential efficiency, and segmenting customers using meter interval data to identify homes with the highest energy savings potential.

CONCLUSIONS

Programs can play an important role in growing consumer demand for home performance work, improving systems and practices that enable contractors to perform quality work while achieving higher energy savings realization rates in retrofit programs. More accurate, reliable realization of savings at the project level opens up more opportunities to use financing strategies that are tied to energy savings, such as pay-as-you-save or on-bill financing. This can also enable better integration of energy efficiency improvements with other home maintenance and renovation projects (such as roofing or siding replacement).

Introduction

The energy savings opportunities from retrofits of existing single-family homes are well known, and there is growing consumer interest in home energy efficiency. Whole home retrofit activity, which aims to systematically address the biggest problems as identified on a house-by-house basis, has grown in recent years. This activity was spurred in part by an increase in utility and state programs during the Better Buildings Neighborhood Program between 2009 and 2012, funded by the American Recovery and Reinvestment Act of 2009 (ARRA). The systematic approach to solving performance issues in the home has helped homeowners make their houses more comfortable, safer, and more durable while reducing the overall energy needed to operate them. While homes that have undergone whole home retrofits have experienced multiple benefits from these improvements, many have yet to be reached, and as a result much of the opportunity for energy savings from residential buildings has yet to be realized.

Despite proven benefits and energy savings for homeowners and programs, the market for home performance has yet to experience significant growth, and many programs fail to capture the full range of available savings. Most programs are reaching less than 1% of eligible customers per year (Hoffmeyer 2016). Program participation has remained low for a number of reasons, including lack of consumer knowledge about home performance improvement and its benefits, high up-front costs with long payback periods from energy cost savings, and lack of recognition of the value of these improvements in the real estate market. Low participation levels result in programs that fall short of their energy savings goals. Programs also sometimes fall short at the household level due to discrepancies between the energy savings predicted by energy models and the actual post-retrofit energy savings determined by billing analysis. Addressing many of the challenges around low project-level savings realization is critical to building a broader market for and interest in home performance strategies.

Short- and long-term solutions are needed to address challenges for home performance programs and the industry at large. At the program level, practices are emerging for increasing participation in residential retrofit programs. Some programs are developing ways to target particular households or communities likely to be well suited to these programs, based on energy use, the home's physical characteristics, and/or household demographics. Other programs have been successful in targeting specific geographic areas with intensive community-focused marketing efforts. Additional strategies, like including efficiency improvements during renovations and encouraging multiyear planned retrofits, may help encourage deeper, more comprehensive energy retrofits.

In other efforts to improve the home performance market, practices are emerging for narrowing the gap between predicted and actual energy savings in individual projects. These efforts are focused on using better predictive methods and more performance-based feedback in programs. Specifically, this includes (1) improving modeling predictions of expected savings, (2) improving real-time feedback on project and program performance during program operation (rather than long after it is complete), and (3) improving feedback to homeowners, contractors, and programs on the actual energy savings (versus modeled results) of projects.

In this report we discuss key home performance program challenges and how to overcome them in order to scale up market interest in this work. We then detail practices within existing programs that address these challenges. We explore emerging research and pilot programs, as well as contractor practices that might be suited for incorporation into programs. We end with a discussion of opportunities that these advances present for transforming the home performance market.

Home Performance Program Characteristics

Comprehensive retrofit programs, also referred to as whole home or home performance programs, are part of many energy efficiency program portfolios in the United States. These programs are designed to systematically address the greatest energy waste in a home as identified on a house-by-house basis using building science principles. They aim to include a suite of improvements, rather than single measures, in order to substantially improve a home's energy performance (York et al. 2015a). In homes constructed before building codes required substantial insulation and attention to air sealing, the primary energy-saving and comfort-enhancing opportunity is often to add insulation and tighten the building shell (air sealing). These measures, generally the base of a whole home retrofit, help reduce the costs of heating and cooling, which account for roughly half of a home's energy usage.

The Consortium for Energy Efficiency (CEE), a membership organization of energy and water efficiency program administrators in the United States and Canada, reports that 31 of its roughly 100 program administrator members run comprehensive programs that use a whole building/home performance approach (Rosenberg 2015). Of those, 19 (61%) offer programs that employ the Home Performance with ENERGY STAR® model, a well-established national platform created by the US Department of Energy (DOE) and the US Environmental Protection Agency (EPA) for delivery of comprehensive home performance work (Rosenberg 2015). The Home Performance with ENERGY STAR model is used by 51 program sponsors in the United States (some of which are not CEE members). More than 550,000 projects have been completed by Home Performance with ENERGY STAR program sponsors. In Canada, two utilities in Ontario (Enbridge Gas and Union Gas) and two in British Columbia (BC Hydro and Fortis BC) offer whole home retrofit programs.

In Canada, a major federal program called EnerGuide for Houses ran from 1998 to 2007, promoting energy efficiency retrofits in existing low-rise homes. This program reached about 3.1% of the eligible housing stock in Canada—more than 252,000 households—achieving average verified energy savings of 28% per household (Francoeur et al. 2006). In the United States, DOE's Better Buildings Neighborhood Program, the largest federally funded effort to encourage whole building energy efficiency upgrades, reached a total of 74,680 single-family homes over a three-year period (2010–2013) and achieved an average of 15% in verified energy savings per household (Research Into Action 2015).

Whole home retrofit programs in the United States tend to achieve verified energy savings of 10–20% (Brook et al. 2012), usually through measures such as insulation, air sealing, and HVAC system improvements or replacements that reduce heating, cooling, and/or water heating loads by 20–35% (Neme, Gottstein, and Hamilton 2011). Project costs average about $7,000 (York et al. 2015a). Home Performance with ENERGY STAR sponsors report average savings of 25% with project costs of about $6,000 (E. Jacobsohn, program manager, DOE, pers. comm., July 25, 2016). A few leading programs, such as National Grid's retrofit program, are reaching about 2% annual market penetration, but most programs reach a far smaller proportion of households (Hoffmeyer 2016).

While various individual home performance projects and research efforts have demonstrated that deeper energy savings are possible, few programs have been able to achieve average energy savings greater than 20%. A utility-scale deep energy retrofit program run by National Grid in Massachusetts and Rhode Island incentivized improvements that aimed to achieve deeper savings, and administrators reported achieving average energy savings of 58% relative to baseline energy use. The effort was a niche program for a few committed homeowners, and participation was limited, but it is notable for its stringent energy measurement efforts and significant savings results (Cluett and Amann 2014).

For more details on experience with residential retrofit programs to date and the existing residential retrofit program landscape, refer to Chapter 8 of the 2015 ACEEE report, *New Horizons for Energy Efficiency: Major Opportunities to Reach Higher Electricity Savings by 2030* (York et al. 2015a). For a review of experience with deep energy retrofit programs, refer to *Residential Deep Energy Retrofits* (Cluett and Amann 2014).

Program Challenges

A variety of challenges have made it difficult for home performance programs to gain significant levels of participation, resulting in lower-than-expected overall program savings. Aspects of programs including (1) getting accurate project-level savings estimates, (2) ensuring that upgrades are installed and performing as expected, and (3) getting people to buy in and participate in programs all affect a program's ability to realize savings. The realization rate expresses as a percentage the difference between predicted and actual energy savings. At the individual project level, the realization rate is the ratio of actual savings (as measured by post-retrofit utility bills) to estimated savings (usually calculated using program-prescribed modeling tools or deemed savings estimates). The realization rate can also refer to the difference at the program level between planned and actual energy savings, which is affected not only by the difference between estimated and actual savings, but also by whether the program reached as many participants as planned, and whether participants invested in projects as large as expected. Achieving high realization rates is critically important for building a long-term market for home performance projects. Low realization rates not only mean that homeowners do not realize the energy and cost savings projected for projects, but also affect program cost effectiveness.

The importance of accurate energy savings estimates for contractors

For contractors (or energy advisers) who sell home performance improvements to customers, articulating the case for a sale requires clear information about the benefits of recommended improvements. Energy savings are not the only reason homeowners undertake home performance improvements, but customers desire certainty about the level of energy savings for improvements they are investing in. If contractors are unable to present that certainty as a starting point, they risk losing credibility.

Program results show that discrepancies between estimated savings and actual energy savings regularly occur. In the Better Buildings Neighborhood Program, upgrades were expected to save an average of 24% of whole home energy use, but post-retrofit utility data indicated savings of about 15%, for a realization rate of about 63% (Hoffmeyer 2014). In California's Energy Upgrade California (EUC) Home Upgrade Program between 2010 and 2012, estimated project level savings were significantly overstated, and the program achieved only 34% of anticipated natural gas savings (Glidden 2016). Participation rates also remain low in many regions. In the EUC Whole House Retrofit Program between 2010 and 2012, 60% of the overall program budget was spent, indicating lower-than-expected program participation (DNV GL KEMA, Inc. 2014).

