Persistence of Energy Savings: What Do We Know and How Can It Be Ensured?

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This paper presents a conceptual framework for analyzing persistence of energy savings, summarizes the limited experience of what we know about persistence, provides guidance for conducting retrospective and prospective persistence studies, and suggests strategies for ensuring persistence. Because this area of research is in its infancy, unequivocal conclusions about persistence would be premature. Accordingly, this paper provides guidance for both conducting research in this area and developing policies and mechanisms to help ensure the persistence of energy savings.

Introduction

The persistence of energy and demand savings is an important issue to many stakeholders: building owners, architects and engineers, utility program managers and evaluators, regulators, utility shareholders, resource planners, forecasters, and researchers. For instance, resource planners need to know if the energy saved through energy efficiency programs will offset generating resources (i.e., is it reliable and durable?), and utility shareholders need to know if financial incentives (based on measured energy savings) received from their utility's investment in energy efficiency measures will continue. The rewarding of financial incentives for utility investment in energy efficiency measures makes it even more imperative to use credible, defensible measure-life data in cost-effectiveness testing, demand-side management (DSM) planning, and program impact evaluation.

In a recent study of research opportunities to improve DSM impact estimates, the persistence of energy savings was noted as probably the single, largest, unanswered question in demand-side management (Misuriello and Hopkins 1991). Until recently, persistence was assumed to be relatively constant, and most analyses of persistence relied on engineering estimates of measure life. For example, most planners assumed that knowing the physical life of an installed measure was sufficient to determine persistence: i.e., first-year savings continued for the life of the measure (e.g., 20 years). Recently, this assumption has been challenged as the issue of persistence has gained more prominence in the evaluation of energy efficiency programs. In fact, the limited empirical research conducted so far (see below) raises questions about the validity of using manufacturer's claims for physical measure lives as a basis for projecting persistence.

Conceptual Framework

Two dimensions of persistence exist: measure persistence and program persistence (Keating 1991). The former focuses on measure lifetime and operation, while the latter emphasizes total and net program energy and peak demand impacts. An assessment of measure persistence would look not only at the number of years the measure was installed, but also at the level of efficiency (was the measure still operating at the same efficiency as it was first installed?); unfortunately, most studies of measure persistence have focused on the first factor (measure life). In contrast, an assessment of program persistence would look at the continuation of energy savings of participants over time (comparing energy savings in the nth year with savings in the first year), and not at the duration of the program (which is an important issue but not addressed in the issue of persistence). In addition to gross savings, net savings are examined in program persistence: are the savings directly attributable to the program?

The two dimensions of persistence are interrelated in that program persistence includes measure persistence as well as other factors. Key factors affecting the different dimensions of persistence are noted in Table 1 (based on Misuriello and Hopkins 1991).

Both technology and behavior affect persistence, they interact often, and they are difficult to separate, particularly behaviorally-dependent measures, such as cleaning of refrigerator condenser coils and the resetting of HVAC time clocks to accommodate occasional, unplanned occupancies (Keating 1991). Also, for both dimensions of persistence, it is important to compare the persistence of energy efficiency measures and programs with a comparison group (e.g., the performance of conventional

Table 1. Factors Influencing the Persistence of Energy Savings

Measure Persistence	Program Persistence[(a)]
Technical lifetime	Rebound (snap-back, take-back) effects
Measure installation	Surge effect (additional measures added by customer after initial program participation)
Measure performance or efficiency decay	Replacement effect (replacing efficiency measures with less or more efficient measures)
Measure operation (behavior)	Energy use by control group
Measure maintenance, repair, commissioning	
Measure failure	
Measure removal	
Changes in the building stock (renovations, remodels, alterations, additions)	
Occupancy changes (turnover in occupants; changes in occupancy hours and number of occupants)	

(a) Program persistence factors includes measure persistence factors plus those listed below.

measures being replaced, or the behavior of nonparticipants) for evaluating net energy savings.

