Establishing Savings Algorithms and Evaluation Procedures for Emerging Technologies and Innovative Program Approaches

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ABSTRACT

Mature efficiency programs are faced with a combination of aggressive savings goals and restricted opportunities associated with their existing measure menus. As a result, they are looking to emerging technologies and new program approaches to keep efficiency advancing in the commercial sector. In order to incorporate these new technologies and approaches, solid savings assumptions and appropriate evaluation protocols will need to be established.

This paper will discuss the Forum's research activities and protocol recommendations for:

- Emerging Technologies
  - LED/solid state lighting
  - Advanced power strips
  - Ductless mini-split AC and heat pumps
  - Biomass wood pellet boilers
  - Heat pump water heaters
- Innovative Program Approaches
  - Commissioning and retro-commissioning programs
  - Commercial lighting design programs
  - Whole building retrofit programs
  - Multi-family whole building retrofits

The paper will also explore the potential of these technologies and approaches for obtaining persistent program savings. The development of robust savings assumptions, protocols, and algorithms will be discussed as will the adoption of defensible deemed savings values. The Forum's recommended evaluation protocols, which will assist impact evaluators in assessing the performance of non-conventional projects and programs, will be presented and compared to established evaluation conventions.

Introduction

The Northeast Energy Efficiency Partnerships' Evaluation, Measurement and Verification (EM&V) Forum, working with a team of contractors, has developed a set of evaluation protocols and savings algorithms associated with emerging technologies and innovative program approaches. The EM&V Forum is an ongoing project of the Northeast Energy Efficiency Partnerships located in Massachusetts with private and public member organizations from the New England states, New York, New Jersey, Maryland, the District of Columbia and Delaware. The Forum's sponsoring programs are in the process of introducing many of the measures and approaches as either pilot programs or standard offerings in 2012. In addition, some of the measures studied are receiving additional primary research during the spring of 2012 in order to fully establish potential program impacts.

Energy & Resource Solutions (ERS) along with partners Dunsky Energy Consulting, Livingston Energy Innovations and Opinion Dynamics contracted with the Forum to research and develop best practice savings methodologies for the target measures. The initial recommendations were delivered in March 2012. (McCowan et al., 2012) Additional research, involving equipment monitoring of two of the technologies; advanced power strips and ductless heat pumps/air conditioners will be conducted over the next several months.

The effort resulted in a series of recommendations for the following technologies and program approaches:

- Emerging Technologies
  - LED/solid state lighting
  - Advanced power strips
  - Ductless mini-split AC and heat pumps
  - Biomass wood pellet boilers
  - Heat pump water heaters
  - Set-top boxes (cable/satellite television)
- Innovative Program Approaches
  - Commissioning and retro-commissioning programs
  - Commercial lighting design programs
  - Whole building retrofit programs
  - Multi-family whole building retrofits

The Forum member organizations have long offered residential and commercial sector energy efficiency programs. However, as markets are transformed, best practice becomes standard practice and new technology and programmatic developments offer new opportunities. The current research effort has succeeded in developing solid strategies that support the introduction of innovative measures within existing efficiency programs, or as pilot programs, while establishing defensible savings methodologies that will be verified by future process and impact evaluation results. In addition, the project team identified significant knowledge gaps associated with the performance, customer acceptance, and savings persistence of emerging technology measures and recommended strategies for closing such gaps.

Because the project covered a total of nine technologies and program approaches, it is difficult to cover the scope of issues within the confines of this paper. In light of that, the following sections will highlight our findings associated with each technology and program approach, concentrating on the viability for efficiency program inclusion and the closing of knowledge gaps.

Emerging Technologies

Solid State/LED Lighting

Lighting systems based on light emitting diode (LED) technology offer the prospect of transforming the commercial and residential electric lighting market in a way unprecedented since the introduction of the ballasted fluorescent lamp in 1938. While most other types of lamps are approaching their maximum theoretical efficacy, the best performing white-light LED products are only half way to their theoretical potential. (Ton et al., 2003) At the same time, production costs and market pricing for LED lighting systems are dropping and are expected to continue to decrease in both cost per lumen and cost per lamp. (Peters., 2012)

Researchers and industry experts have been surprised by the speed with which LEDs have entered a variety of niche markets. As legislation such as the Energy Independence and Security Act of 2007 (EISA) drives minimum performance requirements for general service lighting upward, LED performance and pricing for a variety of interior and exterior lighting applications are becoming increasingly attractive to consumers and institutional purchasers.