GETTING ACCURATE SAVINGS ESTIMATES

One of the challenges for home performance programs and the home performance industry as a whole is the accurate prediction of energy savings. Improving how energy savings are estimated is an important part of improving realization rates. A majority of home performance programs rely on energy modeling to quantify the energy savings a homeowner can expect from specific efficiency improvements (Rosenberg 2015).[1] Program administrators aggregate project-level savings to quantify program energy savings. A number of factors can impact the accuracy of modeled savings, including the type of simulation software used, how well users input building characteristics, how accurate data collection is in the field, and what types of inputs are included about the home and the behavior of its occupants. We explore some of the key issues around energy modeling in the home performance industry in the section below. Challenges with modeling energy savings converge around how energy models are used, rather than problems with the tools themselves. In the section following, we discuss a number of ways these challenges are being overcome.

Duplicative Modeling Practices

Energy savings estimates from program-specified modeling tools can be used by contractors to help sell home performance work. In practice, many programs' input requirements are known to have limitations and are often not relied upon by contractors to produce accurate estimates of energy savings to present to homeowners. Furthermore, programs sometimes require use of modeling tools that are unfamiliar to contractors and different from what they use to calculate energy savings estimates. Contractors sometimes choose the tools they were trained to use, tools that give them more control over inputs (particularly operational and behavioral use characteristics), and/or tools that are integrated with their business software and internal bookkeeping practices (LeBaron and Saul-Rinaldi 2015). While the use of their favored tools allows contractors to arrive at energy savings estimates they feel comfortable reporting to homeowners, the need to use program-prescribed modeling tools results in duplication of effort and typically imposes a significant time burden on contractors. This can result in hasty or inaccurate reporting for program modeling requirements, with programs

[1] CEE's 2015 review of existing home programs found that three comprehensive programs do not use energy modeling to determine savings (Rosenberg 2015). These programs presumably rely on deemed savings estimates. All other comprehensive programs rely on energy models to determine energy savings estimates.

receiving savings estimates that are different from (and likely less accurate than) those given to customers to sell a job.

Gaming of Estimates

An additional challenge associated with energy modeling to calculate savings predictions is the potential for intentional misreporting to increase contractor-reported savings or access to rebates (Gagliano 2015). In the California EUC program that ran from 2009 to 2012, rebates were based on projected savings. In order to increase available rebates for homeowners, some contractors adjusted models so they were not representative of actual use. It is unclear the degree to which gaming contributes to inaccurate energy estimates, but it raises an important point: the way a program's rebates/incentives are structured can affect how program partners calculate savings.

Inadequate Modeling of Operational Use Characteristics

An additional factor that can affect the accuracy of energy modeling is the degree to which contractors are able to adjust for operational use characteristics within energy modeling program requirements, and the extent to which they are trained to evaluate and use key operational data specific to individual homes. A 2013 evaluation by Danny Parker of the Florida Solar Energy Center (FSEC) found that the more operational data collected during an energy audit and used to produce the energy model, the better the energy estimates align with actual home energy use. The key operational data are thermostat set points, hours of operation, and frequency of use of various appliances, equipment, and electronics. Models including key operational use characteristics specific to an individual household were within 1–2% of measured energy use, while models that did not consider operational use and instead used preset/standard values were off by 50–60%, both overestimating and underestimating actual energy use (Parker et al. 2013). This research indicates that energy models that fail to accurately represent how a household uses energy are likely to be inaccurate.

There are numerous reasons that correct operational use characteristics may not be captured in existing energy modeling efforts for programs. Energy modeling software can be used for a number of purposes and can be configured according to the question the user is trying to answer. One of the major uses of energy modeling software is to determine home energy ratings for new homes. For example, modeling software is used to calculate Home Energy Rating System (HERS) scores. A HERS score is based on physical characteristics of the home and requires predetermined set points for various operational aspects of home energy use; it is not affected by how occupants use the home. In other words, the HERS score represents the efficiency of a home's physical characteristics, rather than how occupants affect energy use. While this is valuable for comparing two homes on the real estate market, for example, it is not useful for determining how energy is used in a home by a particular set of occupants in order to prioritize energy efficiency upgrades and calculate savings estimates. To complicate matters, the same modeling tools can be used for energy ratings and for estimating savings from energy efficiency upgrades, so there is potential for confusion by contractors working on numerous efforts in terms of the values they are including in each case. There can also be confusion among programs about how to specify use of modeling tools for their particular use case.

The challenges related to getting accurate savings estimates from energy models need to be addressed in a variety of ways. Improving programs through software choices that better suit the contractor's needs, ensuring consistent access to energy use data, and truing up models to actual usage data are practices that can help make energy modeling considerably more reliable. We discuss these ideas in detail in the following section on program opportunities.

Achieving Expected Savings from Retrofits

Post-retrofit energy savings can be affected by the quality of the retrofit installation, the quality and completeness of the reported billing data, the methods used to normalize weather data, and occupant behavior (such as changes in occupancy or use of the home) (Gagliano 2015). In the section below, we explore some of the key issues in the home performance industry that affect the extent to which predicted savings are actually achieved.

Inadequate Verification of Performance

The level of energy savings achieved depends in part on how well energy efficiency retrofits are installed. For building shell improvements (insulation and air sealing), major equipment, and distribution systems, installation can have a significant impact on energy performance. In current practice, some aspects of project performance are measured with diagnostic tools. Programs specify verification of performance to varying degrees. Most home performance programs require testing the overall building shell tightness using a blower door, and some require testing the tightness of duct distribution systems. Some contractors use other tools, such as infrared imaging in conjunction with blower door and duct testing, to verify their own work. Other diagnostic tools and practices are available for optimizing the performance of HVAC systems. One such practice is testing air volume and flow at distribution grilles using a balometer hood, to help contractors balance HVAC systems and provide correct heating and cooling load according to the needs of individual rooms. Testing refrigerant levels in air-conditioning and heat pump systems using pressure gauges, and adjusting these to levels appropriate for the system design, is another opportunity to affect efficiency.

All of the tests described above are important for helping contractors ensure that the measures they have specified are installed properly and as planned. Yet these types of practices are not commonly included in training for building analysts and energy raters/assessors, nor are they commonly used to verify aspects of home performance projects (Harriman and Chitwood 2012).

Another large gap in home performance programs today is feedback to contractors on how well individual projects meet energy savings estimates. At present, contractors receive no feedback from program administrators about how the individual projects they complete perform against their energy modeling estimates. Up to this point, contractors have largely relied on energy models to predict savings, and then perform testing to verify building air tightness and check for duct leakage. The only information contractors generally receive about actual performance of a project is via informal customer feedback about whether they're comfortable, whether they notice lower bills, etc. This makes it difficult for contractors to know specifically how well they have met their overall energy savings goals or how well a particular installed measure is performing. As a result, there is little opportunity for contractors to learn from the results of completed projects in order to optimize future installations.

Inadequate Energy Use Data

Utilities that have adopted Green Button, described in detail in the next section of this report, are making it possible to automate sharing utility bills with third parties. However, for programs that are not run by utilities (and for many that are), energy consumption data are often difficult for program administrators, contractors, and energy auditors to access. Data are generally released only to customers in the form of a monthly statement that shows monthly energy consumption and cost. This information is increasingly available to customers through online portals, but in many regions, mailed paper statements are still the only way customers receive this information.

Inadequate access to energy consumption data for parties involved in program delivery and evaluation is limiting for a number of reasons. In order to build an energy model that accurately estimates an individual home's energy consumption, auditors/contractors must have a good understanding of how energy is currently being used in the home.

Lack of easy, automated access to utility bills by the party responsible for developing energy models limits that party's ability to systematically (or automatically) incorporate billing data into the modeling process. Many contractors ask for billing data from customers to understand use patterns and characteristics generally, but at present these data are not incorporated into any known program modeling requirements in a systematic way.

A recent study conducted by Performance Systems Development (PSD) on New York State Research and Development Authority (NYSERDA) home performance programs evaluated the key factors that contribute to poor project-level realization rates by looking at utility bill and energy model data from three different program years. They found that the most significant factor affecting the accuracy of savings predictions was the degree to which the baseline energy simulation model was calibrated to match pre-retrofit energy bills for the home. In short, if the energy model's estimate of how much energy a home used pre-retrofit was accurate, the post-retrofit energy savings prediction was more likely to be accurate as well. For example, by calibrating models for NYSERDA's natural gas program years 2007–2008 and 2009–2011, the median realization rate increased respectively from 0.69 to 1.00 and from 0.63 to 0.86 (Gagliano 2015).

In addition, few program administrators have energy use data available so they can analyze results for individual projects. Evaluation studies that assess program performance and realization usually focus on a subset of homes served by the program. Overall program savings are then calculated by extrapolating results from that subset. Evaluation of individual projects and contractor performance is rarely done within the context of an energy efficiency program.