Measure Persistence

Studies of measure persistence typically focus on measure lifetime. Traditionally, the technical lifetime of measures is used in deriving estimates of actual measure lifetime. However, measure lifetime can have at least three definitions (Gordon et al. 1988). For example, "test measure life" reflects how long a measure can be operated until it breaks down irreparably if installed, operated, and maintained according to manufacturer's specifications for best performance. This lifetime is often based on manufacturers' test (laboratory) data and ignores the effects of repeated cycling, improper maintenance and other factors noted in Table 1. In contrast, "operational measure life" is how long equipment is expected to save energy under typical field conditions, if the equipment is not removed. The key factors in Table 1 affecting operation life are the quality of installation, occupant use, and level of maintenance. Finally, "effective measure life" considers not only field conditions, but also the impact of obsolescence, building remodeling, renovation, demolition, and occupancy changes (e.g., new tenants move in and remove measures). The estimation of effective measure life has been the focus of several recent studies on persistence (see below) and will likely be a key component of any future persistence studies.

Program Persistence

In addition to the factors affecting measure persistence, several other factors affect program persistence, particularly the "rebound (takeback) effect." Theoretically, the rebound effect occurs when DSM program participation results in a decline in a participant's energy costs (Violette et al. 1991). Participants then increase their thermostat settings or other energy use levels, thereby decreasing gross energy savings. Two other actions affect the persistence of energy savings from a program: program participants can add additional energy efficiency measures after initial participation in the program ("surge effect"), or they can replace efficient equipment with less or more efficient equipment ("replacement effect").

Persistence Studies

Until recently, there have been few published studies on the topic of persistence of energy savings. The study of persistence is in its infancy, because (1) impact evaluation research on DSM programs has only recently begun, (2) few programs of the duration necessary to provide the data required to investigate persistence have been evaluated, and (3) until recently, persistence has not been an important issue. For the future, however, the outlook is somewhat more encouraging. The California Conservation Inventory Group (CCIG) (see below) is conducting a scoping study of measure life and persistence in the residential and commercial sectors (SRC 1992a; SRC 1992b; SRC 1992c). The New York State Energy Office and the Bonneville Power Administration (BPA) are also planning a persistence study in the residential and commercial sectors. Finally, the New England Electric System (NEES) and Northeast Utilities are planning to study measure life in the commercial sector.

The key highlights of persistence research are noted in the following subsections, and are based on articles summarizing persistence research (Keating 1991; SRC 1992a; Cohen et al. 1991; Makati 1992; and Vine 1992).

Measure Persistence

Recent studies in the Pacific Northwest have indicated that reliance on technical or average service lifetime may overestimate DSM measure savings, particularly in the commercial sector. In studies conducted for BPA, investigators found substantial evidence indicating that renovations and remodeling play a significant role in determining long-term savings attributable to commercial DSM programs (Petersen 1990; Hickman and Steele 1991; Skumatz et al. 1991). For example, almost 50% of the buildings (21 of 46) had undergone renovation or remodeling since participating in a commercial incentives program in the previous two years. Removal or deactivation of energy efficiency measures occurred in almost half of all program participant buildings, mostly due to ballast or lamp failures and problems with setback thermostats. Also, certain building types appeared to be more susceptible to frequent remodeling and turnover. An exploration of building permit data, as an index of remodeling, revealed that the business types most frequently applying for building permits were in the office, retail, restaurant, and warehouse sectors. Remodeling projects may result in the removal of energy efficiency equipment.

Studies on measure life in the residential sector have focused on removal rates of particular measures, with most of these studies relying on mail and phone surveys, with some spot checking through on-site visits. Based on site visits, the measures with the highest removal rates in one residential program were low-flow showerheads (18%), compact fluorescent bulbs (14%), and door weatherstrips (10%) (SRC 1992d).

