The Persistence of Feedback-Induced Energy Savings

Advanced metering devices and new feedback programs and technologies are opening up a wide range of new opportunities to make energy consumption more visible to residential consumers and to engage individuals and households in more thoughtful energy use practices. Data from several recent studies suggest that feedback-induced energy savings can be significant (Darby 2006, EPRI 2009) ranging from 4 to 12 percent on average depending on the technologies employed, the characteristics of the program, and other relevant factors (Ehrhardt-Martinez et al. 2010). However few studies have considered the persistence of feedback-induced energy savings. This paper will assess the persistence of energy savings in three ways: 1) by assessing the relationship between study duration and energy savings across studies, 2) by assessing the persistence of energy savings as reported by a significant subset of the larger sample of primary studies, and 3) by assessing the persistence of energy savings associated with the seven longest feedback studies While the first approach suggests that feedback-related energy savings are smaller for longer studies, the second and third approaches suggests that savings are persistent over time. The paper discusses these seemingly paradoxical results and the insights gained by a further assessment of evidence.

The Persistence of Feedback-Induced Energy Savings

A. Overview of Feedback and Energy Savings
    a. The Invisibility of Energy
    b. The Mechanisms and Types of Feedback and Associated Energy Savings
    c. Important Program Design Elements

B. The Persistence of Savings
    a. Behavior Type and Persistence
        Everyday Practices, stocktaking, investments
    b. A Comparison of Study Duration and Energy Savings
        Comparison and comparison disaggregated by study size
    c. A Qualitative Evaluation of 28 Studies
    d. A Qualitative Evaluation of Nine Longer-Term Studies
        Map these out based on the type of feedback and the use of program design elements
    e. Persistence of Savings versus Persistence of Use

C. Conclusions and Need for Further Research
    a. When are behaviors persistent and when do they require persistent feedback?
    b. When are rewards and incentives useful and when are they counterproductive?
    c. How do monetary versus nonmonetary sources of motivation shape the degree of persistence?
    d. How frequent does the feedback need to be and does this vary depending on the type of behavior that is targeted?
    e. How much do "tips" matter and how tailored do the messages need to be?

The Persistence of Feedback-Induced Energy Savings[1]

A. Executive Summary or Abstract?

B. Overview of Feedback and Energy Savings

The potential energy savings from feedback initiatives are substantial and cost-effective. In a recent meta-review of feedback programs, researchers found that households that received feedback consumed anywhere from 4 to 12 percent less electricity on average (depending on the type of feedback employed) than households assigned to control groups (Ehrhardt-Martinez et al. 2010). Similar results have been documented by other researchers (Darby 2006). Notably, some of the more successful feedback initiatives have reported average household savings in excess of 20 percent. When used to assess national-level savings opportunities, conservative estimates suggest that cost-effective residential sector feedback programs could generate electricity savings of more than 6 percent of total residential electricity consumption (Ehrhardt-Martinez et al. 2010). Such programs would result in the equivalent of 100 billion kilowatt-hours of electricity savings per year by 2030.

Much of the renewed interest in feedback stems from the national effort to create a more modern and technologically sophisticated electricity grid, commonly known as the Smart Grid. One of the unique attributes of the Smart Grid involves the installation of Smart Meters in households and business around the country. These new meters provide the means for two way communications between households (or businesses) and utilities, giving utilities a unique opportunity to provide customers with real-time, detailed information about energy consumption practices and patterns as well as to provide targeted recommendations about how to reduce energy waste. Evidence from some preliminary qualitative research suggests that residential consumers are curious and excited by the potential benefits of the Smart Grid and the ways that Smart Grid technologies may help them to reduce their energy consumption.

Importantly, however, the realization of the potential feedback-related energy savings (especially those that require utility investment in real-time feedback displays) depends heavily on the answer to an important question: Do feedback-induced energy savings persist over time? This purpose of this report is to explore the evidence concerning the persistence

[1] This report draws heavily from the author's earlier report entitled: "Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity Saving Opportunities." 2010. By Karen Ehrhardt-Martinez, Kat Donnelly, and John A. "Skip" Laitner. The report is also based on further analysis performed in preparation of a presentation on the topic for the 2010 Behavior, Energy and Climate Change (BECC) Conference entitled: "The Persistence of Feedback-Induced Energy Savings in the Residential Sector: Evidence from a Meta-Review." (November 2010, Sacramento, CA)

of feedback-induced energy savings and to begin to identify the factors that shape the persistence of energy savings.

What is Feedback and How does It Work?

Feedback describes the situation when output information associated with an event or action in the past will influence an occurrence or performance of the same event or action in the present or future. In the case of energy consumption, feedback provides energy consumers with information about their energy use after they have consumed some amount of energy with the expectation that this information will change consumers' energy use practices in response to the information.

Generally, the use of feedback initiatives and other types of consequence strategies is based on the notion that both positive and negative consequences have the power to shape individual behavior. Attaching positive consequences to energy-wise behaviors makes those behaviors more attractive to consumers, while attaching negative consequences can make unsound behaviors much less desirable (Abrahamse et al. 2005). According to Abrahamse et al., "giving households feedback about their energy savings may encourage them to (further) reduce energy use, because their level of self-sufficiency (i.e., perceived possibilities to conserve energy) has increased."

Feedback also serves to make energy more visible to people. Today's household energy resources are in many ways *invisible* to residential energy consumers; they can't be seen. This makes energy management and conservation practices both difficult and unusual. Compared to the historical use of wood and coal, the more modern reliance on electricity and natural gas serves to distance consumers from the energy resources that they consume, removing the tangible evidence of our society's growing demand for energy resources. While consumer demand for energy resources continues to grow so as to meet a growing variety of energy end uses such as heating (often for larger houses), cooling (increased use of air conditioning), lighting, refrigeration, food preparation, communications, and entertainment – this demand is increasingly fueled by energy sources that flow seamlessly and silently into our homes. For most people, the only measure of their energy consumption is the bill that they receive up to 45 days after consumption. The bill is a rudimentary form of feedback, however it is generally considered to be inadequate for managing energy resources. Although monthly bills typically report the number of kilowatt-hours (kWh) of electricity consumed (or therms of natural gas) as well as the costs of those resources, they don't indicate which end-uses are demanding the most energy, how energy intensive or energy-efficient existing appliances and structures might be, and how changes in choices and behaviors can either enhance or offset energy demands associated with changing weather patterns, new appliances, and other electronic equipment.

The paradox of increased consumption and decreased visibility has resulted in an energy system that is at least partially dysfunctional. This dysfunctionality has been recognized for many years as exemplified by the following illustration written by Kempton and Montgomery (1982) more than a quarter century ago:

> [Imagine a grocery] *store without prices on individual items, which presented only one total bill at the cash register. In such a store, the shopper would have to estimate item price by weight or packaging, by experimenting with different purchasing patterns, or by using consumer bulletins based on average purchases*.

The invisibility of modern energy resources and the inability for people to gauge the impact of their everyday energy practices diminishes people's ability to evaluate and manage their energy consumption practices and also diminishes their sense of self-efficacy (their belief that they can do something that makes a difference). In this sense, feedback provides the means by which people are empowered to become more informed consumers and to recognize their ability to use that information in ways that lessen their impact.

At the community level, the invisibility of energy also serves to impede the establishment of social norms concerning "appropriate" levels of energy consumption. Making community-level data visible provides a basis for comparison and allows people to effectively assess their need to change their energy consumption practices. One effective approach is to provide data concerning the average energy consumption practices in the community along with information concerning the level of energy resource consumption of the most efficient households. By providing a social frame of reference, individuals and households find it easier to determine whether their patterns of energy consumption are excessive or moderate and whether some type of intervention is warranted. In short, feedback works by making household energy consumption visible which serves to empower people to become more active in the management of their energy resources. The effectiveness of feedback can be enhanced by also making community-level energy consumption norms apparent. Households can then use these norms as a guide for evaluating their own consumption levels and changing their practices accordingly.