As a result of the data challenges discussed above, many existing programs are operating without timely feedback on how programs are performing. Program administrators often fail to receive data on program performance until after a program cycle is complete, through a program evaluation. In turn, contractors do not receive feedback from program administrators on performance of individual projects or information on their portfolio of projects. Better data availability is one part of the solution; programs also need the tools and expertise to store and analyze data and then act on results. Fortunately, new software tools and program specifications are beginning to change the way program administrators can track results and recognize opportunities for program improvements during a program cycle.

GETTING HOUSEHOLDS TO PARTICIPATE

While top-performing residential programs have worked hard to develop strategies to increase participation, most still reach only a fraction of eligible households and struggle to encourage comprehensive retrofits that address home energy use in a systematic way (versus a piecemeal, measure-by-measure approach). Furthermore, home performance retrofits are still driven largely by utility, state, and local programs (York et al. 2015b). Whole home retrofit programs often track two primary measures of participation: number of energy audits completed and number of retrofits completed. The ratio between the two is known as the conversion rate, and it is a central focus for programs. Top-performing programs are achieving annual retrofit participation rates of about 1–3% of eligible households, with conversion rates of 40–50%, meaning that for every two energy audits completed, about one household decides to perform a retrofit (York et al. 2015b; Bogovich 2014). In the Better Buildings Neighborhood Program, which leveraged ARRA funding to spur nationwide energy efficiency program innovation over a three-year period, 138,323 assessments were completed and 75,110 upgrades were completed, for a conversion rate of just under 55% (Hoffmeyer 2014). York et al. (2015b) profile strategies used by the residential whole home retrofit programs with the highest participation rates. Achieving high participation and higher-than-average conversion rates has been driven largely by "shrewd marketing and outreach" efforts, contractor engagement and training, and generous financial incentives.

Another aspect of participation level is the size of the projects completed through the program, which can be measured by the project cost, the number of measures installed, and/or the systems and components of the home addressed. In the Better Buildings Neighborhood Program, the mean project cost was $7,027, but a number of projects were significantly smaller, so the median project cost was $5,441. Not all improvements included in this program could be considered comprehensive; about 8,200 of the 65,000 projects for which data were available had costs of $1,000 or less (Hoffmeyer 2014). A comprehensive project that addresses various building shell improvements and HVAC system replacement costs significantly more.

Many of the aspects of existing programs discussed above that make it difficult to achieve high project-level realization rates can affect customer interest and uptake of home performance projects. For example, when programs are difficult for contractors to participate in due to unfamiliar or unreliable modeling tools, as discussed earlier, participants bear the brunt of slow program processes. If it takes contractors too long to give customers project proposals and scopes of work following an energy audit, customers can lose interest or simply not be able to continue devoting time to such a lengthy process. In addition, energy savings estimates that do not make sense for a particular household can reduce customer confidence in the value and efficacy of recommended home performance improvements. And if contractors are unwilling to stand behind savings estimates produced by program modeling tools, customers may be confused and skeptical about what they can actually expect to save. In some programs, contractors are discouraged from presenting customers energy savings estimates so they do not overpromise results.

Improving key factors directly related to project realization rates, such as energy modeling, access to data, and feedback about how retrofits perform, is critical to building interest and confidence in the market for residential retrofit work. Such confidence will lead consumers to seek out home performance services when energy or comfort issues arise.

Program Opportunities

CURRENT PROGRAM PRACTICES THAT ADDRESS PROJECT REALIZATION RATES

Improving Energy Modeling Outcomes

A few small-scale retrofit programs have demonstrated how to reach high project-level realization rates through energy modeling. These efforts have generally involved time-intensive energy assessments and required data that are not easily available to many home performance programs. One example is the Help My House Program in South Carolina. In this program, a group of cooperative utilities reduced electric load in an electricity-constrained region by performing energy efficiency upgrades in 125 homes. Improvements were paid for through bill-neutral on-bill repayment, where payments were set up so the energy savings each month exceeded the payment for retrofit work over a period of 10 years (Keegan 2013). To target high-energy-consuming households that were a good fit for the program, staff evaluated each home meticulously, collected data on how each household used energy in the home, and made sure modeled energy use baselines aligned with actual utility bills. As a result, the program realized 93% of the 11,539 kWh per household savings it projected, achieving 10,809 kWh per household, or $1,157 per year (Keegan 2013).

While the Help My House approach required more time-intensive household screening, energy simulation/model development, and review than might be feasible on a larger scale (while also targeting homes with higher-than-average energy consumption), a number of efforts within the home performance industry are helping to improve and in some cases automate the time-intensive tasks that this example illustrates. Efforts include standardizing home performance project data collection and enabling easier access to energy data for customers, contractors, and third-party program implementers. These steps can help larger-scale programs to achieve similarly accurate modeling results and realization rates at both the individual project and overall program levels.

DATA STANDARDIZATION

Standardization of data collection within the home performance industry is enabling programs to allow participating contractors to use their own preferred modeling software. Over the past several years, the Building Performance Institute (BPI) has developed standards for the collection of residential building data to reduce the costs associated with gathering and sharing data between contractors and programs. The standards include BPI-2100, the Standard for Home Performance Related Data Collection, and BPI-2200, the Standard for Home Performance Related Data Transfer. These standards are sometimes referred to within the industry as Home Performance Extensible Markup Language, or HPXML. They allow interoperability among various software systems used within the home performance industry, which enables programs to collect the data they need from contractors for program management without specifying the tool to be used to collect it (EPA 2015). Improved operability does not stop at the contractor/program administrator relationship. It can also be a game changer for sharing information with the real estate market about the improvements a home has received, such as through the Multiple Listing Service (MLS).

The BPI standards were piloted for program administration in three home performance programs between 2013 and 2014, including NYSERDA's home performance program, the Arizona Public Service (APS) home performance program, and the Local Energy Alliance Program (LEAP) in Virginia (HPC 2013).

The Arizona Public Service (APS) Home Performance program was one of the first programs to report results from HPXML data standards implementation (Hastings 2015a, 2015b). Adoption of the standards allowed participating contractors to choose from a variety of energy auditing and modeling tools that were compatible with HPXML standards, rather than require use of one specific tool. Data from the auditors' preferred tools could then be transferred to the program management software used by program administrators, EnergySavvy Optix Manage. The program was able to reduce the administrative costs per project by 50% through more streamlined data collection and automatic validation of collected data. In turn, contractors reported a 31% reduction in administrative time per project and a threefold increase in satisfaction with the software used for the program. By allowing contractors to pick from multiple modeling tools to find the one that best fits their business practice, programs can cut down on contractors' administrative burden and can expect more accurate modeling.

The Arizona Salt River Project has also adopted the same tools and software as APS to make life easier for its customers and contractors in its territory, which is adjacent to APS, and is seeing similar performance improvements.

NYSERDA has also adopted HPXML for its home performance programs, with the goal of streamlining program delivery and reducing burdensome processes for both contractors and administrators (Caracino 2015). By utilizing HPXML-enabled software, NYSERDA program administrators and contractors have made it easier for customers to participate in the home performance program. Like APS, NYSERDA has utilized a combination of EnergySavvy Optix Manage and multiple modeling tools to give their contractors a choice in the tools they use in the field. This approach, combined with data standardized to HPXML specifications, has allowed the software to automatically approve many projects, enabling work contract approvals within one week and reducing work scope approval time from an average of eight days to one day. It has also reduced the number of full-time employees focused on approving projects from three people to just one (Caracino 2015).

The California investor-owned utilities (IOUs) have also adopted HPXML for their home performance programs (LeBaron and Saul-Rinaldi 2015). Contractors can now choose from a variety of energy modeling tools that meet minimum qualifications when participating in any of these programs.[2] Elsewhere, a number of programs are in the process of transitioning to HPXML or are evaluating the potential for a transition; these include United Illuminating in Connecticut and Ameren Illinois (Rosenberg 2015). At the same time, many major residential energy auditing tools have been updated to meet HPXML data collection requirements (EUC 2015). Program management software is also being designed around HPXML protocols to allow for interoperability among different systems used in different parts of the home performance program delivery process.

ACCESS TO ENERGY USE DATA

Access to energy use data is also important to improving energy modeling outcomes. The basic principle is that consumers "own" their energy data and should be able to access it easily and, if they choose, authorize it to be shared with third parties such as contractors, energy service providers, software developers, and program administrators. For many customers this is not possible at present. For third parties like contractors and energy assessors, more consistent access to quality data for use during energy assessments and modeling efforts can help pinpoint particular sources of energy waste. With more granular hourly or minute-interval data, contractors can determine particular times of day when energy use spikes to understand what devices and equipment are responsible for energy waste, which can help them determine appropriate solutions for the home.