Energy Savings

Most of the persistence studies that have examined energy savings have focused on residential weatherization programs (both low income and standard income) in the Pacific Northwest. Persistence studies have not examined energy demand (kW) savings, only energy use (kWh or therms) savings. Only one study has focused on new construction: the Energy Edge project sponsored by BPA (Diamond et al. 1990). A variety of statistical approaches have been used in studying persistence: calculation of energy savings from raw or weather-normalized consumption data; multivariate regression models; pre-post analyses with comparison groups; and time-series/cross-section regression analyses. Most of the persistence studies have utilized a quasi-experimental design using nonequivalent control groups and weather normalization. The time frame of analysis ranges from two years (Okumo 1990) to eight years (Narum et al. 1992) after the installation of energy efficiency measures. In contrast to the studies on measure persistence, energy-savings studies examine energy savings in large groups of consumers and not at the individual building level.

The limited information on energy savings from persistence studies has shown that DSM program participants have not tended to increase their energy use over time; however, it is also true that the control group of non-participants have tended to lower their energy use over time. As a result, the difference in energy use between the participant and non-participant groups narrows, and "net savings" is reduced. Nevertheless, preliminary results indicate that the potential for the durability of net program savings is very good. With more detailed follow-up of these programs (e.g., on-site visits and case studies) and analysis of subgroups (e.g., tenants versus owners), the reasons for the changes in gross and net energy savings can be examined more carefully.

Structuring a Persistence Study

In an ideal evaluation of persistence, a longitudinal, time-series experimental design is used to track a sample of DSM measures and/or participants. In conducting such a study, one must make sure that program participants are sampled over time to ensure a good mix of participants. Since persistence reflects a dynamic interaction between technology and behavior, focusing only on first-year program participants and early technologies provides only limited (and perhaps misleading) information on program and measure persistence. For example, some weatherization studies have shown that early entries into retrofit programs had the most to gain by their participation; in contrast, the more recent entries into weatherization programs already had some measures in place and were installing a different mix of measures (e.g., more glazing and less insulation) (Brandis and Haeri 1989). In conducting a persistence study, one must also use a control group as a comparison group and baseline for determining net impacts. It is important to know whether efficiency measures are persisting more, or less, when compared to conventional measures (base case equipment), and whether participants in DSM programs behave differently than nonparticipants.

The resources required to administer a persistence study is an important constraint. The two basic data collection techniques (phone/mail survey versus on-site survey) vary in level of expenditures and data quality. In most persistence studies, both techniques are used. Phone and mail surveys represent a well-tested, cost-effective technique for gathering a wide variety of basic data about energy equipment, building, and occupant characteristics (SRC 1992c). Phone and mail surveys offer a number of advantages: (1) they can be conducted inexpensively; (2) they can be as accurate as on-site information for certain kinds of attitudinal and behavioral data; and (3) they can collect a wide range of data. However, this technique suffers from several weaknesses: limited depth of information that can be obtained, and possible bias or inaccuracies occurring from reliance on self-reported data. Accordingly, phone or mail surveys may be most appropriate for examining: (1) certain kinds of measures - e.g., residential measures, inexpensive and low risk measures, and measures with good program tracking data, (2) particular programs - programs that are one-measure oriented (non-customized), (3) presence of equipment - rather than the condition or efficacy, and (4) attitudinal and behavioral questions - e.g., customer's experience and satisfaction with the measure.

In contrast, on-site inspection offers the following advantages: (1) independent (objective) verification of installation and quality of installation; (2) investigation of the appropriateness of the application of the measure; (3) confirmation of proper sizing and operation; (4) identification of the energy systems affected by the measure; (5) inspection of the level of maintenance of a particular measure (e.g., cleanliness); (6) examination of the efficiency level of a measure and performance degradation or failure; and (7) analysis of measure-specific information (model numbers, temperatures, lighting levels, etc.). In sum, more comprehensive and detailed information is collected in on-site surveys. The cost of conducting on-site inspections can be significant, particularly if it is necessary to examine non-participant comparison groups to study selected issues (e.g., the relative degradation in performance of standard versus efficient HVAC systems).