In the residential sector, advancing federal lighting standards defined in EISA legislation call for the phasing out of standard incandescent lamps beginning with 100 watt bulbs in 2012 with other incandescent phase-outs in the following years. Although halogen and compact fluorescent lamps will be market options, LEDs promise to grab a large share of the household lamp market. For commercial applications LEDs are currently replacing exterior incandescent and HID lighting, incandescent and halogen lighting for retail applications, and special display lighting. Flat panel LED lighting is showing promise as general space lighting.

LED knowledge gaps. Despite all the promise, there are knowledge gaps regarding LED lighting that if closed will make it easier for program administrators for promote the products with financial incentives. Because the technology is advancing so fast and the product promises long lifetimes, there is little reliable data or track record on operating hours in general as well as in various types of residential and commercial occupancies. At a minimum, pilot studies are needed to determine if occupant behavior with regard to LED operating hours is any different from what has been observed and documented for other lighting products.

It is also difficult to identify the technologies LED products are likely to replace. In homes, will purchasers replace incandescent lamps in order for the high savings to justify the cost; or will the same early adopters that purchased CFLs now replace them with LEDs? The savings that can be claimed by efficiency programs will be dramatically different in those two scenarios. For commercial projects, because of the color and directional characteristics it is not uncommon for LEDs to replace a lighting fixture that has a higher lumen output. As such the conventional method of comparing baseline and proposed lumen outputs may not be appropriate for LEDs.

Several recommendations were delivered to the Forum members for predicting programmatic savings and for evaluating program performance:

- *Measure life; 25,000 hours* – The best available data on measure life is associated with the DOE/EPA developed standards for LED lighting. ENERGY STAR® listed LEDs are rated for 35,000 – 50,000 hours for equipment life depending on application. However, they lose output before they reach the end of technical life, therefore ENERGY STAR LEDs are rated to produce a minimum of 70% of their initial lumen output at 25,000 hours of operation. The DesignLights Solid State Lighting Initiative (DLC-SSLI), a NEEP initiative, also adheres to this standard which is termed L_{70}.
- *Measure persistence; discount from measure life* – The average life of a measure is not necessarily the amount of time that the measure will stay in place. Many factors affect persistence. For LEDs the identified factors included: renovation cycles; replacement

with the next generation of solid state lighting; change of ownership; change of space usage; etc. These factors, and average annual operating hours, were used to recommend net measure lives from 8-15 years depending on the application. An exception is LED lighting for refrigerated cases which have a lower anticipated life, estimated at 5.5 years.

- *Adopt deemed savings values for simple residential and commercial LED measures* – In order to predict and report savings, a power consumption value (wattage) must be identified for the replaced technology. For residential and simple commercial measures it is difficult or impossible to record the actual equipment replaced. The project team developed a table of deemed savings values generated from the anticipated average wattage of the replaced measure for each currently popular LED product type.
- *Perform follow-up research* – Although all the Forum member programs are evaluated on a schedule, it was recommended that program administrators perform research as a component of their LED programs. Research topics include: what lamps are actually being replaced with new LED purchases; the persistence of the measures in homes and businesses; customer satisfaction with the products; actual operating hours (this data is needed for all lighting measures); and for commercial applications, the typical lighting power densities (watts per ft^2) that are achieved with various LED products.
- *Utilize ENERGY STAR and DLC-SSL* – These two programs develop/publish standards and certify products meeting those standards. ENERGY STAR focuses on residential products while the SSL focuses on the commercial/industrial marketplace. Individual program administrations cannot properly evaluate LED products on their own, and the two programs offer an opportunity to move forward with LED programs without investing too deeply in technical efforts.