Access to better usage data can also help contractors build energy models that are more representative of a home's actual energy usage. As discussed earlier, Performance Systems Development's recent study of project-level realization in NYSERDA home performance programs found that the most significant variable contributing to the accuracy of modeled savings predictions was how well the baseline simulation model matched the actual pre-retrofit energy usage in the home. To understand the degree to which calibrating energy models to actual energy use could improve realization rates, PSD applied a standard called ANSI/BPI-2400 for calibrating energy models to actual energy use data. It was originally developed to limit energy savings estimate inflation for a proposed tax credit for energy efficiency improvements that was based on savings predictions (LeBaron and Saul-Rinaldi 2015). The standard lays out a process for adjusting energy models to utility data to help reduce uncertainty in model projections.

Using data from two New York home performance program years (two electric and two natural gas program data sets), PSD researchers tested the degree to which retroactive application of the ANSI/BPI-2400 standard for energy model calibration could improve realization rates. Table 1 details the results after models were calibrated to actual use data (Gagliano 2015). As shown in table 1, for the two natural gas project years, energy savings were overpredicted. When energy models were adjusted to line up with pre-retrofit household energy use, actual reported savings decreased, but realization rates increased. For the electricity project years, savings were underpredicted. When energy models were

[2] Software modeling options for California's Advanced Energy Upgrade program are detailed in the following document: www.caltrack.org/uploads/8/6/5/0/8650231/at-a-glance_software_comparison_v1_jan2015.pdf.

adjusted to line up with pre-retrofit household energy use, estimated savings increased (but were still below actual savings).[3]

Table 1. Adjusted savings and realization rates of NYSERDA home performance programs using ANSI/BPI-2400 standard

Project year and fuel	Total number of projects	Contractor reported savings (sum)	Calibration adjusted savings (sum)	Percentage change due to calibration	Reported realization rate (median)	Adjusted realization rate (median)
2007–2008 gas (therms)	903	312,366	201,075	−36%	0.69	1.00
2009–2011 gas (therms)	1,241	316,880	225,585	−29%	0.63	0.86
2007–2008 electricity (kWh)	482	508,190	535,295	5%	1.65	1.40
2009–2011 electricity (kWh)	572	336,673	390,675	16%	3.18	2.84

Source: Gagliano 2015

Implementation of model calibration in accordance with the ANSI/BPI-2400 standard is a key strategy that should be used in home performance programs to improve realization rates. However energy consumption data must be available to energy modelers in order for this to occur. The standard specifies two pathways to generate the pre-retrofit calibrated model—one using detailed (monthly) utility bill information for each fuel used in the home, and the other using annual consumption information for each fuel (BPI 2012). The PSD analysis used the more detailed approach to test the effect of ANSI/BPI-2400 on realization rates. A model calibrated to detailed, monthly energy use data for all fuels used in the house will have less uncertainty than predictions calibrated to simplified, annual energy use (BPI 2012). The degree to which the process of calibration is automated depends on the energy-modeling tool and the form of energy data available. With quality energy data inputs, some tools, such as the TREAT tool developed by PSD, are able to automate many of the steps necessary to calibrate the model (EUC 2015).

Easier customer access to utility data and the ability to easily share these data for energy auditing purposes is moving forward via the Green Button initiative. This initiative, spurred by a 2012 industry call to action by the White House, is an effort to develop and adopt an industry standard for transferring energy use data to retail customers and third parties. Utilities are encouraged to offer customers an easy way to access their own energy use data through an online portal. Green Button–enabled utilities allow customers to download a file containing their usage data via a functionality known as Green Button Download My Data. Customers can then share their data file with third-party providers if they choose. As of

[3] PSD attributes this to conservative contractor inputs to the energy modeling software for the "dominant electricity improvements (e.g., lighting, refrigerators, and AC upgrades)" (Gagliano 2015).

2014, 30 million customers in 17 states and Washington, DC, had access to Green Button data; this represents approximately 24% of all US households (LeBaron and Saul-Rinaldi 2015).[4] However to date this information has not been widely downloaded and used by customers. Furthermore, it is not automatically transferred to third-party energy service providers. Far fewer utilities (five in the United States as of January 2016) have enabled a functionality called Green Button Connect My Data, by which customers can see real-time (or updated-daily) energy use data on an online portal and authorize automatic, ongoing transfer of usage data to a third party, as shown in figure 1. This allows a more streamlined process for third parties to access and analyze data. The utilities currently offering Green Button Connect My Data include Pacific Gas and Electric, San Diego Gas and Electric, Southern California Edison, PEPCO in Washington, DC territory (for commercial customers) and Commonwealth Edison (for commercial customers) (Murray and Hawley 2016).

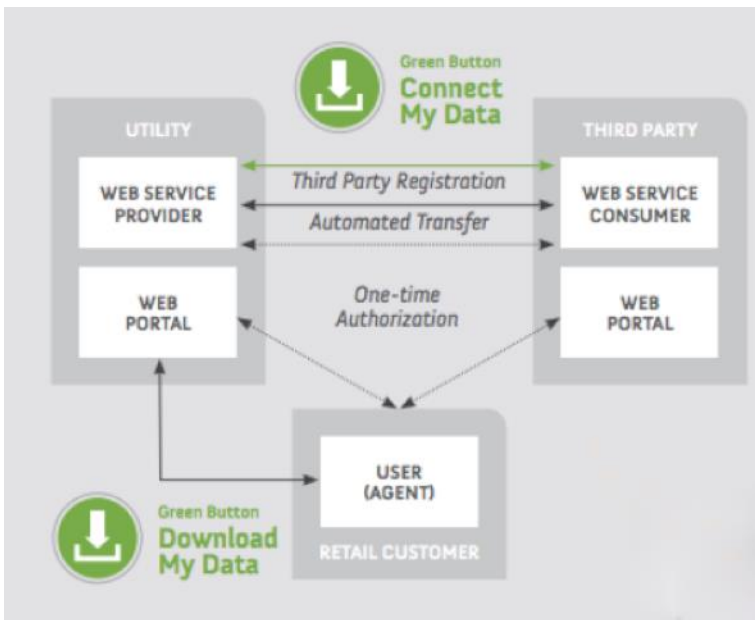

Figure 1. Green Button Download My Data and Connect My Data overview.
Source: **Murray and Hawley 2016.**

While some utilities are taking the initiative to improve data access by adopting Green Button, efforts are also taking place at the state policy level to require utility action. A number of states are developing data access protocols and requirements for utilities to ensure that customers have access to their own energy use data at no charge. California leads the way on data access policy, requiring access for customers to their data and restricting utilities from selling consumption data. Utilities can contract with third parties that use consumer data, but they must disclose any third-party intent to use data for

[4] More than 50 utilities covering approximately 60 million homes and businesses have committed to adopting Green Button capabilities. energy.gov/data/green-button.

commercial purposes (e.g., selling energy efficiency projects) (LeBaron and Saul-Rinaldi 2015). Other states, including Illinois and New York, are making strides in open data access.

In Illinois, regulators at the Illinois Commerce Commission are considering adopting a framework developed by the Environmental Defense Fund (EDF) and the Citizens Utility Board (CUB) that lays out guidelines for "protecting, collecting, and sharing energy use data" (Munson 2016). The framework would enable consumers to have access to real-time energy use data in 15-minute intervals that they could automatically transfer to third-party providers if they desired, providing the same functionality as that of Green Button Connect My Data, as described above (Kolata and Barbeau 2016).

In tandem with the Green Button initiatives and state/utility policy efforts to improve access to data, more smart meters are being installed across the country, which makes it easier for utilities to offer access. As of 2014, 51 million smart meters had been installed in the residential sector, reaching about 40% of US households (EIA 2016). However having this new technology does not guarantee that utilities are collecting more granular data—in hourly or daily intervals, for example—or that they are granting access to customers and third parties. These initiatives and policies are critical to getting access to the data that contractors and energy auditors need to improve energy modeling.

Evaluating Real-Time Project Performance

Better data protocols for home performance measures and projects, better access to energy usage data, and new software tools are making it possible for programs to track results more thoroughly during the program cycle. New software tools and practices can help administrators understand how individual projects and contractors are performing and how energy savings are adding up to overall program goals in real time, so problems can be diagnosed and addressed while the program is in progress. A number of examples of program optimization through evaluation of real-time project performance are emerging.

SOFTWARE TOOLS

A growing number of companies offer software tools to measure and manage program activity. These tools are generally capable of storing and analyzing large volumes of energy usage and project data to support program delivery. A number of these companies serve the commercial sector. This market is more developed in part because it has needed a way to track and verify energy savings for energy service company (ESCO) projects. In the residential sector, EnergySavvy and Resispeak offer tools for measuring energy savings from individual projects and overall programs. Resispeak pinpoints savings opportunities for homes and programs based on metered data and then measures savings for individual retrofits and on a program-wide scale, comparing weather-normalized, pre- and post-retrofit energy use data. The software platform can be used by contractors to track their individual projects and by program administrators to track a portfolio of projects. Resispeak markets software tool options for nonprofit energy efficiency programs that may have limited budgets for program administration (Kauffman 2016).