In addition to expense, on-site studies may suffer from the following problems: (1) expertise of on-site auditors may be limited; (2) access to equipment and measures may be limited; (3) physical inspection alone cannot provide information about historical equipment failures and behavioral factors; and (4) possible large non-response biases (attempts at obtaining representative samples will make on-site inspection even more expensive). Accordingly, on-site visits should target "high priority" measures, such as: measures with complicated installations (e.g., HVAC systems and energy-intensive industrial process measures); measures with high savings, high costs, or high risk; measures needing high maintenance; and measures with poor program tracking data.

Finally, regardless of technique, the selection of measures is an important issue in structuring a persistence study, particularly where there are significant resource limitations. First, certain technologies may be more susceptible to reduced persistence than others, for technical and/or behavioral reasons: e.g., screw-in compact fluorescent lamps, shading devices, low-flow showerheads, weather-stripping, caulking and sealing, clock thermostats, air-conditioning filter cleaning, refrigerator coil cleaning, heating and lighting controls, and occupancy/motion sensors (in contrast to wall and ceiling insulation and refrigeration). Second, certain technologies are only cost-effective if the savings persist for a number of years (i.e., long effective measure life is necessary): e.g., storm windows, wall or floor insulation, vent dampers, economizers, and certain boiler retrofits. Third, one must decide whether to examine the persistence of measures that may not be used in future DSM programs, or measures that are about to enter the marketplace. And fourth, persistence studies may want to focus on certain sub-sectors that will be providing most of the energy savings in a particular region (e.g., high-rise offices).

Persistence can be evaluated retrospectively (evaluating what has happened) or prospectively (hypothesizing about what is to occur). Each approach has its own advantages and limitations, as discussed below.

Retrospective Analysis

All of the previous studies have relied on retrospective analysis. In this type of analysis, existing utility conservation program information is used to estimate measure and program persistence. Samples of program participants are selected and interviewed by phone/mail or through on-site visits. Table 2 presents the key factors on effective measure life which need to be collected. This information is then used to estimate effective life.

Table 2. Effective Measure Life Information[a]

Confirmation that the measure was installed
Confirmation that the measure installed is still in place and functioning properly
What the measure replaces (more or less efficient)
Hours of use
Measure maintenance
Reliability of the measure since installation
Customer satisfaction with the measure
If the measure is no longer installed or operable, when and why that condition occurred
If the measure is no longer installed or operable, what, if anything, replaced the measure

(a) Source: SRC (1992b)

The major limitation of retrospective analysis is the quality and detail available from program tracking systems: customer recollection and verification by written records diminish rapidly over time, and reported current and past behavior (e.g., operating hours) may be unreliable. Good program tracking systems that identify the particular measure installed and contain observations made soon after installation is completed are critical for evaluating the quality of installation.

However, some kinds of data can be easily obtained with this type of approach: (1) maintenance contracts and records; (2) test measure life data (by surveying manufacturers and, where available, independent testing laboratories); and (3) building permit data and utility service records (to identify customers that may likely have experienced remodels and renovations). The last type of information may be more useful for identifying types of buildings that can be targeted for sample selection.

Prospective Analysis

While rarely used, prospective analysis of persistence offers an important and viable alternative to retrospective analysis. In prospective analysis, effective measure life (as well as other issues related to persistence) is estimated by following program participants over time (e.g., ten years). The strength of this approach is the better depth, quality, and timeliness of utility program data. For example, information can be obtained shortly after a measure has been installed: e.g., sizing and operation of measure, identification of equipment that has been replaced, hours of use, and level of satisfaction. This approach could also rely on on-site submetering for measuring hours of operation, particularly for measures where usage is highly variable.