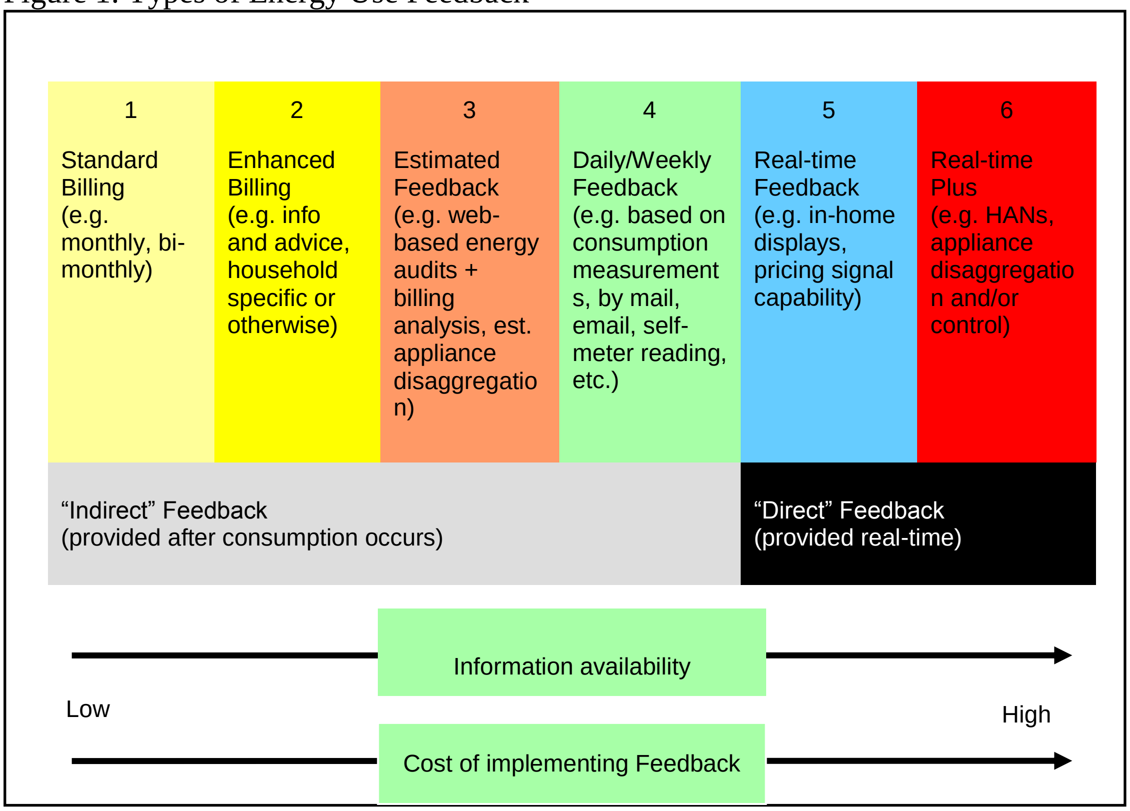
What are the Different Types of Feedback and How Much Energy does Each Type of Feedback Save?

Most research on energy-related feedback recognizes the importance of distinguishing between *indirect* and *direct* forms of feedback (Ehrhardt-Martinez et al. 2010, Darby 2006, EPRI 2009). Direct feedback consists of energy consumption information that is provided instantaneously (in real time or near real time), while indirect feedback consists of feedback that has been processed in some way before reaching the energy user, normally through a billing mechanism. According to research by Darby (2006), indirect feedback is usually more suitable than direct feedback for demonstrating the effect of changes in space heating, household composition and the impact of investments in efficiency measures or high-consuming appliances. Average, program-level household energy savings from indirect feedback have ranged from 4 to roughly 8.5 percent (Ehrhardt-Martinez 2010), but were also found to vary in response to the quality of the information given to households and the use of contextual measures. On the other hand, Darby (2006) suggests that instantaneous feedback is more suitable for providing information regarding the energy impact of smaller end uses. "An instantaneous, easily accessible display may give the consumer adequate information on different end-uses, by showing the surge in consumption when the kettle is switched on, or the relative significance of a radio, vacuum-cleaner or toaster".

According to Darby (2006), potential savings from motivated participants can be in the range of 10 to 20 percent. A more recent meta-review, found the average household energy savings from direct forms of feedback ranged from 9 to 12 percent (Ehrhardt-Martinez 2010).

A more recent study (EPRI 2009) builds on Darby's distinction between direct and indirect forms of feedback by breaking indirect feedback into four distinct types and direct feedback into two distinct types. The six categories correspond to the amount of information provided as well as the costs associated with providing a particular type of feedback. According to EPRI's classification scheme (also adopted by Ehrhardt-Martinez 2010), the four types of indirect feedback include standard billing, enhanced billing, estimated feedback and daily/weekly feedback. The two types of direct feedback include real-time feedback as well as real-time plus feedback. Not surprisingly standard billing tends to be the least costly to implement but also provides the least amount of information to households. At the other end of the scale, real-time and real-time plus systems provide instantaneous energy use data. Real-time plus systems disaggregate energy data by appliance and even plug load and often work in conjunction with home area networks and automation technologies. These types of systems tend to be more costly but also provide much more detailed data to households, enhancing their understanding of the energy resources that are needed to meet specific end- use demands.

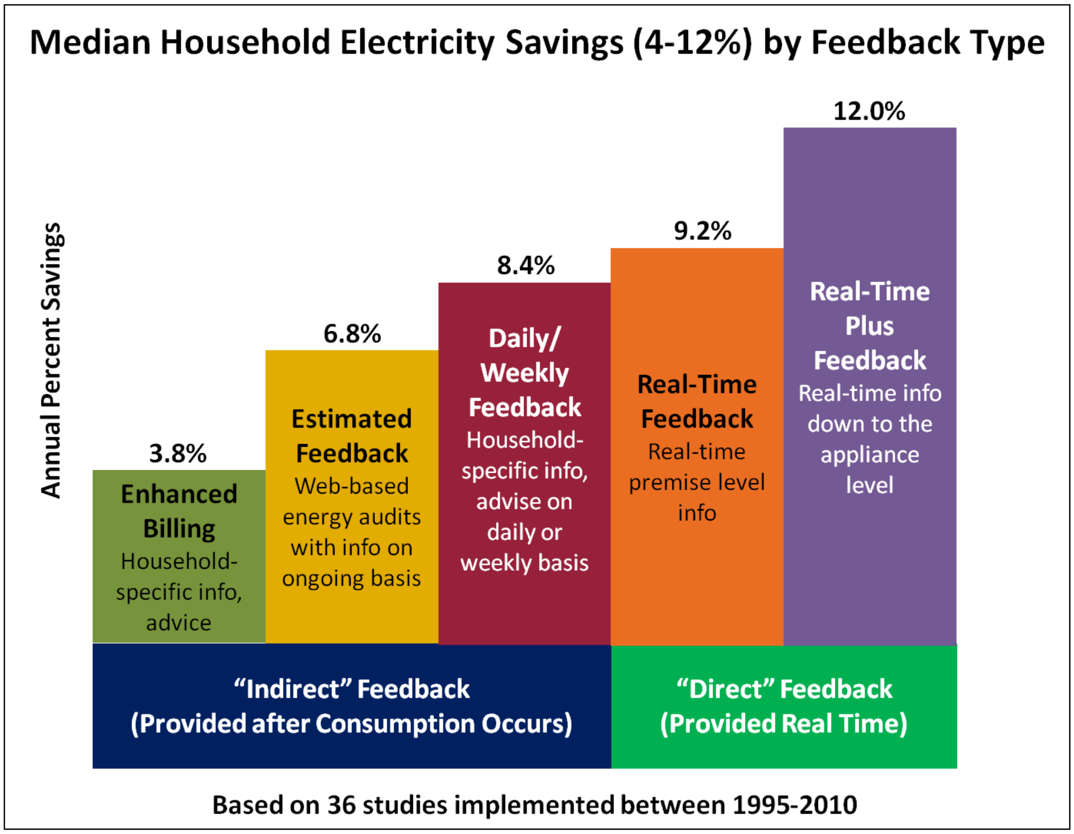
Figure 1: Types of Energy Use Feedback



Source: EPRI 2009.

Ehrhardt-Martinez et al. (2010) used the EPRI classification scheme in a meta-review of 57 different feedback initiatives to determine the energy savings associated with each of these types of feedback. In a preliminary review of the empirical evidence, the meta-review found that there was a clear distinction between the results from feedback studies that had been performed during the "Energy Crisis Era" (1974-1994) and those performed during the "Climate Change Era" (1995-2010). Overall, the findings from the meta-review support earlier work that suggests that direct forms of feedback result in higher levels of energy savings (5-15%) than indirect forms of feedback (0-10%) (Darby 2006). An assessment of the Climate Change Era feedback initiatives found that average, program-wide energy savings for households that received enhanced billing were on the order of 3.8 percent, while estimated feedback and daily/weekly feedback resulted in savings of 6.8 percent and 8.4 percent, respectively. Savings from real-time feedback and real-time plus feedback were 9.2 percent and 12 percent, respectively, as shown in Figure 2.

Figure 2: Energy Savings by Type of Feedback



What are the Important Program Design Elements that Influence Feedback-Induced Energy Savings and Potentially the Persistence of Energy Savings?

As noted by Darby in her more recent report on smart metering and household engagement (2010), feedback alone isn't automatically effective. Instead, it is also important to recognize that feedback-induced energy savings are also shaped by a variety of program design elements such as whether the program is focused on energy conservation or peak load shifting and whether the program integrates efforts that guide occupants toward appropriate action. Such efforts might include goal setting, commitments, competitions, social norms, modeling, and the building of appropriate community support networks. This section briefly summarizes some of the literature on relevant program design elements and discusses their impact on feedback-induced energy savings and the persistence of those savings.

Focus on Demand Response versus Conservation. Among the potential benefits of advanced metering technologies and their associated behavioral responses are their potential contributions to, and enhancement of, utility-based demand-side management (DSM) programs. DSM programs include a wide range of efforts to understand and manage customer demand for energy resources, with the goal of reshaping the quantity or pattern of energy use.