EnergySavvy offers a large suite of software tools for management of utility energy efficiency programs. These help administrators with customer engagement and management, online auditing, project management, and measurement. One offering is the Optix Quantify tool, which uses real-time energy use data to measure savings as the program is in progress and provides actionable insights to administrators for improving program outcomes. The tool provides a billing analysis on each project in the program, evaluating pre- versus post-retrofit energy usage to understand individual household savings. Pre- and post-retrofit energy use data are adjusted for differences in temperature and other weather variables. The tool also compares treated homes with a large group of similar but nonparticipating homes to help adjust for external factors that might affect energy use. The software can then calculate savings from the actual usage data on a continuous basis. As of April 2016, seven utilities had adopted Optix Quantify for their programs (Oster 2016). Users are reportedly focusing on various aspects of the tool's capabilities. Some programs are using it to better target quality assurance efforts and reduce costs, others are using it to understand the performance of different contractors, and some are using savings results to determine better deemed savings estimates that are more relevant to their region or locality (Oster 2016). Some programs have started including feedback on actual project performance in existing contractor feedback channels.

PROGRAM EXAMPLES

A pilot conducted on a heat pump replacement program offers insights relevant to home performance programs. Ameren Missouri ran a study to evaluate its residential HVAC program for the 2013 program year using the EnergySavvy Optix Quantify tool (Lovett 2015). The program was evaluated after completion as a demonstration project, but the study was set up to simulate how real-time monitoring could improve outcomes. The study demonstrated how real-time program savings measurement could give administrators information to act on during the program cycle to improve outcomes.

Savings data about each individual home and contractor provided administrators with clear opportunities for improving realization rates. For about 60% of the homes that received air source heat pump replacements for electric furnaces (80 homes), deemed savings estimates were unrealistically high, given baseline usage conditions. In fact, the study found that in 22% of households, deemed savings estimates were higher than the home's total annual pre-retrofit usage (Lovett 2015). Real-time savings data allow programs to set far more accurate deemed savings estimates for program planning purposes and to rely on actual savings results for assessing program performance. The study also found one contractor's savings far exceeded others', and that the contractor doing the most jobs was getting very poor savings numbers. Linking the performance of projects to particular contractors can help programs manage and provide support to trade allies, as detailed in figure 2.

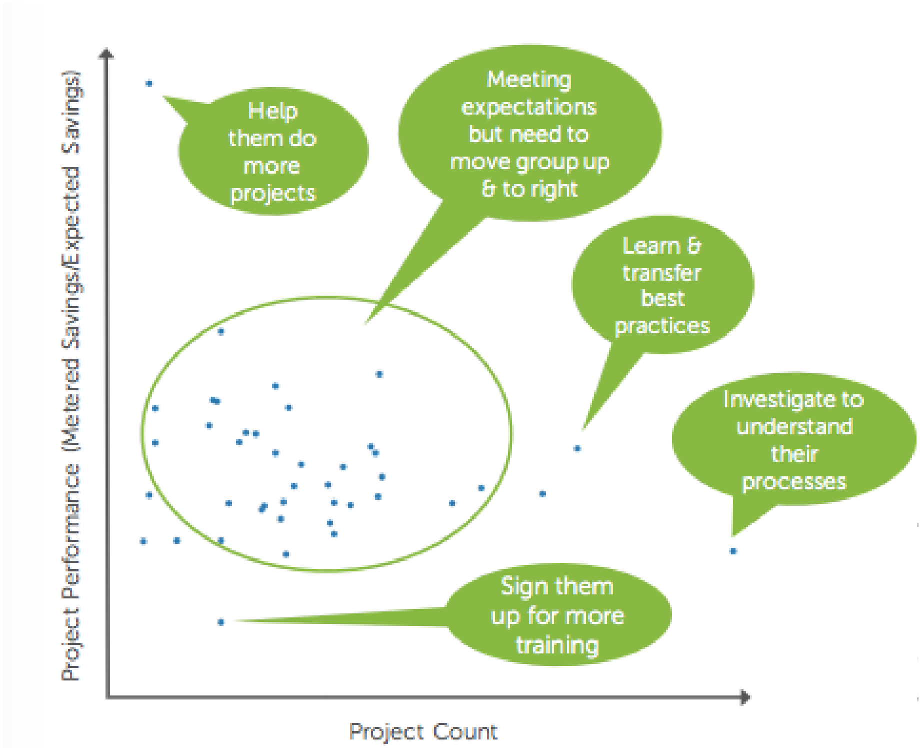

Figure 2. Sample data on contractor performance from Ameren Missouri program.
Source: Lovett 2015.

Resispeak has been used at the program level for some small-scale initiatives in North Carolina, including an employee home energy improvement benefit program at Duke University and a retrofit contest run through Appalachian Voices, a nonprofit in the western part of the state. The software was used in both of these programs to validate actual energy savings one year after improvements were completed, using weather-normalized pre- and post-retrofit utility data (Adair, Weiss, and Elliot 2016; Kauffman 2016).

EMERGING PROGRAM PRACTICES FOR ADDRESSING PROJECT REALIZATION RATES

A variety of pilot program concepts and demonstration projects incorporating measured performance techniques and energy use measurement are emerging. Most of these efforts are in the beginning stages and do not yet have results to report. In this section we introduce the concepts and explore their applicability to increasing uptake of comprehensive home performance projects.

Home Energy Management Systems as a Measurement Tool for Retrofits

Home energy management systems (HEMS) offer opportunities for enhancing home performance projects and could be used as a tool in programs to improve delivery of results. HEMS are defined as devices or services that monitor, control, or analyze energy use in a home (Bojanczyk 2013). In current practice, smart thermostats are the primary technology being used for home energy management in energy efficiency programs. Programs use smart thermostats to save energy through temperature setbacks during periods when the home is unoccupied or through modest reductions that are designed to be unnoticeable to occupants. HEMS can also be used as a data collection and measurement tool in residential retrofit programs, allowing contractors to assess and understand pre-retrofit housing conditions. Some systems can be used to obtain real-time energy use data directly from a home's smart meter. These systems can also be used to measure and verify post-retrofit performance for customers, contractors, and program administrators alike.

Some home performance contractors are installing smart thermostats in customers' homes for use as data collection tools to help inform retrofit needs and to provide quality assurance that completed improvements are working as intended (DOE 2015). Smart thermostats equipped with multiple sensors can provide data on temperature in various areas of the home and on equipment operation (e.g., run times, ability to meet temperature demand in various rooms of the home).

HEMS can also be useful for connecting to and viewing energy use data directly from a home's smart meter, rather than through an online utility account or monthly bill. Some HEMS are able to collect energy use data directly via smart meters that can transmit data over a short range. This can allow customers and contractors access to energy use data that is more granular than what is saved by the utility. San Diego Gas and Electric has enabled smart meters to communicate with HEM devices via a wireless communications protocol called ZigBee. Devices linked directly to the smart meter through the ZigBee protocol are able to receive energy data in near real-time fashion (LeBaron and Saul-Rinaldi 2015). The ability to receive real-time, granular energy use data could be useful for contractors and energy assessors trying to understand and correct irregular energy use.

HEMS may also provide an opportunity for programs to give real-time feedback to their customers who have undergone a retrofit project, in order to improve realization of savings. For example, messaging could help households improve the operation of new, more efficient home systems that they are not yet familiar with. Some utilities use real-time messaging capabilities to communicate with customers, but these capabilities have not been widely employed in conjunction with retrofit program delivery.

Measurement and Verification of HVAC System Design and Installation

Home performance contractors are no strangers to performance testing for some aspects of building retrofits. Contractors performing air sealing measures have long relied on blower door testing to assess how leaky a home is pre-retrofit, and how well it has been sealed up post-retrofit. Some programs require meeting a certain air leakage reduction level to obtain incentives. Many home performance contractors also use the blower door as a tool during the retrofit process to guide air sealing efforts and to ensure that they address the biggest leaks. Programs offering incentives for duct sealing have similar requirements for pre- and post-retrofit testing of ductwork air leakage. Air leakage testing for ductwork and for the building shell is a critically important tool for verifying the performance of improvements that would otherwise be invisible and is commonly practiced in the home performance industry now.

While these performance measurements are important, they give contractors only part of the picture about how the overall HVAC system is performing. Testing other aspects of HVAC systems (particularly for heat pumps and air conditioners) is critical to realizing expected energy savings. Factors including duct leakage, duct conduction, air flow to individual rooms, overall system air flow, size of equipment, and refrigerant charge can all impact the overall performance and the ability of a system to perform to its rated capacity (MacFarland et al. 2016).