Using this approach, one can establish research priorities, conduct research to address specific issues, sample for previously-identified high priority measures, and test and refine measurement protocols. In addition, program tracking databases can be improved to collect information on such key items of interest as customer identification, type and number of measures installed, and type and number of measures replaced. Also, with proper planning, the researcher can choose a sample of buildings that is likely to be remodeled within the next 6 months to 1 year.

With sufficient resources, independent longitudinal testing of failure rates of certain measures can be conducted under ideal conditions and under different load and operations and maintenance (O&M) conditions. These tests would help establish the range of mean time to failure and the sensitivities to key conditions affecting measure life.

The prospective approach tracks measures rather than the specific customers that originally installed the measures. Consequently, one of the key problems with this approach is the attrition of the sample: some new occupants may not be willing to participate in the panel research. However, this problem is somewhat ameliorated by adding new participants to the sample over time to ensure a good mix of participants (see above), so that the sample size can remain relatively constant. In addition to sampling design issues, this approach must address the following issues: the need for a non-participant control group, type of data collection method (telephone survey, mail survey, on-site interview, and metered data), frequency of contact with sample, and whether self-selection causes a bias in estimating effective measure life.

Strategies for Ensuring Persistence

Until recently, persistence has not been an important issue. Although it is expected that the issue of persistence will become one of the key evaluation issues in the near future, a number of strategies are available for ensuring the persistence of energy savings, regardless of research value: (1) measurement and verification plans; (2) program design; (3) operations and maintenance; (4) building commissioning; (5) training and education; (6) technology performance tools; and (7) cooperative research projects. Implementing these strategies should lead to a more lasting resource that the stakeholders mentioned earlier can rely on.

Measurement and Verification Plans

Measurement and verification plans developed by utilities can be an important tool to promote the persistence of energy savings. For example, the Central Maine Power Company has developed a measurement and verification plan that requires measurement of their energy efficiency programs one year after measure installation (for years 1991, 1992, and 1993) and a second measurement in 1997 (Haeri 1991). Accordingly, program persistence will be examined 4-6 years after initiation of the program. In January 1992, the Massachusetts Department of Public Utilities ordered the Cambridge Electric Light Company and the Commonwealth Electric Company to monitor savings annually, until a consistent savings level (within 10%) is maintained for at least two consecutive years in order to establish confidence that significant changes in savings will not occur within the intervals (every three years) proposed by the utilities (Hastie 1992).

Program Design

Programs can be designed to promote the persistence of energy savings by focusing on: (1) measures that are assumed to be long lasting, reliable, and compatible with the needs of the building operations staff; (2) sectors where the length of time until the next remodel is the longest, and where incremental costs are lower, compared to retrofit costs (e.g., new construction, remodeling, and renovations); and (3) operations and maintenance, building commissioning, and training and education (see below). Programs can also be designed to assist and facilitate the study of persistence: e.g., sampling of previously-identified high priority measures, testing and refining measurement protocols, and improving program tracking databases to collect information on key items of interest.

Operations and Maintenance

Improper or neglected maintenance may significantly shorten the life of equipment and may lead to a significant decrease in the performance of the equipment. For instance, the deterioration of savings from heating system control retrofits in steam-heated, public housing buildings may have been solely due to inadequate maintenance (Greely et al. 1986). A regular maintenance program, skilled maintenance staff, and training and education of O&M personnel (see below) are needed to ensure the effective operation of a facility's systems and measures. In addition to following maintenance manuals and keeping accurate records of work completed, systems need to be periodically re-tested to measure actual performance, and a standard method of recording complaints regarding the operation of systems and measures needs to be developed and maintained. Finally, O&M should be treated as an energy efficiency measure, rather than as a support service for other measures. Discrepancies between predicted and actual performance, and/or analysis of the complaints received, may indicate a requirement to re-commission the system or review the commissioning plan (see below).