"Demand response" is one type of demand-side management strategy that involves the use of pricing structures, programs, and related technologies and services to encourage consumers to reduce their consumption at critical times in response to market information.[2] In addition to the goal of avoiding blackouts, one of the primary purposes of demand response is to avoid the significantly greater costs associated with meeting the dramatic increases in energy demand that are often associated with high temperatures and increased demand for air conditioning. During times of peak demand, prices of electricity as exchanged on wholesale markets can increase many fold. At such times it may be much less costly for utilities to reduce electricity demand through a variety of load management options than to meet demand through the purchase of additional electricity resources.

Importantly, advanced metering technologies and new feedback devices provide new means of enabling a variety of demand response and other load management options. Advanced metering systems—coupled with advanced control and communications technologies and new electricity rate structures—are being designed to improve the ability of utilities and system operators to monitor and control customer power demands to lessen the costly peaks in consumption.

Unlike demand response programs that focus on shifting electricity use from peak periods to off-peak periods, programs that focus on energy efficiency and conservation are concerned with reducing overall levels of energy consumption – 24 hours per day and 7 days per week. Given these program differences, the meta-review by Ehrhardt-Martinez et al. (2010) sought to document potential differences in feedback-induced, household electricity savings for programs focused on demand response versus programs focused on efficiency and conservation. Their findings indicate that while demand response programs were largely successful in reducing peak-

[2] Market information may take the form of time-variable energy pricing, non-price incentives and notifications of system supply problems.

load demand, the overall energy savings from programs focused on demand response was a mere 3 percent while the overall energy savings from programs focused on energy-efficiency and conservation was more than three time greater (10%).

These findings are important since most utilities are moving in the direction of using smart meters and feedback technologies in an effort to reduce peak loads as opposed to promoting efficiency and conservation practices and overall energy savings. Importantly, these utility-led efforts include plans to introduce new rate structures that would charge households higher rates for energy used during peak periods. The message to consumers is that they don't need to be concerned with how much electricity they use, rather that they should focus their attention on *when* they use electricity. By framing these programs around time-of-use rather than efficiency and conservation, households are less likely to achieve substantial energy savings and be less motivated to maintain overall energy savings. Instead, consumers are much more likely to be focused on simply reducing the electricity costs by avoiding energy use during peak periods.

Aside from the difference in overall energy savings that are generated by demand response programs versus efficiency and conservation programs, the evidence from the recent meta-review by Ehrhardt-Martinez et al. (2010) provides preliminary evidence that the energy savings from both types of feedback programs tends to be persistent. In other words, while median energy savings were lower among those programs focused on peak-load shifting (3.3% versus 9.3% for energy efficiency and conservation programs), many of these initiatives indicated that significant peak-period reductions in energy use (5.5 to 23.3%) were achieved and that these peak-period saving persisted over time. As discussed in greater detail later in this report, energy savings from programs focused on conservation and efficiency also appeared to be persistent across time and in some cases savings actually increased.

Goal Setting and Intention. Several past studies have explored the use of goal-setting in conjunction with feedback as a means of motivating new behaviors (Abrahamse et al. 2007, Abrahamse et al. 2005, McCally and Midden 2002, van Houwelingen and Raaij 1989). Goal-setting is one means by which people can use the information provided through feedback mechanisms to make comparisons – in this case, between the present and a desirable future situation. According to Van Houwelingen and Raaij (1989), "by making satisfaction conditional on a desired level of performance, individuals motivate themselves to persist in their efforts to reach the goal." Other researchers have focused on the size of the goal and its effectiveness in motivating behavior change. Craig and McCann's research (1978) suggests that the goal should be both reachable and believable. However research by Becker (1978) suggests that the goal shouldn't be too easy. His research found that a more challenging goal (20% energy savings) proved to be more effective than an easy goal (2% energy savings). In general, goals are thought to be an effective form of motivation because the achievement of a predetermined goal gives a person a feeling of accomplishment and well-being (Bandura 1986).

According to the findings presented in the meta-review by Ehrhardt-Martinez et al. (2010), goal setting appears to enhance the energy savings from feedback, however relatively simple goals (2% energy savings) tend to be relatively ineffective (See also Locke et al. 1981 on goal setting and task performance). While more research on the power of goal setting is clearly needed, existing evidence suggests that when energy use feedback is combined with goal setting, household were able to reduce their energy consumption by 5 to 17 percent. Lower levels of savings were associated with more modest goals (5%) while higher levels of savings were associated with more challenging goals (10 to 20%). Most of these savings were achieved using daily/weekly feedback (Seligman 1978, Winnet et al 1982, van Houwelingen and Raaij 1989)) or estimated feedback (Abrahamse et al. 2007) although one used real-time feedback for one of the experimental groups (van Houwelilngen and Raaij 1989). The evidence concerning the effect of goal setting on the persistence of savings is mixed and inconclusive. Participants in the study by Van Houwelingen and Raaij (1989) were given a savings goal and were successful in reducing their energy demand by 12.3 percent, however after the in-home displays were removed, the energy savings did not persist. On the other hand, research by Winett et al. (1982) found that a program that combined daily/weekly feedback with modeling and a savings goal of 15 percent was successful in achieving reductions in overall winter electricity use of 15 percent and reductions in winter electricity used for heating of 25 percent. They found that these savings were persistent over time although they only tracked persistence for a few months following the end of the program. A similar experiment performed during summer months found that feedback, modeling and goals setting resulted in overall savings of 15 percent and reductions in summer electricity used for cooling of approximately 34 percent.

Prompts and Alerts
McKenzie Mohr and Focus group research

Commitments and Competitions. Commitments and competitions are both recognized strategies for motivating and sustaining behavioral change. A commitment involves a verbal or written pledge or promise to change one's behavior. Commitments can be private (made to oneself) or public. Private commitments are thought to activate personal norms by creating a moral obligation to achieve a particular goal, while public commitments (made in ways that share one's goals with others) are thought to activate the power of social norms which may either be injunctive or descriptive in changing individual behavior (Abrahamse 2005). [COULD ADD MORE HERE FROM MCKENZIE-MOHR].

Research on commitment strategies suggests that these techniques often produce behavioral changes that are relatively long lasting when compared to techniques that rely on voluntary cooperation (De Young 1993). The potentially long-lasting effects of commitment are further supported by at least two primary studies by De Leon and Fuqua (1995) and Pallack et al. (1980). The first study considers the effect of commitment and feedback on recycling activities and finds that households receiving feedback increased the weight of recyclable paper by 25.4%, while households that made a commitment (and also received feedback) increased the weight of recyclable paper by 40%. In the second study, Pallack et al. (1980) explore the effect of commitment on energy conservation and found that a commitment approach resulted in effects lasting at least 1 year. Finally, in a study of eco-team interventions, Staats et al. (2004) explore the use of eco-team interventions as a means of providing feedback, generating commitment, and creating durable energy savings in the Netherlands. Their 3-year study of 150 households found that the eco-team approach was successful in generating immediate electricity savings of 5 percent and that those savings *increased* over time. Two years later, household that participated in the eco-team project were consuming 8 percent less electricity.

Although there is less energy-related research on the ability of competitions to change behaviors, there have been several studies performed on university campuses that have achieved dramatic, short-term energy savings as a result of competitions between dorms. These competitions (in conjunction with the use of feedback) clearly provided a source of motivation. Ehrhardt-Martinez et al. (2010) cite recent research by Petersen et al. (2007) that used aggregate, real-time feedback as a means of inducing energy savings in 18 dormitories at Oberlin University. Petersen characterizes the study design as involving "a two week long campus-wide "Dormitory energy competition"" in which conservation incentives were provided to students to reduce their energy consumption. During the intervention period, students competed to reduce their resource use. The intervention resulted in average electricity savings of 32%. Their findings suggest that the challenge itself and the social interaction involved in meeting the challenge were likely to have provided the primary source of motivation for the students involved. While competition-induced savings have been shown to result in dramatic energy savings, the longevity of these savings has been called into question.

Social Norms, Modeling and Community Support Networks. A growing number of intervention programs have documented the effectiveness of using social norms as a means of changing "socially significant behaviors". In a recent study on the impact of social norms on energy consumption behavior, Schultz et al. (2007) explore the use of both descriptive and injunctive norms and their unique ability to reshape individual behaviors. The research provided weekly feedback on household energy consumption (via the use of door hangers) to 290 California households. The door hangers told people how much energy they had consumed and also included a descriptive normative message regarding average electricity use, and energy saving tips. The second group also received a smiley face or sad face to communicate approval or disapproval (the injunctive norm). Households assigned to the first treatment group experienced an overall decline in electricity consumption of 5.7%. However in the absence of the injunctive norm, households that were initially consuming below the average experienced a 7.9% increase in consumption. Notably, however, when the injunctive norm was added to the door hanger, low energy consumers maintained their low levels of consumption and the average energy savings increased. A similar study by Nolan et al. (2008) found that normative messaging was more effective than three alternative messages that emphasized non-normative messages including the environmental, social, and economic benefits of saving energy. Overall, the normative messaging was shown to achieve energy savings of 10%. Results from the meta-review of residential feedback studies showed that feedback-induced energy savings from programs that integrated a social normative approach reduced energy consumption by 2 to 10 percent on average (Ehrhardt-Martinez et al. 2010).