Ductless Mini-split Heat Pumps and Air Conditioners

The ductless heat pump (DHP) market is well-established in other parts of the world, but far less in North America. However, recent advances in technology have made DHPs an attractive option for certain North American markets such as new construction and retrofit for homes with heating systems that don't use ducting.

Several North American suppliers are now providing DHPs with performance characteristics that make them more suitable for use in colder climates. DHPs available in North America up until 2011 were rated to operate at temperatures of 17°F and above. Recently introduced models are rated for operation as low as 0°F. This is a crucial factor for the northern United States and Canada. DHPs have the potential to significantly reduce home heating and cooling costs by reducing the amount of energy needed to condition the space.

The overall efficiency for both heating and cooling has experienced steady improvement over recent years. The current minimum ENERGY STAR qualifying standards for split systems is 8.2 HSPF for heating and 14.5 SEER for cooling. Several ENERGY STAR listed products are available with HSPF ratings over 10 and SEER ratings over 20.

Due to the high levels of insulation and air tightness required by current building codes, properly sized and configured DHP systems can be used as the sole HVAC solution (heating and cooling) for residential new construction. In the retrofit market the goal is often to displace as much of the heat coming from electric resistance equipment, or fuel oil, as possible. Ductless air conditioners can also be installed for cooling only, and are efficient alternatives to window mounted units. Features of DHPs that enhance performance compared with conventional air-source heat pumps, are as follows:

- *Inverter-fed motor* – Inverting AC to DC, allows for variable speed use, avoiding on/off cycling of the unit, and increased efficiency and durability.
- *Scroll compressor* - Operates more smoothly than a regular piston compressor, reducing noise and electric consumption and enhancing the compressor's expected life.
- *Electronic (precise) expansion device* - Better refrigerant flow control provides a superior level of room temperature control and uses less energy.

A recent study of installations in Massachusetts and Connecticut, conducted by KEMA (KEMA. 2009, 2012) Consulting, reported that actual heating savings had been lower than predicted by the National Grid and Connecticut Light and Power efficiency programs that subsidized the installations. In addition, it was found that the level of homeowner satisfaction was lower when the units were used for heating than when used for cooling. This was partly attributed to comfort issues related to the placement of the fan units and resulting delivery of air at a temperature that felt cool to the occupants.

Knowledge gaps. The KEMA study pointed to the need for program administrators to better understand the unique operational characteristic of the ductless systems and to consider installation requirements and training. Following the initial project phase, additional research is being conducted by the project team to address the following knowledge gaps:

- The impact on heating savings associated with newly-introduced DHP systems rated for operation in a heating mode down to 0°F.
- *Space conditioning interactions with other heating systems*. Because systems are being installed as supplemental to existing heating systems, data regarding how customers utilize the two systems and how the performance characteristics interact is needed to accurately predict savings.
- *Impact of sizing and the number of zones on savings*. Sizing is often done by rule-of-thumb (Btu output per room area), which is further complicated as the size needed for air-conditioning may be significantly different than the size needed for heating.
- *Electric load building; the impact of summer AC load for buildings in cold climates.* For some of the Forum member territories, air-conditioning is rarely installed in homes as there are few severely warm days and the installation expense is not justified. However, installing a heat pump in these regions will surely encourage a certain amount of summer cooling. The installation of heat pumps could be problematic for programs in regions where lowering summer demand is a programmatic priority. .
- *Savings attributable to the elimination of duct losses & zoning capabilities.* It has been common practice to assess heat pump savings only based on improved efficiency ratings. However significant savings are achievable through improved zoning and the elimination of duct losses.
- *Reliability of EER, SEER and HSPF ratings for DHPs due to the use of inverter-fed motors.* These rating systems were developed before the widespread use of inverter-fed direct current (DC) motors. Are new rating systems needed for mini-splits, as has been developed (IEER) for larger ductless systems?

- The economic and environmental viability of fuel switching from fuel oil heating to DHPs.