Building Commissioning

Building commissioning is a "process for achieving, verifying, and documenting the performance of buildings to meet the operational needs of the building within the capabilities of the design and to meet the design documentation and the owner's functional criteria" (Jones 1991). This process extends through all phases of a project (usually for a large commercial/industrial building), from concept to occupancy. The commissioning process is a team effort, involving the commissioning authority (the person or organization that plans and carries out the overall commissioning process), the owner, the designer, the building contractors, and the O&M staff. The ultimate goal of building commissioning is that the building operates efficiently, according to its design intent, and maintains occupant comfort. In addition to verifying equipment performance and ensuring savings from energy efficiency measures, building commissioning can be used to identify other energy efficiency opportunities and to evaluate the true cost of energy efficiency measures.

Commissioning offers many advantages to the parties involved in the project (Table 3). Based on work that has been conducted on commissioning in Canada and England, the additional cost of commissioning mechanical systems generally runs from 1-4% of the total cost of the HVAC contract for the project, and these additional costs are usually recovered in a reasonably short period of time from the operating savings and benefits mentioned in Table 3 (Jones 1991).

Table 3. Advantages of Building Commissioning

- Building operates as designed.
- Reduced lifecycle costs (longer equipment life and lower construction and O&M costs).
- Building is tuned to occupants' needs: less occupant complaints, increased employee productivity, less O&M
- Improved practical knowledge for designers, owners, and developers.
- Reduced call backs for contractors.
- Better training of operating staff.
- Advances energy efficiency technologies.
- Ensures persistence of savings.

Building commissioning typically covers installation and start-up. However, during the life of the building, it is likely that tenants will change their occupancy needs, new tenants will move in, and equipment will wear out and be replaced. Thus, "re-commissioning" is needed to periodically ensure that the systems and equipment are operating correctly and the building is functioning in an efficient manner. Jones (1991) suggests that this re-commissioning process may occur every 2-5 years, or other reasonable period depending on the changes that take place with the building and occupants. Most likely, the frequency of re-commissioning will be site specific.

Unfortunately, commissioning (referring to both commissioning and re-commissioning) has been a neglected element in the building process, primarily due to owners and developers wanting to keep first costs down. As buildings and systems have become more complex over time and as the persistence of energy savings becomes more important, the need for commissioning has become increasingly important. Accordingly, commissioning should become an integral part of the design and construction process (e.g., by documenting performance targets), helping to ensure that buildings operate and function as originally designed.

Progress in building commissioning is being made. BPA, the National Institute of Standards and Technology, and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers have recently published guidelines on building commissioning (ASHRAE 1989; Jones 1991; Kao 1990). The guidelines provide procedures and methods for documenting and verifying the performance of measures and systems so that they operate in conformity with the design intent. The guidelines are intended for use by all members of the commissioning team. A few utilities are also active in this area. For example, Pacific/Utah Power plans to commission buildings that exceed 12,000 square feet. Commissioning is limited to funded energy efficiency measures and to efficiency measures that have the potential for failure. The utility pays the administrative cost of commissioning as part of its program delivery costs. To date, approximate commissioning costs range from a minimum of $10,000 up to $25,000 per building.

Aside from some of the figures mentioned above, evidence on the real costs and savings from commissioning is lacking. Moreover, different levels of commissioning will result in different costs: for example, checking switches to see what they control is a good example of "low level commissioning" that should not cost too much. Accordingly, the appropriate level of commissioning funds will depend on the type of efficiency investment; information on this relationship should help mitigate the perceived problem of the high costs for conducting commissioning.