Evidence from a recent study of energy savings from OPower's enhanced billing program (Ayers 2009) suggests that the use of social norms in conjunction with continuous monthly feedback successfully generated persistent energy savings. The study reviewed the findings of two separate programs that distributed OPower's Home Energy Reports. The first was a 12 month intervention in which 35,000 households in the Sacramento Municipal Utility District where mailed oPower's Home Energy Reports – a form of enhanced billing. The second program involved a similar number of households in the Puget Sound Energy program. Energy savings were relatively modest ranging from an average of 1.1 percent in the Puget Sound program to

2.35 percent in the SMUD program. Notably, however, participation levels were very high in both programs and the savings were found to be persistent over the course of the studies.

Modeling may also enhance the effectiveness of feedback. As explained by Bandura's Social Learning Theory (1977), people often learn new behaviors through observation of other people, through vicarious experiences, and through imitation. Modeling allows people to see examples of ideas in practice, offers social proof that the behaviors will have positive results, and suggests that other people are engaging in these practices. Modeling is often performed through mass media channels including television, movies and the internet. In 1982, Winett et al. studied the effects of modeling a variety of energy-saving measures via cable TV on the energy consumption of middle-class homeowners. Energy consumption was reduced by 10 percent in the experimental group, however these savings were not maintained one year later.

Finally, more recent research on social interaction, social practices, social networks and community support suggest that group dynamics and community support often play an important role in reshaping individual behaviors through the provision of social support and encouragement, community engagement, discourse, modeling, knowledge diffusion, and social pressure. According to Lewin's change theory, the development of new and *long-lasting* patterns of behavior requires the "unfreezing" of existing patterns of behaviors through the discursive elaboration of new and preferable alternatives in a group setting. These ideas are consistent with the work of Anthony Giddens who argues that individual behavior is given coherency and meaning through conformity to inconspicuous social structure.

The importance of group dynamics, social interaction and community support are effectively illustrated in a recent study entitled "Promoting Durable Change in Household Waste and Energy Use Behavior" (Nye and Burgess 2008). Their research used qualitative research methods to assess the most important mechanisms for behavioral change toward less energy intensive practices. The results indicate that group dynamics – including social support, social pressure, and the diffusion of new, green knowledge through team members and local contexts – was a central factor in achieving energy savings of 7 percent (Nye and Hargreaves 2010). While participants indicated that feedback was important in developing an awareness of waste and a sense of competence and control, group dynamics were important in the sharing and processing of that information and finding suitable ways to integrate solutions into new ways of doing things. Moreover, by working through local groups, participants were able to address distinct local barriers and formulate ways of overcoming those barriers. Importantly, the research suggests that working within a group setting is likely to result in more durable forms of behavior change and more persistent energy savings.

C. The Persistence of Savings: Evidence from the Field

As interest in feedback-induced energy savings continues to grow, a central question on the minds of policymakers, researchers and residents concerns the durability of resulting energy savings. This section of the paper will use evidence from a variety of field studies to explore the persistence of feedback-induced energy savings and provide some preliminary insights into the factors that distinguish programs that result in persistent savings versus programs whose savings are short-lived.

In general, this section seeks to answer the question: Do feedback-induced energy savings persist over time? Currently there are both skeptics and optimists. The skeptics tend to be concerned that although feedback may result in short-term energy savings, over time the novelty of energy feedback may wear off, and people may fall back into old habits and practices, resulting in a subsequent reversal of past savings. Among the optimists, there are at least three reasons why energy savings might be expected to persist, including evidence that suggests that:

- Feedback could help people to learn the energy consequences of specific behaviors, thereby reducing uncertainty in people's minds about the effectiveness of new behavior patterns and practices and effectively help people to choose lower-energy ways of doing things (a rational choice model),
- Feedback could help people to establish new habits, routines, and personal norms – over time they would no longer need to consciously make decisions about how to use things in ways that waste less energy (planned behavior),
- Feedback could increase people's awareness and sense of self-efficacy (their belief that their actions matter) and result in greater participation in energy conservation behaviors resulting in a shift in how people think of themselves and their social normative expectations (identity and culture shift)
- Feedback combined with injunctive and descriptive norms could help people to evaluate their own energy consumption patterns in new ways that prompt a persistent concern and effort to reduce their consumption practices in line with the average household or social/cultural expectations (theories of social norms).

While the following exploration of the evidence is meant to shed some light on whether feedback-induced energy savings persist over time, it is not meant to provide evidence concerning the specific social or psychological processes by which persistence is achieved or not achieved. However, given the discussion to this point, this exploration of the evidence begins with the hypothesis that feedback-induced energy savings will either be sustained or increase over time.

The remainder of this section begins with by distinguishing between three distinct types of behaviors that could potentially be the source of feedback-induced energy savings in households and then identifies the specific types of behavioral changes that typically result from feedback. The main body of the section then explores the evidence concerning the persistence of feedback-induced energy savings using three discrete approaches: 1) a comparison of study duration and energy savings in 57 feedback studies, 2) a qualitative evaluation of the persistence of energy savings within the 28 studies that specifically document persistence, and 3) a qualitative evaluation of the nine longest-term studies and their findings with regard to persistence. The section concludes with a discussion of the important distinction between the persistence of energy savings and the persistent use of feedback devices.

Behavior Type and Persistence: The Behaviors behind Feedback-Induced Energy Savings.

A wide variety of behaviors can result in energy savings but some types of behaviors may be more likely than others to result in persistent savings. As such, it is important to both recognize the different types of energy saving behaviors, as well as understand which types of behaviors are likely to result from feedback initiatives.

While standard efforts to encourage energy efficiency and conservation in households often begin by mapping out existing energy end-uses and everyday practices as well as the malleability of these practices, the characteristics of feedback programs are somewhat unique in their less prescriptive approach to energy savings. Rather than requiring a discrete focus and advocacy for engagement in a particular energy saving behavior, feedback programs let the consumer decide which actions he or she finds most appealing or most feasible. As such, feedback initiatives themselves can provide valuable insights into the malleability of different types of behaviors while allowing for greater flexibility in how people meet their energy saving goals.

Whether defined by end use or malleability there are hundreds of different types of behaviors that people can choose to engage in to save energy. A useful way to simplify this very long list of behaviors is to categorize them by significant attributes such as the economic costs associated with a particular activity and the frequency with which people need to engage in the behavior. Cost can be an important barrier that will keep many people from engaging in a particular behavior, while the frequency of the action will be an important factor in determining the types of programmatic support that are likely to be most effective. Figure 2 provides a typology of energy behaviors as a function of the frequency of the action taken and the economic cost associated with the undertaking of the action (Laitner et al. 2009). When broken down in this way, three categories of behavior emerge.

The first category of behaviors includes those that are performed infrequently and at a relatively low cost (or at no cost) such as installing compact flourescent lamps (CFLs) and weatherstripping or choosing to live in a smaller house or apartment. These might be thought of as *Energy Stocktaking Behaviors* and *Lifestyle Choices*. The second type of behavior involves energy saving actions that must be performed or repeated frequently. These are generally referred to as *Routine or Habitual Behaviors* but they may also involve some lifestyle choices. Examples include laundry routines and whether we tend to wash our clothes in cold water, use a mechanical dryer, or air dry our clothes and linens. This category of behaviors also includes habits associated with appliance use and lighting and the frequency with which we turn off computers and other devices when not in use. The final type of actions involves infrequent but higher-cost behaviors. These actions are generally referred to as *Consumer Behaviors, Technology Choices* or *Purchasing Decisions* and involve the purchase of more energy-efficient products and appliances (Laitner et al. 2009).

Frequency of Action

	Infrequent	Frequent
Low-cost / No-cost	**Energy Stocktaking Behavior and Lifestyles Choices**	**Routine and Habitual Behaviors**
	Reprogram the thermostat Install weather stripping Replace furnace filter Caulk windows Lower temperature on hot water heater	Wash only full loads of laundry Wash clothes in cold water Air dry laundry Reduce oven use Use window fans instead of AC
Higher Cost / Investment	**Consumer Behaviors and Technology Choices**	
	Purchase new EE Appliances Purchase new insulation Purchase a new EE Furnace Purchase new EE Windows Purchase new EE electronics	

Figure 3. Energy Behaviors as a Function of Frequency and Cost* (Adapted from Laitner et al. 2009)

Providing consumers with feedback on their energy consumption patterns has been shown to have an impact on a variety of different behaviors associated with each of the three categories. The fact that people have multiple means of reducing their energy consumption means that some people/households may be more likely to pursue energy savings through investment decisions in more energy-efficient technologies while others prefer to take stock of their energy consumption patterns to make thoughtful adjustments in everyday practices.

A recent report uses this catagorization scheme and data from 13 primary research studies to assess the types of behaviors that feedback typically elicits (Ehrhardt-Martinez 2011). According to the study, people were most likely to report turning off lights, replacing incandescent bulbs with CFLs, and/or changing their thermostat setting. Among the other frequently reported behaviors were: reducing the use of, or turning off the air conditioner, turning down the temperature on the space heater, reducing the use of the clothes washer, using cold water to wash clothes, and reducing the length/number of showers. Common but less frequently reported behaviors included reducing the use of certain appliances including the clothes dryer, dishwasher and electric oven, and reducing the use of computers and standby settings in all electronics.