Recommendations. The ERS team's overall recommendation is that there is enough knowledge to provide incentives now for systems that are replacing or displacing resistance electric heat or older less efficient heat pumps. We developed minimum heating and air-conditioning ratings for both heating and cooling seasons. We also supplied savings algorithms that could be used to predict system savings on a project or program basis.

In order to further understand the savings potential of the systems, it is recommended that in situ monitoring of installations be carried out in order to gather all the relevant data needed to determine the level of savings that DHPs provide. Because DHP systems are promoted for both partial heat displacement and as a sole HVAC system for homes, both types of installations should be monitored across a variety of climatic conditions. An approach that allows for engineering modeling to create calibrated building prototypes based on the metered sites would allow savings to be predicted for a variety of buildings.

Heat Pump Water Heaters (HPWHs)

Despite decades of development, until recently HPWH s seemed stuck in the emerging technology category. The convergence of the ENERGY STAR specification for residential HPWHs with the involvement of prominent manufacturers and the upcoming federal energy standard for units over 55 gallons promises to give HPWHs a real place in the market if they are promoted, installed, and supported wisely.

HPWHs were first introduced in the UNITED STATES during the 1970s in response to the energy crisis associated with the first OPEC oil embargo. Within a few years, most major air conditioning and water heater manufacturers had introduced HPWH products and within a few more years most had been withdrawn from the market due to a combination of technical, marketing, and business-concept failures. Successive generations of HPWHs have been brought to market since that initial introduction but each time adoption has been cut short by technical and market shortcomings.

HPWHs extract thermal energy from ambient air using a vapor compression system similar to those in space conditioning devices such as heat pumps and air conditioners. The compressor is small (typically 500 watts) and is sized to run 3 to 4 hours per day, keeping electric demand low while it is running. The condenser transfers heat from the heat pump to water in the storage tank and may be immersed in the tank, wrapped around the tank wall, or placed inside the insulation blanket. The fan exhausts air cooled by the evaporator to the area around HPWH. Most units are constructed with conventional electric resistance heating which is automatically activated when the compressor cannot meet the demand. Typically a manual switch allows users to override the compressor, at which point the unit switches over to 100% electrical resistance heating.

Several factor were identified that should be considered the program administrators so that past HPWH marketing mistakes are not repeated:

- HPWHs must be installed in locations with at least 1,000 cubic feet of air space around the water heater and where the temperature remains between 40°F and 90°F in order to operate in heat pump mode. If inexperienced program implementers and HPWHs do not recognize this limitation, the result will be units that operate primarily as standard electric water heaters.

- The industry utilized efficiency ratings for HPWHs are based on operation at one ambient temperature (68°F). If accurate savings predictions are to be had, it is imperative to understand that the performance of the units is tied directly to the ambient temperature. As the temperature drops below 68°F, performance deteriorates. At 45°F, most HPWHs have reached a balance point, meaning that there is no longer any efficiency advantage compared with conventional electric resistance heating, and in fact most will operate only on resistance heat below 45°F.
- Additionally, the ratings do not include the energy needed for making up any of the heat extracted from the installation area. This is of no concern in the summer, but in cold climates the space heating system may be called on to make up the differential.
- Electric resistance water heaters are silent. HPWHs are not, which is often a surprise to homeowners. Care must be taken with installation location to assure that the manual switch is not turned to resistance heating in order to eliminate operating noise.
- The exhaust air from HPWHs is cool. Unless ducted to the outdoors, exhaust air potentially lowers the ambient temperature, reducing efficiency, and the moving cool air can be a comfort issue in some installations.
- HPWHs have small compressors and do not recover as fast as electric resistance heaters. The sizes for residential use range from 40-80 gallons. Families presently using 40 gallon conventional electric tanks may find that a larger HPWH is needed to satisfy demand.

With the above caveats, the study recommends that programs not yet promoting HPWHs introduce closely-monitored pilot programs. Some Forum member programs have recently introduced HPWH measures as mail-in rebate programs. Such programs, along with upstream discounts, can lower administrative costs. However, quality assurance must be addressed through installation guidelines and installer training or the result will be dissatisfied customers and poor realization rates.