Finally, a number of options are available to promote persistence through building commissioning: (1) treat building commissioning as an individual energy efficiency measure; (2) establish maintenance contracts in which vulnerable technologies are targeted for annual follow-up; (3) create an O&M program that regularly maintains systems and equipment (see above); (4) establish performance contracts in which third-parties are responsible for installing and maintaining energy efficiency measures; (5) integrate building monitoring (especially, short-term monitoring) with commissioning; (6) integrate building energy management control systems with commissioning; (7) provide for commissioning in all project-related contracts (design, construction, and operation); (8) create a commission contingency fund (similar to a construction contingency fund) to help fund the testing of building systems and make corrections; (9) establish a commissioning team and plan; and (10) distribute energy efficiency measure payments over time to ensure that the measures are working properly and saving energy (in contrast to providing all funds up-front).

Training and Education

A diverse group of people need to be informed about the critical importance of the persistence of energy savings and, in particular, to be educated and trained about O&M and commissioning: design professionals, construction contractors, building owners, building operators, facility managers, maintenance workers, utility managers, lenders, and state and federal agencies. Training and education is an on-going activity: because occupants and staff experience turnover, building operations change, and O&M is often neglected, there is a need for written documentation, hands-on training, and follow-up training.

Technology Performance Tools

New and/or improved technologies are needed for measuring persistence. A recent report identified research and development opportunities that could improve capabilities to determine the energy use and demand reductions achieved through DSM programs and measures (Misuriello and Hopkins 1991). Table 4 identifies these recommendations, most of which are applicable to the study of persistence. Because of the magnitude of the effort, coordinated and cooperative research is needed, as illustrated below.

Cooperative Research Projects

As noted above, significant resources are needed for examining persistence over time. However, these budgetary limitations represent an unexpected and exciting opportunity for the research community: the creation of cooperative projects among utilities and other energy organizations in a specific region or state, or participation in a national program on persistence. For example, the California Conservation Inventory Group (CCIG) is conducting a statewide study on the persistence of energy savings. The members of the CCIG include the California Energy Commission, the California Public Utility Commission, each of the State's major electrical and gas utilities, the Natural Resources Defense Council, Lawrence Berkeley Laboratory, and the California Institute for Energy Efficiency. The purpose of CCIG is to collect and analyze statewide data on the potential to reduce energy use through efficiency improvements. Recognizing that persistence is a statewide problem, funds from the utilities are being used to address this critical issue. The research project will: (1) identify current research in the area of effective measure life and other persistence issues; (2) evaluate the feasibility of utilizing existing utility conservation program information to estimate effective conservation measure life; and (3) develop a panel group evaluation design to follow a group of current program participants over a number of years.

Conclusions

This paper presented a conceptual framework for analyzing persistence of energy savings, summarized the limited experience of what we know about persistence, provided guidance for conducting retrospective and prospective persistence studies, and suggested strategies for ensuring persistence. The study of persistence is in its infancy. As more research is conducted in this area and as the issue itself becomes more salient to key stakeholders, information on persistence will become more available and widespread, giving us a more complete understanding of the durability and reliability of energy efficiency.

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Table 4. R&D Recommendations for Improving the Analysis of Persistence[a]

Priority 1 Opportunities
Fill Critical Steps to Meet Basic Evaluation Requirements

Statewide DSM persistence study
Impact methods using whole-building data
Short-term measurement techniques
Integration of statistical, engineering, and behavioral models
Value engineering study to reduce monitoring costs
Specialty "test kits" for DSM field measurement
Field test methods for HVAC measures
Methods to evaluate low-impact measures
Methods to evaluate low-frequency measures

Priority 2 Opportunities
New or Advanced Methods to Replace Less Effective Ones

Guidelines to calibrate simulation models with measured data
Literature guide to experimental design
Statewide baseline performance data compilation
Reduce multicollinearity through advanced sampling techniques
Expert system applications for field monitoring projects
Site measurement plan "recipe book"
Intra-building sampling techniques

Priority 3 Opportunities
Enhancements to Existing Methods

Protocols for data collection project planning
Improvements for DSM administrative tracking systems
Feasibility study on self-metering appliances
Resolve issues with interactive and secondary effects

(a) Source: Misuriello and Hopkins (1991)

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