The following table (Table 1) illustrates the frequency of different energy saving behaviors as reported in Ehrhardt-Martinez (2011). Caution should be used in interpreting the results since many of these programs provided specific energy saving tips or suggestions as to the actions that households could or should take to save energy and these tips may have influenced both actual and reported behaviors.

Among the many potential types of energy efficiency and conservation behaviors, people were most likely to make changes in a wide variety of everyday practices and engage in some energy stocktaking behaviors. Notably, only a small proportion of people reported having made investments in more energy efficient products and appliances. Interestingly, however, investments in new equipment and appliances appeared more likely within more affluent populations and were generally undertaken in conjunction with a change of residence or a remodel or part of a stylistic (as opposed to functional) upgrade (Lutzenhiser et al. 2003). Longer term studies are needed to assess whether the behavioral effects of feedback are likely to change over time and whether short-term changes in routines and everyday practices may eventually translate into a higher likelihood to invest in new appliances and home retrofits.

Table 1 presents data on five categories of behaviors: lighting and electronics, heating and cooling, appliances, hot water heating and use, and other types of behaviors. Within these five categories specific behaviors are identified and categorized as either pertaining to habits and routines (H/R) or energy stocktaking (ST). This list does not include investment activities because these were not reported among the behaviors that people took in response to the feedback that they received. The Table provides information concerning the relative importance of each of these different behaviors using four different means. The first means is a measure of the overall frequency with which households reported having engaged in the particular behavior. This measure is a categorical measure which combines information from reports that provide quantitative indicators of household engagement and those that simply provide lists of the most frequent behaviors. The second means is an indication of whether the studies found either a significant reduction in a particular behavior or if they found a significant difference between the behaviors of an experimental group and a control group following a defined period of intervention. The third means of measuring behavior change reports the proportion of households that reported engaging in a particular behavior. This measure is generally shown as a range to capture the variation across studies. The final means of measuring behavior change reports the average percent energy savings achieved by changes in a particular behavior.

These finding provide important insights for research on the persistence of feedback-induced energy savings. The results provide strong, albeit preliminary, evidence that most of the energy savings from feedback are generated through changes in everyday practices or stocktaking behaviors and very little comes by means of investments in new, energy-efficient technologies. As such, the persistence of feedback-induced savings are highly dependent on the continued engagement of people in energy-smart practices. The following discussion explores what the historical evidence suggests regarding the persistence of these savings[3].

[3] The following discussion draws heavily from a previous study on this topic (Ehrhardt-Martinez et al. 2010) and a subsequent presentation (Ehrhardt-Martinez 2010) prepared for the 2010 Behavior, Energy and Climate Change Conference.

Table 1: Relative Frequency of Reported Energy-Saving Behaviors

	Behavior Type	Conservation Behaviors	Overall Frequency of HH Reporting this Beh.	Significant Reduction/ Significant Difference	% of HH Reporting this Behavior: Peak Focus	% of HH Reporting this Behavior: Conserv. Focus	Avg Energy Savings for Each Behavior
Lighting, Electronics	H/R	Turned off lights	VH	sr / nsd	48-54%	54-91%	
	ST	Install energy efficient light bulbs	H	sr / sd		59-79%	
	H/R	Used task lighting	L				
	H/R	Reduced Television use	ML			20-25%	
	H/R	Reduced use of Stereo	ML			9-24%	
	H/R	Reduced use of Computer CPU	M			27-39%	
	H/R	Reduced use of Computer Monitor	M			36-48%	
	ST	Reduced use of stand-by settings	M	sr /sd			17.6%
Heating & Cooling	H/R	Turned off AC or reduced use	MH	**sd**	36-41%	52-58%	
	H/R	Turned down electric space heating	MH		53%	42-53%	
	ST	Reduced heating/cooling demand (thermostat)	H	sr /sd **nd**	5-7%	27-74%	
	ST	Reduced the number of hours heating is on	VL				
	ST	Reduce number of rooms heated/cooled	VL				17%*
	H/R	Pulled Window Shades	VL		2-7%		
Appliances	ST	Turned down refrigerator thermostat	L				9-24%
	H/R	Opened refrigerator less often	L				
	H/R	Reduced use of clothes washer	MH	sr / sd	36-66%		
	H/R	Used cold water wash in clothes washer	MH			41-56%	
	H/R	Reduced use of clothes dryer	M	sr / sd	33-66%	22-53%	
	H/R	Reduced temperature on dryer	L			12-16%	
	H/R	Reduced use of electric range	ML			18-28%	
	H/R	Reduced use of electric oven	M			12-43%	
	H/R	Reduced use of microwave oven	VL				

	H/R	Reduced use of dishwasher/only full loads	M	sr / nsd **sd**	36-42%	16-21%	
	H/R	Used cold/short cycle on dishwasher	M			28-37%	
Hot Water Heating	H/R	Reduced hot water demand	ML	sr / nsd		29%	
	ST	Turned down water heater	L				
	H/R	Reduced number or length of showers	MH	sr /sd	81%		
	ST	Turned down electric water heating	ML			18-40%	
Other Behaviors	H/R	Reduced use of Hot tub	M L			6-33%	
	ST	Turned off pool filter	VL		3-5%		
	H/R	Reduced use of ventilation fans	VL				
	H/R	Ironed in batches	VL				
	ST	Turned off pool pump	VL		9-10%		
	H/R	Reduced meat consumption	M L	sr /sd			
	H/R	Reduced food waste	M L	sr /sd			
	H/R	Transport mode shifting	L				

*This number represents the energy savings associated with two behaviors: reducing the number of hours that rooms were heated and (to a lesser degree) by reducing the room temperature.
Source: Ehrhardt-Martinez 2011

KEY for TABLE 1:

VH = very high, **H** = high, **MH** = med. High, **M** = medium, **ML** = medium low, **L** = low, **VL** = very low

sr/nsr = significant (or non-significant) change in a particular behavior over the intervention period,

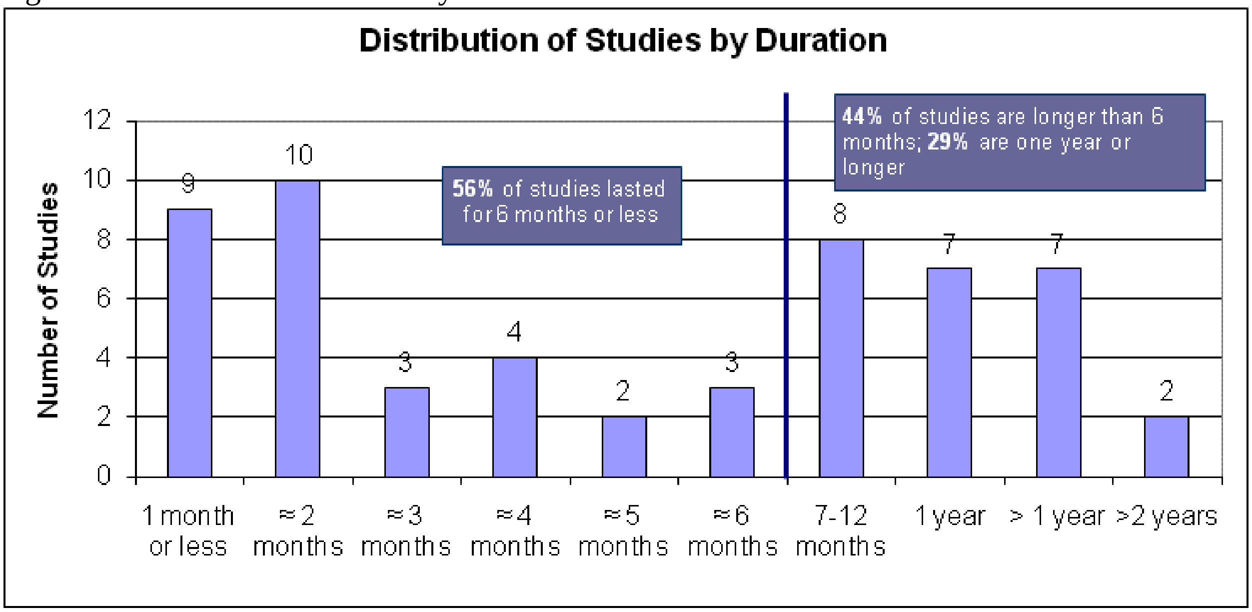
sd/nsd = significant (or non-significant) difference between the experimental group and the control group

A Comparison of Study Duration and Energy Savings.

An initial assessment of the persistence of energy savings over time can be attained by looking across multiple feedback studies to assess the relationship between study duration and the level of energy savings attained. If energy savings are persistent over time, we would expect one of the following outcomes: a) energy savings are greater for studies that are longer in length, or b) energy savings are the same for both longer duration studies and shorter duration studies. Results consistent with the first scenario would indicate that energy savings increase over the course of the feedback initiative with maximum energy savings associated with the longest studies. Results consistent with the second scenario might indicate that feedback-induced energy savings are achieved relatively quickly as a result of feedback and then remain constant over the duration of the initiative.