Biomass-Wood Pellet Heating Systems

The project focused on wood pellet-fueled furnaces, boilers, and combination systems (providing space heating and domestic hot water) that incorporate or can accommodate automatic fuel feeding. Since the 1990s, Europe has been the major proving ground for biomass technology, with users on the North American continent importing boilers and furnaces. However, with the rise of interest and use in the United States. and Canada, North American manufacturers have begun to emerge. Ironically, the United States and Canada have long been major pellet suppliers for European demand, with pellet exports reaching 1.6 million metric tons in 2010. Other research suggests that states such as Maine could replace 49% of its liquid fossil fuel dependence in the home-heating sector with wood pellets.

In the United States, biomass energy accounts for 45% of renewable energy used. (Cleaves. 2011) Most biomass is burned in old furnaces and boilers, leading to hazardous particulate emissions (PM2.5) as well as Volatile Organic Compounds from incomplete combustion and unsuitable fuels. (Torres-Duque. 2008)

The creation of wood pellets as a suitable biomass fuel was prompted by the oil crises of 1973 and 1979. While subsequently low oil prices led to a decline in interest, pellets have since been revived alongside interest in climate change, renewable energy, resource sustainability and energy efficiency.

Before looking at savings algorithms, it is important to note that the implementation of wood pellet equipment constitutes a fuel switch. It is possible that installing a wood pellet appliance will cause a drop in efficiency compared with an existing gas system; however we assume that the primary purpose of this measure when adopted by efficiency programs is not to increase theoretical end-use efficiency, but rather to reduce consumption of electricity and non-renewable fuels. This is the same logic that would apply to the promotion of other renewable resources such as solar PV, wherein efficiencies can be far lower than those for fossil fuel equipment. While the principal focus may be on reducing fossil fuel consumption, just as with other measures that allow a fuel switch, an additional focus should be on supporting best practice, high efficiency, systems. In fact, under current regulatory structures, most ratepayer funded programs will be required to calculate incentives based on incremental performance differences and the associated installation cost differences.

We assume that homes installing this technology through a program will be moving from, or supplementing, either electric or natural gas heating. We understand that there are programs that do include various fuels such as fuel oil, but these programs are funded differently and are not addressed here. As such, once included in a program, the appropriate approach to assess savings for wood pellet appliances is consistent with those for residential fossil fuel boilers and furnaces provided in the current NEEP EM&V Guidelines. (NEEP 2010) This approach uses algorithms that are supported by billing analysis and/or on-site inspections for verification , in order to provide savings when the fuel switch is used in a furnace/boiler early or natural (end-of-life) replacement situation. However, this approach is not useful if the customer was going to move to an energy code level piece of equipment and chose instead to install a wood pellet appliance.

Knowledge gaps - Identified gaps requiring further research before implementing programs, include:

- Measured *in-situ* system performance and displacement of electricity and gas are needed and should be associated with local climatic conditions.
- The electricity consumption of pellet systems over a typical heating season is not well-known and should be specifically measured to obtain net energy effects.
- Research is needed regarding wood pellet supply distribution to assess the probability of future substantial supply difficulties that might be faced as residents move to this technology. Naturally, long-term savings of displaced fuels will degrade if supply issues adversely affect the availability and price of pellet fuel.
- Research is needed regarding electric and gas residential energy usage for space heating to determine the magnitude of biomass pellet potential for a given service territory.
- The efficiency impact of system sizing needs to be assessed.

Recommendations. Upon filling the identified data gaps, program implementers should consider biomass pellet systems when regulations allow a fuel neutral approach to savings. Without the ability to assess impacts across fuels and allow fuel switching, the electricity savings afforded by pellet systems may be too small, or perhaps negative, and would not support program involvement.

Advanced Power Strips

The initial research into this technology has been performed by the NEEP Advanced Power Strip (APS) Working Group, which is a volunteer effort shared by several NEEP sponsor organizations. They will be presenting a paper on the subject at Summer Study. As such, this paper only briefly covers the issues and outlines efforts for further research being performed.