Numerous studies and field research efforts have indicated that systems may not be installed according to manufacturers' specifications and industry standards (e.g., the Air Conditioning Contractors of America quality installation standard), thus significantly increasing the expected energy use of the units.[5] An evaluation of 80 homes in California, conducted between 2009 and 2010 to measure the effectiveness of California's Title 24 building codes (some of the most stringent energy codes in the country), indicated that HVAC systems were significantly underperforming, providing an average of 55% of their rated capacity (Proctor, Chitwood, and Wilcox 2011). Furthermore, improving key aspects of the system such as reducing flow resistance of the return duct system between the house and the furnace or air conditioner, or replacing the system's refrigerant, led to an average efficiency improvement of 24% (Proctor, Chitwood, and Wilcox 2011). A study performed by the National Institute of Standards and Technology (NIST) quantified the significant energy penalties that result from how equipment is typically installed today. Researchers estimated that improper installation of air conditioning and heat pump systems can increase energy use from heating and cooling by 30% relative to what they would use if installed to industry standards (Domanski et al. 2014). Figure 3 illustrates the expected energy losses from air conditioners and heat pumps as typically installed today.

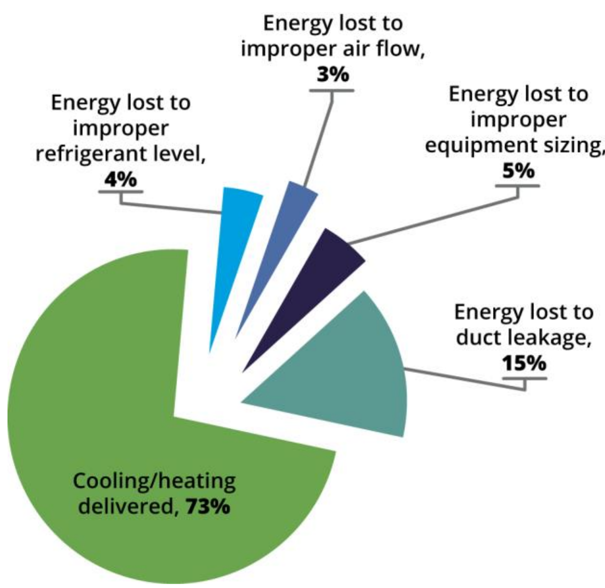

Figure 3. Energy losses in a typical air conditioner or heat pump installation. *Source:* EPA 2016.

[5] ACCA Standard 5 (ANSI/ACCA 5 QI-2010) HVAC Quality Installation Specification: Residential and Commercial Heating, Ventilating, and Air Conditioning (HVAC) Applications, www.energystar.gov/ia/home_improvement/home_contractors/qispec.pdf.

HVAC system improvements are part of many retrofit projects, yet home performance programs do not often have a way to verify proper installation of HVAC systems, nor do they have quality installation requirements in place. Furthermore, energy raters, or energy professionals who are verifying installations of insulation, air sealing, and duct sealing upgrades, often lack the expertise to ensure that HVAC systems have been designed and installed correctly. To optimize results from a system upgrade or improvement in home performance projects, some contractors who perform insulation, air sealing, and HVAC upgrades are using monitoring and testing strategies to ensure systems are designed and installed to work as specified. Research has shown that without basic design and testing after installation, it is highly unlikely that a system will perform as the manufacturer intended (MacFarland et al. 2016).

PROGRAM EXAMPLE

One demand reduction program in Redding, California, installed residential capital improvements using measured home performance techniques to reduce peak demand. Program managers recognized that to achieve expected results, they needed to improve the status quo ways of installing HVAC equipment in the region. They provided training and mentoring for HVAC techs and energy raters who verified post-retrofit work to ensure equipment was installed correctly. The program reduced peak demand by an average of 35%, including a 25% measured reduction in average monthly cooling energy and a 65% measured reduction in average monthly heating energy (Harriman and Chitwood 2012). The primary measures enabling these improvements were air sealing to tighten the building shell combined with repair of ductwork and new HVAC equipment that was properly sized and installed (system size was decreased in most cases). The smaller, correctly sized HVAC equipment guaranteed that the electricity demand from the HVAC system would not exceed the available supply at any given time because systems did not draw loads as large.

CONTRACTOR PRACTICES

Some contractors are developing procedures to ensure proper installation of HVAC systems, realizing that many home performance issues they encounter cannot be solved without addressing all aspects of HVAC system performance. Heat pump and air conditioner system efficiency is affected by the amount of refrigerant charge, the balance between supply and return airflow, and whether the equipment is appropriately sized for the home. HVAC system design is not one-size-fits-all, and skilled HVAC technicians know that a system's design characteristics such as air velocity, fan size, and static pressure need to be optimized for the specific home conditions. For example, if ducts are buried in insulation or are in conditioned space, air velocity through the ducts can be a little slower. Therefore the fan can be smaller, while static pressure should always be low. Home performance contractors balancing multiple design characteristics of an HVAC system realize that in order to optimize the efficiency of a system, measurement is a necessity. Measurement is also important to some contractors in helping to manage accountability in a growing company with many crew members. For example, the ability to measure a system as installed and compare it against design specifications assures contractors that their crews are meeting the standards for work that were developed for each project.

Pay-for-Performance Pilot Programs

The pay-for-performance program model is a fundamental shift in how utilities currently deliver energy efficiency programs. This approach is structured around utilities' paying project aggregators for energy savings as measured through metered energy data. The pay-for-performance model is not new—some programs tested this approach on a small scale in the 1980s and 1990s. More recently, pay-for-performance pilots for the commercial sector have popped up, including in Rhode Island, New Jersey, Seattle, Portland, and California. Pacific Gas and Electric is in the process of launching a residential pay-for-performance pilot program to test whether a market-based solution can scale the market for residential energy efficiency. This will be the first pay-for-performance utility pilot targeted to residential customers in the age of access to high-quality energy usage data. Instead of following the current energy efficiency program delivery model of developing program infrastructure to encourage upgrades, PG&E will select three to five project aggregators who will work directly with residential customers to reduce energy use in any way they choose. This could include behavioral, retrofit, and/or operational reductions in energy use (Magnuson 2016). Aggregators must participate in a bidding process to be selected for the program, providing project energy savings estimates, the anticipated target market, and proposed interventions.

Energy savings analysis will be performed using CalTRACK, a set of standards designed to systematize analysis of project performance data using different tools, to provide continuous feedback on savings and program-level realization rates. Payment for energy savings will be based on each aggregator's overall portfolio savings. Aggregators will receive payment for savings in the first year they are realized, and then for one additional year if the savings are sustained over that time (Jacobson 2016). As the program is currently designed, aggregators would not be eligible to continue receiving payment for savings longer than two years, even if capital measures persist longer than that.

It is not clear the degree to which comprehensive whole home retrofits will play a part in the pilot. California is in the process of choosing aggregators, who will ultimately be responsible for determining measure types. For an aggregator to be a successful participant in the pay-for-performance program, it is likely to already have a successful strategy in place for predicting and realizing actual energy savings. Aggregators may apply for the program in partnership with multiple companies, where one company may possess the analytical capability to assess savings and the other may have a strong strategy for finding customers and performing upgrades.

In Colorado, Boulder County's Office of Sustainability is piloting a pay-for-performance program on a much smaller scale. For the initial pilot, 12 households have been selected to participate. They will receive rebates for savings realized between specific dates as measured using the Resispeak platform. Program staff conducted an initial screening to choose households where occupancy changes were unlikely to occur so that energy use would not be affected by such changes. The selected households can undertake any behavioral or retrofit measures they desire to reduce usage (B. Smith, sustainability outreach and education specialist, Boulder Office of Sustainability, pers. comm., May 18, 2016). This program is designed to encourage lower energy use through sustained behavioral changes and/or retrofit improvements.

OPPORTUNITIES TO INCREASE PARTICIPATION IN DEEPER RETROFITS

Another aspect of realizing deeper program savings is the project size that households undertake. To encourage more comprehensive projects, a number of strategies have been proposed or are being tested. In this section we discuss some of these strategies and explore cases in which they have been tested.

Major Renovation and Deep Retrofit Programs

Major home renovations have long been discussed as a period of opportunity for improving energy efficiency in residential homes, because major projects result in changes to the building shell and often require changes to mechanical systems as well. Planned upgrade and maintenance projects such as roofing and siding replacement also afford a good opportunity to add energy efficiency improvements to the building shell. Some programs have attempted to leverage homeowners' major renovations or additions to include efficiency upgrades for both the addition or renovated area and the building as a whole.

From 2009 to 2012, Mass Save ran a pilot program to encourage upgrades at the time of major renovation. The Major Renovations pilot began as a program providing incentives to homeowners to make energy efficiency improvements to their whole home when building additions of 500 square feet or greater. In 2012 the program was changed to instead offer incentives to contractors who were performing additions of any size or a partial gut renovation. Participation in the program required that ventilation rates and existing parts of the home including ductwork in unconditioned space, exterior walls, flat attic ceilings, and basement/crawl spaces be brought up to minimum specified levels of performance. The program also specified levels of minimum performance for new additions and gut renovations (Conant 2012). This pilot effort was incorporated in 2013 into Mass Save's Home Energy Services, one of four core initiatives of its Whole House program; the other three are New Construction, Multi-Family Retrofit, and a Behavioral/Feedback component. All four initiatives are meant to allow for variations in program delivery and marketing that address "specific moments in building life cycle, customer type, or market demand" (Mass Save 2015).