The results reported here are based on data from the 57 feedback initiatives reviewed in the meta-review mentioned earlier (Ehrhardt-Martinez et al. 2010). The studies that were under review varied notably in their duration from a single day (in one study) to as long as two or three years (in several studies). Most studies lasted between 2 and 12 months with a median study duration of 5 months. Overall, 56% of studies lasted for 6 months or less, 44% of studies were longer than 6 months, and 29% of studies were ongoing for a year or more. Figure 1 shows the distribution of studies by duration.

Figure 4: Distribution of Studies by Duration



Notably, a review of the relationship between study duration and feedback-related energy savings revealed that average energy savings were *higher for shorter studies* (10.1%) than for longer studies (7.7%) as shown in Table XX. These preliminary findings are contrary to both of the hypothesized results specified earlier, and they raise some doubts about the persistence of energy savings over time. Nevertheless, the cause of this unexpected relationship is unclear. The observed pattern could be the result of a non-linear relationship between study duration and energy savings indicating that feedback-induced energy savings are short-lived, or it could be the result of a spurious relationship between a third variable, and measures of study duration and energy savings. Notably, however, the unexpected relationship remains even after controlling for feedback type and the era of the study in bivariate assessments.

Table 2: Energy Savings by Study Duration

Study Duration	Number of Studies #	Number of Studies %	Range of Savings	Average Savings	Median Savings
Shorter (≤ 6 months)	31	56%	0.5 -32.0%	10.1%	9.3%
Longer (> 6 months)	24	44%	-5.5 - 21.0%	7.7%	7.4%

As a further assessment of the relationship between study duration and energy savings, the research sought to determine whether the observed relationship was consistent regardless of the size of the study (i.e. the number of participants). Because shorter studies often involved fewer participants and therefore may not be representative or generalizable, the research assessed whether the relationship held true for both larger and smaller studies (i.e. those with 100 participants or more versus those with less than 100 participants).

As shown in Table XX, an assessment including all three variables indicates that smaller feedback studies tend to result in higher energy savings regardless of the study duration. Importantly, however, the findings also show that longer research studies DO NOT consistently result in smaller levels of savings. As shown in Table XX, *the evidence provided by the larger studies indicates that average household level savings are roughly the same for both short and long studies*. These findings provide contradictory evidence to the data shown in Table X. Instead, the subsequent comparison suggests that energy savings estimates from small studies are likely to be more highly influenced by the length of the study and that the level of energy savings are roughly the same for both short studies and long studies when the comparison is limited to studies of 100 or more participants. Part of this discrepancy might be explained by the fact that the shorter-term studies are predominantly carried out exclusively during the summer months when air conditioning demands dramatically skew energy consumption patterns. The higher levels of energy savings associated with small studies carried out during summer months indicates that greater levels of electricity savings are achievable when air conditioning plays such a large role in shaping overall electricity demand.

Table 3:

	Small (≤100)			Large (>100)			Total		
	Avg. Savings	Median Savings	Number of Studies	Avg. Savings	Median Savings	Number of Studies	Avg. Savings	Median Savings	Number of Studies
DURATION									
Short (≤6 months)	13.3%	13.0%	18	6.6%	6.0%	13	10.1%	9.3%	31
Long (>6 months)	8.7%	7.2%	9	6.7%	6.3%	14	7.7%	7.4%	23
Total	11.6%	12.0%	27	6.6%	6.0%	27	9.1%	8.5%	54

In summary, a preliminary evaluation of the relationship between study length and the average level of energy savings achieved indicates that:

- Among those studies with 100 participants or less, feedback-induced energy savings are greater among studies of a shorter duration (6 months or less) than for longer-term studies (greater than 6 months). Among the smaller studies, median energy savings were 13 percent for shorter-term studies and 7.2 percent for longer-term studies.

- Among those studies with more than 100 participants, feedback-induced energy savings are roughly the same, regardless of study duration. Among the larger studies, median energy savings were 6 percent for shorter studies and 6.3 percent for longer-term studies.
- In general, the findings from larger studies are considered to be more generalizable and therefore additional weight is given to the evidence provided by these studies.

Results of a Qualitative Evaluation of 28 Studies

While the cross-tabs discussed above indicate an inverse relationship between study duration and energy savings in some cases and a lack of a relationship in other cases, a subsequent review of the subset of 28 studies that specifically considers the question of persistence provides evidence that supports the expectations that feedback-induced energy savings are likely to persist over time. As shown in Table 4, 73 percent of the studies that assessed the persistence of energy savings over time found that savings either remained constant or increased. Of the remaining studies, roughly 11 percent found that savings diminished over time, while 16 percent resulted in inconclusive findings.

Table 4: Findings from Feedback Studies that Assessed Persistence

	Across 26 Studies that Assessed Persistence*		Persistent Feedback		Discontinued Feedback	
	Number	Percent	Number	Percent	Number	Percent
Persistent Savings	15	58%	12	60%	3	50%
Increased Savings	4	15%	2	10%	2	33%
Diminished Savings	3	12%	2	10%	1	17%
Unclear/ Other	4	15%	4	20%	0	0%
Total	26	100%	20	100%	6	100%

* Two studies assessed persistence by measuring the persistence of device usage as opposed to the persistence of energy savings.

Notably, however, as suggested by Darby (2006) and reinforced by several studies reviewed here, *persistence of energy savings may rely on the continued provision of feedback*. For example, in a recent study of an enhanced billing program, Alcott (2009) found that there was some decay in the months between reports for those households receiving quarterly reports. However, this decay in energy savings was not found for households receiving more frequent (monthly) reports. Similarly, in a 12-month study of the effects of real-time feedback in the Netherlands, van Houwelingen et al. (1989) found that in-home displays were highly successful in reducing energy consumption (by 12.3%), however when the energy monitors were removed from households following the 12 month intervention period, energy savings did not persist.

In response to these findings, the persistence of feedback-induced energy savings was assessed separately for the subgroup of studies that provided persistent feedback and for the subgroup that discontinued feedback. As shown in Table 4, within the first group (persistent feedback), 70 percent of studies found that energy savings either remained constant or increased over time. Notably, an even higher proportion of studies that discontinued feedback (83%) found constant or increased levels of energy savings. These studies call into question the notion that feedback must be provided indefinitely in order to generate persistent energy savings. More research on this topic is clearly needed to answer a variety of related questions, such as:

- Does the persistence of feedback matter more for certain types of feedback and less for others?
- Is there a time threshold before which persistent feedback is needed to ensure long-lasting energy savings but after which feedback is no longer needed?
- How do other program characteristics and elements shape the need for ongoing feedback?

This review of research findings from the 28 studies that explored the question of persistent savings also provides addition support for the notion that while average household savings may be lower in longer-term studies, the lower rates of savings are more likely to be associated with the ability of these studies to capture seasonal variations in energy end uses rather than a reflection of a decline in the persistence of savings over time. Notably, some of the longest studies that specifically address the question of persistence (Mountain 2006 and 2008, Nielsen 1993, Staats et al. 2004, Staats et al. 2000, Wilhite and Ling 1995, Wilhite et al. 1999) show that energy savings do persist over time.

In summary, a review of the 28 studies that explores the question of persistence indicates that regardless of whether the feedback is discontinued, energy savings tend to persist over time.

- 70 percent of studies that provided persistent feedback saw persistent savings (N=20)
- 83 percent of studies that discontinued feedback saw persistent savings (N=6).
- Shorter-term studies tend to have higher average program savings because they are often conducted during summer months, fail to capture seasonal variations, and maximize energy savings associated with changes in air conditioning use patterns.

Results of a Qualitative Evaluation of Nine Longer-Term Studies.

The final evaluation of the persistence of feedback-induced energy savings narrows the range of studies under consideration to the nine studies with the longest duration. (See Table 5.) The nine studies range in duration from 12 to 36 months and involve three different types of feedback including enhanced billing (4), daily/weekly feedback (1), and aggregate real-time feedback (4). Among the programs that provided *indirect* forms of feedback (#1 through #5 in Table 5), average household energy savings were found to range from 2.1 percent to 12%. Energy savings from programs providing *direct* forms of feedback (studies # 6 through #9 in Table 5) were found to range from 2.7 percent to 18.1 percent. A summary of the characteristics of each study is provided in Table 5.