At the same time that HVAC and lighting efficiency program measures have been reducing energy demands, plug loads have been increasing. Much of the equipment contributing to this increasing load not only uses electrical energy when it is active, but also when it is inactive in a sleep, or stand-by mode. APS products are intended to reduce these loads both by turning equipment fully off when not in use and by reducing total full-power usage when users neglect to turn equipment off. Typically an APS includes on “master control” outlet and several “controlled” outlets. The operational status of the equipment plugged into the master control outlet determines whether or not power is delivered through the controlled outlets.

The Working Group concludes, and we agree, that there are significant saving to be realized with home entertainment systems, home offices and commercial work stations. It has been decided to pursue further research into how APS is put to use, and to determine the level of savings. The results of homeowner and APS purchaser surveys, as well as data logging of workstation installations will we be included in the Summer Study presentation.

Set Top Boxes

Set-top boxes (STBs) are electronic devices that enable entertainment and other content delivery from a service provider to televisions and other electronic entertainment systems. Current STB penetration in the United States is about 160 million units, an average of 1.6 STBs per household. The average STB consumes about 170 kWh per year, and the energy use per home is climbing as service providers add new features in response to competition and technology advances. Although we recognize potential savings, they are not achievable through individual program activities. The deployment decisions for STBs are made by large companies covering large geographic territories. Individual users, and local cable service providers are not in a position to make decisions regarding STB efficiency upgrades.

However, ENERGY STAR does set efficiency tiers for STBs and has been somewhat successful at obtaining agreements with the industry for specifying upgrades to more efficient equipment. It is recommended that program administrators invite regional providers to discussions and seek to influence purchasing decisions through those contacts. If program implementers receive cooperation, it may be cost-effective to offer an upstream incentive for improved efficiency STB deployment within a region.

New Program Approaches

In addition to exploring new technologies the project team was charged with developing recommendations for new program approaches, or refining methodologies for recently introduced program approaches. The three selected are all program models that some, but not all, of the Forum member programs have recently introduced with varying levels of effort and success. The mission of the project team was to identify best practices of those and other programs around the United States and Canada and to make recommendations for predicting and evaluating the savings available from such approaches.

Commercial Lighting Design Programs

In large part, lighting efficiency programs have focused on the adoption of advancing technologies as replacements for existing equipment or as substitutes for baseline, standard-practice equipment at time of replacement or in new construction or major renovations. In contrast, ASHRAE Standard 90.1 based energy codes approach lighting energy savings on connected lighting load metrics, expressed as lighting power allowance (LPA), which is the maximum lighting power density (LPD; watts/ft^2) allowed for each space or building area type.

Fortunately several of the Forum member programs have implemented LPD-based lighting design programs that serve as models for a regional procedure that could be shared. This model is commonly termed "Performance Lighting" in the Northeast and promotes lower LPDs and control of the subsequent lighting load. Additionally the program mode promotes advanced technologies such as LEDs, low-power ballasts, high-efficiency fixtures, and high-efficacy lamps and ballasts as a means to obtaining lower LPDs; and bi-level switching, daylight dimming, vacancy/occupancy sensing to further reduce consumption.

Recommendations. The recommendations of the project team include:

- Adopting LPD as the principal savings metric
- Familiarizing program staff and third-party evaluators with the LPA/LPD methodology
- Applying the metric for all new construction and larger renovation and replacement projects
- Promoting advanced technologies through program guidelines or bonus incentives
- Utilizing fully-vetted deemed operating hours for space types for smaller projects and field gathered project specific operating hours for larger projects

Commissioning Programs

Commissioning (Cx) is the systematic process of evaluating, testing, and documenting the equipment and systems within a facility to ensure that they meet the defined performance objectives and criteria and operate in an integrated and optimized manner. Retro-commissioning (RCx) is the process of commissioning existing systems that were not properly commissioned during construction or are no longer operating optimally and need to be brought back to their designed operating specifications. Proper commissioning of facility equipment and systems not only leads to energy efficiency and savings, but can also improve indoor air quality, occupant health and comfort, and reduce equipment downtime and maintenance costs.