The Deep Energy Retrofit Program run by National Grid in Rhode Island and Massachusetts offered an opportunity to understand the costs of adding high-efficiency building shell upgrades to an existing project. On average, the incremental cost of adding air sealing and roof insulation to a roof replacement was about 30% of the total project cost. The incremental cost of adding insulation during a siding replacement was about 50% of the total project cost (Cluett and Amann 2014). This program also indicated the importance of workforce development for more complex measures that are not common aspects of current home performance projects. Cluett and Amann discuss other deep retrofit research and development projects as well, including the NYSERDA Advanced Buildings Deep Energy Retrofit Program, the Thousand Home Challenge, and DOE's Building America Deep Energy Retrofits (Cluett and Amann 2014).

Road Map for Retrofitting Buildings over Time

Programs and contractors often face the challenge of helping homeowners understand how much impact a given energy efficiency improvement can have on energy use. After participation in one energy efficiency program or replacement of one measure, customers may feel they have sufficiently improved their home's efficiency, not understanding the other opportunities they have for improvement.

Efficiency Vermont is expanding efforts to address this issue and achieve deeper savings in residential buildings by motivating customers to take initial steps and then providing a road map for achieving more comprehensive savings over time, taking into account a home's particular characteristics. Efficiency Vermont aims to help customers approach household energy performance not as a single, large-scale project but as a process during which efficiency improvements are made as other renovation and maintenance efforts occur, or as household budget and timing allow (VEIC 2015). This strategy intends to target moderate-income households that are unable to afford the up-front cost of a comprehensive whole house upgrade all at once.

A similar approach has been proposed in Germany, where aggressive retrofit goals for reduction of energy use in the residential building sector have been set as a part of the German *Energiewende*, or energy transition. Various strategies are needed to meet the short-term goal of reducing the overall demand of residential buildings by 20% by 2020, and the long-term goal of having a carbon-neutral building stock by 2050 (Strunz, Durth, and Wolff 2014; Pehnt et al. 2013). Germany has an extensive energy efficiency renovation and construction program, run by the German development bank KfW, that has helped to drive investment in energy efficiency improvements. While participation in loan and grant programs for single measures have been significant, policymakers struggle to get households to invest in comprehensive upgrades. This program helps to achieve around one third of the annual reduction required from the residential sector to meet national goals, signaling that other strategies are needed.

One of the proposed strategies involves creating individual building renovation road maps to help plan a customized, long-term strategy for reducing energy to the level specified by national goals. Each road map (an example is given in figure 4) would be built upon required efficiency labels/energy performance certificates that all residential buildings must obtain when sold and serves as an actionable map for how to get an individual building to the efficiency level required to meet national goals (which equates to efficiency level B in Germany on an A-to-G (best to worst) scale (Pehnt et al. 2013). The renovation road maps would provide individual buildings renovation strategies specific to their situation and would document the steps for meeting the requirements of each efficiency rating. They would give building owners an optimal sequence and packaging of measures and raise important considerations in cases where the work was done over time, versus all at once (Pehnt et al. 2013). This strategy could help homeowners undertaking single measures to understand the relative impact on energy use of a particular improvement, and lay out additional steps that could be taken over time to reach optimal efficiency levels.

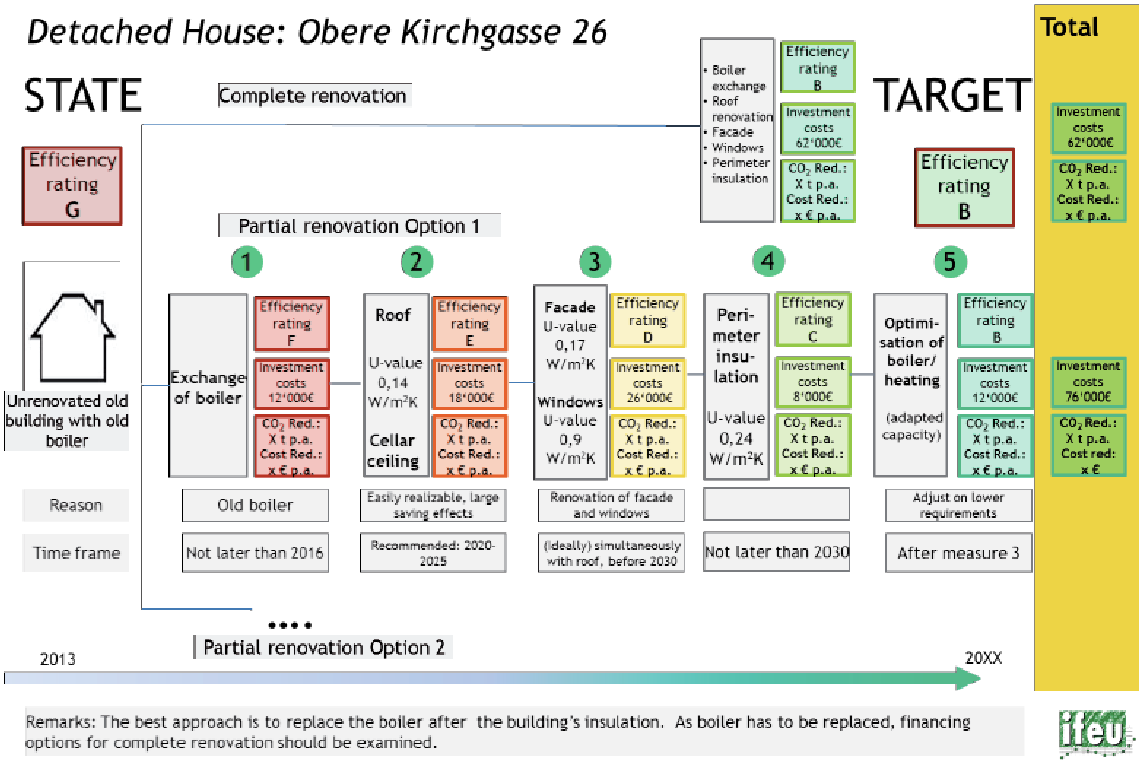

Figure 4. Sample road map for energy efficiency improvements for a residence in Germany. *Source:* Pehnt et al. 2013.

Customer Segmentation Using Meter Interval Data

Data about customer behaviors, attitudes, demographics, and perceptions have been used in a number of cases to target energy efficiency and demand response programs (Smith, Wong, and Rajagopal 2012). For example, Pacific Gas and Electric has used a range of variables such as demographic attributes and level of engagement with the utility (such as use of online tools and participation in energy efficiency and demand response programs) to segment its customer base into 11 groups. The utility then identifies products and programs best suited to each particular group, creates appropriate messaging, and determines best methods of customer contact.

The increasing availability of meter interval data provides utility programs with additional opportunities to segment customers and design and target energy efficiency program offerings that meet customer needs. Smith, Wong, and Rajagopal (2012) demonstrate a method for analyzing interval data to group households by load shapes, which indicate when and how much energy is used. The authors demonstrate how demand response programs can target households based on their time of peak energy use and suggest that these data, when combined with other customer data, can also inform energy efficiency program targeting.

For instance, programs can use interval meter data to identify and target homes with the highest energy use or energy intensity. A recent study conducted by Seventhwave found that of nine utilities interviewed in the Midwest, two had efforts underway to segment residential customers by usage. The utilities used this information to target high energy users for energy audit programs (Pigg et al. 2016). Utilities not currently targeting customers based on energy use noted barriers including limited time, funds, and internal resources. They also mentioned the need for additional data about their customers (such as home size and number of occupants) to be able to effectively target programs. An assessment conducted by Seventhwave demonstrated the feasibility of combining energy use data with property tax information (home age, size) on a large scale to assess the energy use intensity and potential for improvements in individual homes. Studying 100 homes in Minnesota, the researchers found an energy savings potential of more than 3,600 kWh per year for high electricity users and about 400 therms per year for high natural gas users. Two-thirds of the identified savings opportunities involved building shell and equipment improvements rather than behavioral changes to reduce usage. (Pigg et al. 2016).

A similar approach combining energy use data with property tax information was used in Chicago to identify housing characteristics and energy use for common home types. Planners then produced packages of energy efficiency measures that could be implemented by home type. In this effort, led by the Partnership for Advanced Residential Retrofit (PARR), a DOE Building America team, tax records from the Cook County property assessor were combined with energy consumption data from all three utilities serving the Chicago metropolitan area for 432,605 single-family homes, about 43% of the total. Tax assessment data in Cook County contain comprehensive information about each home, including characteristics relevant to energy use such as exterior construction, type of attic, presence of a basement, and type of heating and cooling systems (Spanier et al. 2012). The structural and energy use characteristic assessment was used to identify housing types with the greatest energy savings potential, based on the total number of those houses in the sample population and the annual source energy savings that could be expected from the designed measure package. This type of assessment can be used to design programs and target geographic areas that have the highest energy intensities and potential for savings (Scheu, Robinson, and Evens 2014).