Table 5: Characteristics of Nine Feedback Studies of the Longest Duration

	Study	Country	Type of Feedback	Duration of Study (months)	Energy Savings	Persistence of Savings
1	Ayers (2009)	USA (California)	Enhanced Billing	12	2.1% to 2.5%	Savings found to increase over 12 month study period while feedback was received.
2	Nielsen (1993)	Denmark	Enhanced Billing	36	7% to 10% for single family homes	Persistent conservation effect.
3	Staats et al. (2004)	Netherlands	Daily/Weekly	36	7.6%	Energy savings *increased* from 4.8% (at 8 months) to 7.6% at 2 yrs. Savings persisted long after intervention ended. Persistence came from supportive social environment.
4	Wilhite and Ling (1995)	Norway	Enhanced Billing	36	7.6% after year 2 and 10% after year 3	Energy savings *increased* from 7.6% at end of yr 2 to 10% at end of yr 3.
5	Wilhite (1997)	Norway	Enhanced Billing	21 + 16 month post evaluation	Savings of 8 to 12% depending on exp. Group	The longer the duration of the intervention and the more information was made available to the household, the more persistent the impact.
6	Mountain (2006)	Canada	Real-time Aggregate (Blue Line Power Cost Monitor)	18	6.5%	Persistent conservation effect. Feedback was not removed.
7	Mountain (2008)	Canada (New Foundland)	Real-time Aggregate (Blue Line Power Cost Monitor)	18	18.1%	Persistent conservation effect. Feedback was not removed.
8	Mountain (2008)	Canada (British Columbia)	Real-time Aggregate (Blue Line Power Cost Monitor)	18	2.7%	Persistent conservation effect. Feedback was not removed.
9	Van Houwelingen (1989)	Netherlands	Real-time Aggregate (The Indicator)	24	12.3%	Energy conservation effect did not persist after energy monitors were removed.

Looking across these nine long-term studies, the persistence of energy savings over time is dramatically clear. Among the seven studies that provided consistent feedback, all were found to have persistent savings. Moreover, two of these seven studies (both using enhanced billing) found that savings *increased* over time.

Only two of the nine long-term studies tested for the persistence of energy savings after the discontinuation of feedback (Staats et al. 2004, Van Houwelingen 1989). Among these studies, energy savings persisted in one (Staats et al. 2004) but not in the other (Van Houwelingen 1989). Notably, these two studies used two different types of feedback and the characteristics of the initiatives also varied dramatically. In the study by Van Houwelingen (1989), researchers used real-time aggregate feedback by means of an in-home energy monitor to provide households with aggregate levels of feedback. The approach was successful in generating average household energy savings of 12.3 percent. However, after the monitors were removed, energy savings were lost. According to Van Houwelingen (1989) "The savings effect was present only when the Indicator or the other feedback systems were present. In the post-experimental period, energy use increased again." This result was found to be consistent with several earlier studies by Hayes and Cone (1981), Kohlenberg et al. (1976), Mauser and Filiatrault (1985), and Palmer et al. (1977). The findings suggest that the Indicator was not successful in helping people to form durable, new routines in their energy end use patterns and indicate that people seem to need a permanent reminder in order to continue to save energy. Also of note, the research found that the in-home monitor seemed to "give rise to discussions among family members" and that after the removal of the monitor, discussions on energy matters seemed to diminish (Van Houwelingen 1989).

Conversely, in the study by Staats et al. (2004), researchers explored the use of daily/weekly feedback via an innovative socially-based approach that used neighborhood groups called EcoTeams to engage people to learn more about their consumption and waste-related behaviors through social interaction. This approach deliberately developed a feedback program that integrated feedback into a social context through the use of regular group meetings. In fact, the approach was specifically designed to address the lack of persistent energy savings that had been documented by Van Houwelingen and others. In designing the program, Staats et al. (2004) hypothesized that by providing feedback in a *supportive social environment* participants would be more likely to change their behaviors in lasting ways. The hypothesis was based on earlier research that noted that contexts of social interaction provide people with the opportunity to discuss the advantages and disadvantages of potential changes before making an explicit decision thereby providing the means for the development and sharing of group standards that play an important role in shaping individual behavior. Moreover, the group setting also enhanced participants' level of problem awareness and provided information concerning the efforts of others which may increase cooperation. Finally, Staats et al.(2004) also note that providing a supportive social environment strongly resembles what are often called commitment techniques in which a pledge or promise is made regarding performance of future behavior. Such techniques have resulted in behavior changes that are relatively long lasting (De Young 1993).

The EcoTeam approach brings together small groups of people to address six sustainability-related themes over an 8 month period. One of the six themes focuses on energy use and conservation. The research monitored the progress of 150 group members over a three year period. As shown in Table 6, this innovative 36-month study found that energy savings of EcoTeam participants were significantly greater than the general population (7.6%) and that their savings actually *increased* over time, well after the program had ended, from 4.8 percent at the end of the first year to 7.6 percent at the end of the third year. The main conclusion from Staats et al. (2004) is that *a supportive social environment can play a large role in determining the durability of energy savings*.

Table 6: Findings from Staats et al. (2004)

	M	% change	M	% change	M	% change
Solid Waste (kg per person per day)	0.216	0.0%	0.153	28.5%	0.145	32.1%
Natural Gas (cubic meters per person per day)	0.299	0.0%	0.237	20.5%	0.248	16.9%
Electricity (Kwh per person per week)	27.20	0.0%	25.90	4.6%	25.10	7.6%
Water (cubic meters per person per week)	0.854	0.0%	0.830	2.8%	0.796	6.7%

In summary, information from some of the longest-term studies indicates that feedback-induced energy savings are persistent over time, and that in some cases savings may be found to increase across time. In particular, among *all* studies in which feedback was provided throughout the course of the research (i.e. not discontinued), energy savings were maintained across all years of the study. However, when feedback was discontinued, the persistence of energy savings becomes less clear. While the existing research is limited, evidence from two of the longest-term studies (one lasting two years and the other three years) indicates that persistence may be a function of program design. In a comparison of these two studies, evidence suggests that the provision of a supportive social environment played an important role in maintaining energy savings after the discontinuation of feedback.

Persistence of Savings versus Persistence of Use

It is important to note that the question of persistence has taken on a new dimension with the rapid expansion of web-based feedback devices and in-home monitors. In particular, the relatively high cost of installing in-home feedback devices has raised questions concerning the persistence of use of these devices. Given that the term "persistence" is now being used to address two different concerns (persistence of energy savings and persistence of device usage), there is a need to address the question of how these two measures are related.

As is well documented earlier in this paper, the evidence from past studies clearly suggests that feedback-induced energy savings do persist over time. In contrast, evidence from studies that measure the persistent use of in-home feedback displays indicates that the frequency of use of these devices tends to decline over time (Hutton et al. 1986, Ueno et al. 2006, MacLellan 2008).

Such findings have raised discussions about the length of time that devices should be provided to households in order to maximize the cost-effectiveness of feedback initiatives. As a result, some researchers have suggested the possibility that feedback monitors could be rented to households or provided temporarily for a particular length of time and then installed in a new set of residences. Given that the current body of knowledge on this topic is limited and that a variety of program characteristics are likely to influence the use of feedback devices and energy savings over time, these suggestions should be approached with much caution. For example, there are reasons to believe that the emerging use of prompts and alerts in conjunction with feedback may change the frequency of device use. Moreover, seasonal variations in certain climates may also play a role in determining the need for people to revisit their displays over the course of the year to understand how different energy end uses (air conditioning and heating, for example) are likely to affect household consumption patterns in different ways.

Finally, it is important to note that the decline in the frequency of use of feedback devices does not appear to be related to the persistence of energy savings. In particular, the installation of real-time in-home displays tends to result in very high frequencies of use early on as individuals use these devices to experiment by testing the impact of turning on and off devices throughout their homes. There is reason to believe that this early experimentation provides users with a base of information that they can subsequently use to inform their everyday energy use practices, reducing their need to consult the monitor as frequently over the course of time.

D. Conclusions and Remaining Questions

Past research clearly shows that residential feedback can significantly reduce household electricity use. In a recent study by Ehrhardt-Martinez et al. that looked across 57 different feedback initiatives, average household energy savings were found to range from 4 to 12 percent depending on the type of feedback. One of the most successful programs achieved average household savings above 20 percent. The actual level of savings achieved by any specific program seems to be a function of two variables: the type of feedback and the program's successful integration of one or more social-scientifically derived mechanisms for motivating, engaging and empowering participants to take action. With regard to the type of feedback, direct forms of feedback tend to generate greater levels of energy savings as compared to indirect forms of feedback. In addition, to the type of feedback, however, feedback programs also seem to benefit from the integration of numerous socially-rooted measures that help people to translate feedback information into action. More specifically, past research suggests that feedback initiatives that integrate motivational components, empowerment measures, and support structures (such as social norms, goal setting, and group-based programs) are likely to achieve greater levels of energy savings than those that do not include these components. Of particular importance for this study, is that some of these same elements have been identified as playing an important role in determining the persistence of behavior change.

This study uses three related approaches to assess the persistence of feedback-induced energy savings over time. All three approaches provide strong support for the notion that feedback-induced energy savings are durable. The first approach looked across 57 different feedback initiatives to consider the relationship between the length of the study and the level of energy savings. Although initial results suggested that longer studies achieved lower levels of energy savings, a closer examination of the evidence found that after controlling for the size of the study, energy savings were roughly the same for both short term studies and longer term studies.

The second approach explored the research results of the subset of feedback-studies that explored the question of persistence. This assessment found that 20 out of 28 studies (73%) found that savings either remained constant or increased. Of the remaining studies, roughly 11 percent found that savings diminished over time, while 16 percent resulted in inconclusive findings.