Recommendations. Program administrators struggle to predict, assign, and evaluate savings for commissioning. In large part, this is because the savings methodologies for installing efficiency measures typically include an assumption that the measure will operate as intended. This leaves little headroom for assigning additional savings for Cx and RCx measures, despite the fact that studies show significant savings from these procedures. Recognizing this issue the project team made the following principal recommendations:

- Determine local standard practice for functional testing, operations and maintenance training, and system balancing in order to establish a baseline.
- For new construction and new systems, commissioning ensures predicted savings more than it creates additional savings. Commissioning savings should be integrated with the project implementation savings.
- For projects involving RCx of installed systems, net savings should be determined as follows:
  - Determine measure life/persistence of the particular RCx procedure
  - Log pre- and post-commissioning system usage
  - If existing system was installed without program assistance, claim all measurable savings. In some circumstances, impact evaluators may discount these savings if it is determined that some of the RCx activities would have been performed without incentives due to normal maintenance procedures.
  - If the existing system was installed with program assistance:
    - Determine claimed savings to date
    - Claim savings for any performance gain above installed program practice
    - Claim additional savings for extended measure life beyond program-specified “in service” limits. The service term is typically 5 years before previously program-supported measures can be replaced and receive incentives and harvest savings. The RCx service would reset the term.

Comprehensive Whole-Building Approaches

Whole-building retrofits are characterized by a major energy-performance upgrade with a comprehensive approach, rather than evaluating each individual system separately. This approach recognizes the fact that the components of a building, including insulation, ventilation, air sealing, windows, doors, and control systems are interconnected and interactive. Conventional energy retrofits focus on isolated upgrades and often miss cost-effective opportunities for additional energy savings. Whole-building retrofits, on the other hand, typically involve a comprehensive audit that may be followed by an array of efficiency improvements in building envelope and HVAC, plumbing, and electrical system systems.

Recommendations

- Offer programs on a fuel-neutral basis, calculating economic and environmental effects with an energy source methodology in order to deal with fuel switching fairly.
- Develop prototype simulation models that are then calibrated through pre- and post-monitoring of a representative sample of projects, to be used as the primary way to estimate savings in whole-house single-family retrofit programs.
- Implement quality assurance protocols in order to realize persistent savings.
- Utilize a verification protocol for modeling software that assures ongoing improvement.
- Follow established procedures for auditor training and certification.
- Utilize certified insulation and air sealing contractors and establish a training program.

Summary

Introducing emerging technologies and new program approaches is challenging. Compact fluorescent lamps, electronic ballasts, occupancy sensors, and ground source heat pumps were all introduced as emerging technologies. Program implementers as well as their customers surely recall painful experiences involved in introducing those measures. Poor performance, product failures, customer distrust in efficiency efforts, and poor realization rates were all products of those efforts. Yet valuable lessons were learned that paved the way for successful programs incorporating all these measures.

With these lessons providing guidance, careful planning can result in the support of new technologies in a manner that promotes continuous improvements and increasing market shares. With the knowledge gained in this study, the following recommendations apply to all introductions of new program approaches and technologies:

- Engage both technology and program experts in the planning stages. These are rarely the same individuals.
- Establish a set of goals for technology and measure introduction. If a major goal is to learn from field experience then implementers, evaluators, and regulators should be prepared to accept lower realization rates than achieved by mature programs.
- Implement robust quality control. Inferior products, untrained installers, and inappropriate applications have all plagued emerging technologies, but all can be avoided through proper quality control procedures.
- Incorporate monitoring and verification. Emerging technology programs should not wait for impact evaluation results to assess program progress. The reporting of poor realization rates can kill promising programs. It is much preferable to perform ongoing monitoring and verification and make program adjustments.
- Collaborate. Efficiency programs across the country are faced with the same issues involving the introduction of new measures and programs. Much can be learned through cooperative efforts such as the EM&V Forum.
- Develop deemed savings and algorithms, making sure to verify both with field assessments through monitoring and/or billing analysis.

Through the process described in this paper, the EM&V Forum hopes to establish a robust standard for introducing new technologies and ideas, and anticipates the eventual development of solid markets for the measures covered.

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