Community-Focused Approaches

Focusing retrofit programs on a particular geographic area or community has also been an effective strategy for achieving high participation rates. The Hood River Conservation Project intensively marketed retrofits in the 1980s in Hood River, Oregon, as a strategy to reduce the overall electricity consumption in a capacity-constrained area to avoid building a new power plant. The program conducted energy audits on 91% of 3,500 eligible homes and retrofit 85% of them. The program paid the majority of the retrofit cost, up to the avoided cost of the new power plant (York et al. 2015b). The local community played a key role in the program's marketing efforts. About 10% of local households participated in some form of pre-program study (e.g., end use monitoring of home energy use) or focus group, which raised awareness about the program before it started. Many of these households became the first program participants and then served as champions of the program, recruiting neighbors and friends. Word-of-mouth marketing from past program participants was ultimately found to reach approximately 80% of program participants. Traditional marketing through newspaper advertisements and news coverage of the program also contributed to the high level of community awareness. In the final months of the program, participants were reached through more aggressive marketing tactics such as door-to-door canvasing and phone calls (Fuller et al. 2010).

Another initiative, the Marshfield Energy Challenge, targeted the community of Marshfield, Massachusetts. The two-year pilot aimed to reduce peak electricity demand using a community-focused messaging approach to promote the energy efficiency program administered by the regional utility NSTAR (York et al. 2015b). The program recruited local leaders and ambassadors from schools, elected office, churches, and businesses to make efficiency improvements in their own homes and then talk to community members about the program. Administrators also relied heavily on messaging focused on the benefits to the Marshfield community as a whole from participating in the program. The town-specific messaging around the Marshfield Energy Challenge spurred neighboring towns to ask NSTAR to bring the Energy Challenge to their communities. About 1,300 households received an energy assessment (the program goal was 1,200), and approximately 15% of those households installed insulation, air sealing, or heating measures (Fuller et al. 2010). While follow-through with energy efficiency improvements was much lower than in the Hood River Conservation Project, measures were not reimbursed at the same level by the utility in this program. Participation was significantly higher than in adjoining towns that were also eligible for the same NSTAR program but were not targeted with community-specific marketing (York et al. 2015b).

Some participants of DOE's Better Buildings Neighborhood Program also focused program efforts on motivating specific communities to take action. In the RePower Bainbridge program in Washington State, community-specific messaging helped to make the program relevant to local residents. Program administrators issued a clear call to action, citing the need to reduce electricity demand to avoid the construction of a new power substation. The program set and published its goals of conducting 4,000 home energy assessments and 2,000 upgrades in a community of 6,800 single-family homes. In the end, the program reached 2,467 households with energy assessments (36% of eligible households) and completed 848 upgrades (12.5%). Projects saved an average of 31% per home (Kraus 2014).

The Better Buildings funding recipient NeighborWorks of Western Vermont (NWWVT) relies on its relationships with and understanding of homeowners in the region to encourage participation. NWWVT focused its initial program efforts under the Better Buildings funding on Rutland County, Vermont, an area where few residents were taking advantage of statewide energy efficiency program offerings through Efficiency Vermont. The organization focused on low-cost community-based methods of outreach, including a phone campaign hosted by a local volunteer group that engages in various environmental projects. Within six months of the program launch 386 evaluations were conducted and 196 upgrades completed, for a conversion rate of 51% (US DOE 2011).

Building Support for Retrofits in the Market

Programs have an important role to play in developing the market for home performance upgrades, by encouraging high-quality work practices that help build contractor skills and abilities and by growing consumer understanding of the value of comprehensive energy efficiency improvements. Programs can facilitate high-quality, accurate practices for estimating energy savings, making contractors' and energy advisers' predictions more reliable. They also can help enhance the quality of retrofit work through real-time monitoring of energy reduction outcomes for individual jobs and contractors.

More accurate, reliable realization of savings at the project level opens up greater opportunity to use financing strategies that are tied to realized savings, like certain types of on-bill programs. Among these is Pay as You Save® (PAYS®), a program model developed by the Energy Efficiency Institute, Inc. (Cillo 2011). It is an on-bill fixed charge for energy efficiency improvements that allows project costs to be paid over time, with monthly project payments that are designed to be lower than the energy bill savings. The project cost remains on the utility bill for a particular location, rather than for a particular customer, until the utility recovers its cost. This means the customer assumes no personal debt, and projects can be completed on rental properties. PAYS aims to leverage third-party financing that utilities can use to cover the up-front costs of energy efficiency projects. To provide assurance that these retrofits are yielding the expected energy savings, real-time program evaluation is an essential tool.

On-bill programs can be structured as a tariff, like the PAYS system, or as a loan. An on-bill loan program is offered to a particular utility customer (rather than tied to a property) for payment of energy efficiency improvements over time. It follows a similar model of project cost payment over time through a utility bill, with monthly project payments sometimes designed to be lower than the value of energy savings. Programs that require the expected energy savings from energy improvements to offset the total project cost are referred to as "bill neutral." In 2012, four residential on-bill programs had bill neutral requirements, while 10 programs did not (Thompson et al. 2014). Efforts to develop bill neutral and Pay as You Save projects in which energy savings exceed project repayment can be enhanced by better project realization rates.

The bill neutral on-bill model has been piloted at some rural cooperatives in the Southeast. For example, three Arkansas electric cooperatives offer on-bill loan repayment for energy efficiency improvements (primarily insulation and air sealing) through their Home Energy Lending Program. In 2015, the first full year of the program, one of these cooperatives financed more than 300 retrofits, achieving an average of 19% verified energy savings from basic weatherization measures (air sealing and insulation), with bill neutral payback. The program used pre- and post-upgrade smart meter data for quality assurance and verification of savings. Conversion rates from audit to project hovered at around 80% (Agard 2016). Despite successful results, program administrators noted that additional savings were left unrealized in many households because HVAC replacements were considered too risky to finance. Accurate energy savings estimates and quality installation could help reduce that risk. One of these Arkansas cooperatives, Ouachita Electric Coop, is also piloting a PAYS program. The addition of this financing option has allowed multifamily and single-family renters to participate and has opened up the availability of HVAC replacements (Agard 2016).

Outside of program efforts, a New York–based home performance company called Sealed is tying financing to realized energy savings through a pay-as-you-save model. The company guarantees savings from energy efficiency improvements by replacing electricity and fuel bills with one bill, paid to Sealed, that combines all energy and project costs. With improvement costs included, the bill is guaranteed to be lower than the cost of past usage, after adjusting for weather and energy price fluctuations. The company calculates energy savings using "analytics that leverage machine-learning principles to accurately predict energy usage" (Salz 2016).

Reducing the uncertainty associated with the value of improvements in terms of the savings they deliver can help households make informed decisions about the best opportunities for improvement. In addition, reliable estimation of energy savings also opens up the door for better integration of energy efficiency improvements with other renovations.

Recommendations and Conclusions

The following recommendations are already being implemented in some retrofit programs to improve realization rates and achieve greater energy savings.

Improve energy modeling outcomes through better access to energy use data, model calibration, and adoption of standardized home performance data protocols. Utilities can make energy use data more easily transferrable to energy assessors, contractors, and program administrators for use throughout a program by adopting Green Button Connect My Data. For contractors, easier data access means energy models can be consistently calibrated to a household's actual baseline energy use data using the industry standard ANSI/BPI-2400, which has been shown to improve modeled savings estimates. In addition, standardization of program data collection and transfer by enabling use of HPXML standards allows contractors to use their own modeling tools and reduce the administrative time spent on each project.

Enable real-time feedback on project and program performance during program operation, rather than after it is complete. Data protocols on home performance measures and projects, access to energy usage data, and software tools are making it possible for programs to track results more thoroughly during a program cycle. Administrators can then refine and adjust delivery of the program while it is in progress to optimize results, and also can give contractors feedback on how individual projects are performing.

Stimulate participation in retrofit programs. Programs can start by targeting households with high energy intensity that could greatly benefit from home energy improvements. By focusing program outreach and marketing efforts on specific communities or geographic regions, administrators can make programs relevant to local residents and encourage word-of-mouth referrals among neighbors and friends.

Whole building retrofit programs can be an important means to scale up energy savings in the residential sector. These programs play an important role in growing consumer demand for home performance work and in improving systems and practices that enable contractors to perform quality work, thereby achieving higher realization rates in retrofit programs. More accurate, reliable realization of savings at the project level opens up more opportunities to use financing strategies that are tied to energy savings, such as pay-as-you-save or on-bill financing. This can also enable better integration of energy efficiency improvements with other home maintenance and renovation projects (such as roofing or siding replacement). Programs should work to incorporate practices for delivering reliable savings, both to increase their own energy savings realization and to contribute to transformation of the home performance market as a whole.

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