The third approach considered the findings from the nine feedback studies with the longest duration (12 to 36 months). Evidence from these studies clearly indicates that feedback-induced energy savings are persistent over time, and that in some cases savings may be found to increase across time. In particular, among *all* studies in which feedback was provided throughout the course of the research (i.e. not discontinued), energy savings were maintained across all years of the study. However, in the two cases in which feedback was discontinued, the persistence of energy savings becomes less clear. While the existing research is limited, evidence from two of the longest-term studies (one lasting two years and the other three years) indicates that persistence may be depend heavily on program design when feedback is discontinued. In a comparison of these two studies, evidence suggests that the provision of a supportive social environment played an important role in maintaining energy savings after the discontinuation of feedback.

Because the research on feedback has been relatively limited in scope and number, many research questions remain to be explored. Some of these research questions include:

- When are feedback-induced behaviors persistent and when do they require persistent feedback?
- When are rewards and incentives useful and when are they counterproductive?
- How do monetary versus nonmonetary sources of motivation shape the degree of persistence?
- How frequent does the feedback need to be in order to maintain energy savings and does this vary depending on the type of behavior that is targeted?
- How much do “tips” matter and how tailored do the messages need to be?

In conclusion, the evidence presented in this paper provides strong support for the notion that feedback-induced energy savings are persistent over time. However, important questions remain concerning the role that specific feedback program characteristics play in shaping both the level of energy savings and their persistence over time.

References

Abrahamse, W., L. Steg, C. Vlek, & T. Rothengatter. 2005. “A review of intervention studies aimed at household energy conservation.” *Journal of Environmental Psychology*, 25: 273-291.

Abrahamse, W., L. Steg, C. Vlek, & T. Rothengatter. 2007. "The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviors, and behavioral antecedents." *Journal of Environmental Psychology*, 27: 265-276.

Alcott Hunt. 2009. "Social Norms and Energy Conservation." Available at: http://web.mit.edu/allcott/www/papers.html.

Bandura, Albert. 1986. Social Foundations of Thought and Action: A Social Cognitive Theory, Englewood Cliffs, NJ: Prentice-Hall.

Becker, Lawrence J. 1978. "Joint Effect of Feedback and Goal Setting on Performance: A Field Study of Residential Energy Conservation." Journal of Applied Psychology 63 (4): 428-433.

Craig, C. Samuel and John M. McCann. 1978. "Assessing Communication Effects on Energy Conservation," Journal of Consumer Research, 5 (September), 82- 88.

Darby, S. 2006. "The Effectiveness of Feedback on Energy Consumption: A Review for DEFRA of the Literature on Metering, Billing and Direct Displays." http://www.defra.gov.uk/environment/climatechange/uk/energy/research/pdf/enegyconsump-feedback.pdf. Oxford, UK: Environmental Change Institute, University of Oxford.

De Leon, Iser G. and R. Wayne Fuqua. 1995. "The Effects of Public Commitment and Group Feedback on Curbside Recycling." *Environment and Behavior* 27 (2): 233-250.

De Young, R. 1993. "Changing behaviour and making it stick: the conceptualistion and management of conservation behaviour." Environment and behaviour 25 (4), 485-505

[EPRI] Electric Power Research Institute. 2009. "Residential Electricity Use Feedback: A Research Synthesis and Economic Framework." Report 1016844. Palo Alto, CA: Electric Power Research Institute.

Ehrhardt-Martinez, Karen. 2011. "Changing Habits, Lifestyles and Choices: The Behaviours that Drive Feedback-Induced Energy Savings." Proceedings of the eceee Summer Study.

Ehrhardt-Martinez, Karen; Donnelly, Kat A.; and John A. "Skip" Laitner. 2010. "Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review for Household Electricity Savings." Report e105. Washington, DC: ACEEE.

Hayes, Steven C. and John D. Cone. 1977. "Reducing Residential Electrical Energy Use: Payments, Information, and Feedback." *Journal of Applied Behavior Analysis* 10 (3): 425-435.

Kempton, W. and L. Montgomery. 1982. "Folk Quantification of Energy." *Energy -- The International Journal 7 (10): 817-827.*

Kohlenberg, Robert, Thomas Phillips, and William Proctor. 1976. "A Behavioral Analysis of Peaking in Residential Electrical-Energy Consumers," Journal of Applied Behavior Analysis, 9 (Spring), 13-18.

Laitner, John A. "Skip", Karen Ehrhardt-Martinez, and Vanessa McKinney. 2009. "Examining the Scale of the Behaviour Energy Efficiency Continuum." in ECEEE 2009 Summer Study: Act! Innovate! Deliver! Reducing Energy Demand Sustainably. La Colle sur Loup, France: European Council for an Energy-Efficient Economy.

Locke, Edwin A., Lise M. Saari, Karyll N. Shaw, and Gary P. Latham. 1981. "Goal Setting and Task Performance: 1969-1980," Psychological Bulletin, 90 (1), 125-152.

Lutzenhiser, Loren, Rick Kunkle, James Woods, and Susan Lutzenhiser. 2003. "Conservation Behavior by Residential Consumers during and After the 2000-2001 California Energy Crisis." Appendix A in *Public Interest Energy Strategies Report*. (100-03-012F). California Energy Commission.

Mauser Gary A.and Pierre Filiatrault. 1985. "The Long-Term Effects of the Energy Cost Indicator (ECI)," Report to Consumer and Corporate Affairs, Hull, Quebec, Canada, February 1985.

McCalley, L.T. & C.J.H. Midden. 2002. "Energy Conservations through Product-Integrated Feedback: The Roles of Goal-Setting and Social Orientation." *Journal of Economic Psychology* (23) 589-603.

Mountain, D. 2006. *The Impact of Real-Time Feedback on Residential Electricity Consumption: The Hydro One Pilot*. Mountain Economic Consulting and Associates Inc.: Ontario

Mountain, D. 2008. "Real-Time Feedback and Residential Electricity Consumption: British Columbia and Newfoundland and Labrador Pilots." Ontario, Canada: Mountain Economic Consulting and Associates Inc.

Nielsen, L. 1993. "How to get the birds in the bush into your hand: Results from a Danish research project on electricity savings." *Energy Policy* 21(11): 1133–1144.

Nolan, J. M., P. W. Schultz, R. B. Cialdini, N. J. Goldstein & V. Griskevicius. 2008. *Personality and Social Psychology Bulletin* 34 (7): 913-923.

Nye, Michael and Jacquie Burgess. 2008. "Promoting Durable Change in Household Waste and Energy Use Behaviour." A technical research report completed for the Department for Environment, Food and Rural Affairs.

Nye, Michael and Thomas Hargreaves. 2010. " Exploring the Social Dynamics of Proenvironmental Behavior Change: A Comparative Study of Intervention Processes at Home and Work." *Journal of Industrial Ecology* 14 (1): 137-149.

Pallack, M., D. Cook, and J. Sullivan. 1980. “Commitment and Energy Conservation.” In L. Bickman (ed.) *Applied Social Psychology Annual* 1: 235-253. Beverly Hills, CA: Sage.

Palmer, Michael H., Margaret E. Lloyd, and Kenneth E. Lloyd. 1977. "An Experimental Analysis of Electricity Conservation Procedures," Journal of Applied Behavior Analysis, 10 (Winter), 665-671.

Petersen, J., V. Shunturov, K. Janda, G. Platt & K. Weinberger. 2007. “Dormitory Residents Reduce Electricity Consumption when Exposed to Real-Time Visual Feedback and Incentives.” *International Journal of Sustainability in Higher Education*, 8(1): 16.

Schultz, P. Wesley, Jessica M. Nolan, Robert B. Cialdini, Noah J. Goldstein, and Vladas Griskevicius. 2007. “The Constructive, Destructive, and Reconstructive Power of Social Norms.” *Psychological Science* 18(5): 429-434.

Seligman, C., J. M. Darley & L. J. Becker. 1978. “Behavioral Approaches to Residential Energy Conservation.” *Energy and Buildings* 1(3): 325–337.

Staats, H., E. van Leeuwen, & A. Wit. 2000. “A longitudinal study of informational interventions to save energy in an office building.” *Journal of Applied Behavior Analysis* 33, 1, 101-104.

Staats, H., P. Harland, & H.A.M. Wilke. 2004. “Effecting Durable Change: A Team Approach to Improve Environmental Behavior in the Household.” *Environment and Behavior* 36(3): 341–367.

van Houwelingen, J. T. & W. F. van Raaij. 1989. “The effect of goal setting and daily electronic feedback on in-home energy use.” *Journal of Consumer Research* 16, 98–105.

Wilhite, H. & R. Ling. 1995. “Measured energy savings from a more informative energy bill.” *Energy and Buildings* 22(2): 145–155.

Wilhite, H., A. Hoivik & J. Olsen. 1999. “Advances in the use of consumption feedback information in energy billing: the experiences of a Norwegian energy utility.” In *Proceedings of the ECEEE 1999 Summer Study*, 2: 02. European Council for Energy-Efficient Economy.

Winett, Richard A., Joseph W. Hatcher, T. Richard Fort, Ingrid N. Leckliter, Susan Q. Love, Anne W. Riley, and James F. Fishback. 1982. “The Effects of Videotape Modeling and Daily Feedback on Residential Electricity Conservation, Home Temperature and Humidity, Perceived Comfort, and Clothing Worn: Winter and Summer.” *Journal of Applied Behavior Analysis* 15 (3): 381-402.