A Comparison of Feedback-Induced Behaviors from Monthly Energy Reports, Online Feedback, and In-home Displays

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ABSTRACT

Advanced metering devices and new feedback programs and technologies are opening up a wide range of novel 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 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 behaviors that underlie the energy savings achieved and whether the types of behaviors that result from feedback vary depending on the type of feedback provided. Once people receive information about their energy consumption patterns, a wide variety of actions can be taken to reduce the amount of energy consumed. Such changes may involve: 1) simple changes in routines and habits, 2) infrequent and low-cost energy stocktaking behaviors (i.e. replacing incandescent bulbs with CFLs, weather stripping, etc) , or 3) consumer investments in new energy-efficient appliances, devices and materials. Preliminary evidence from several feedback studies has indicated that most feedback-induced savings result from changes in everyday practices and stocktaking behaviors as opposed to investments (although people who invest tend to save the most energy). This paper considers the range of energy saving behaviors associated with three different types of feedback, explores an alternative classification scheme for understanding feedback-induced energy saving behaviors, documents household preferences for engaging in certain types of energy saving behaviors, and examines whether feedback-induced behaviours vary as a function of feedback type. The three types of feedback programs examined include enhance billing, on-line feedback, and real-time in-home displays.

Introduction

A variety of new feedback initiatives are making energy resources visible to residential consumers throughout the United States (and many other developed countries). These initiatives are opening the door to potential, short-term, energy savings that of 4 to 12 percent and potentially even larger savings in the medium- and long-term (Ehrhardt-Martinez et al. 2010). In so doing, feedback is proving a critical first step in engaging and empowering consumers to thoughtfully manage their energy resources.

While it is clear that feedback programs have resulted in significant reductions in energy use and that more sophisticated forms of feedback offer the promise of even greater levels of savings, few studies have explored what actions people are taking to bring about these reductions and how those actions vary across different types of feedback. This knowledge is essential to assess patterns and trends in consumers' responses to feedback, identify the types of energy-saving behaviors that are not being stimulated by certain types of feedback, develop better feedback programs that engage households in a broader array of energy-saving behaviors, and to

begin to recognize and address the variations that exist between households in how they translate feedback into energy savings.

This paper represents an early attempt to look inside the black box of American households to understand how they are translating energy feedback into energy savings and whether different types of feedback result in different types of energy-saving behaviors. The paper begins with a brief discussion of energy as an invisible resource in modern society and a description of current patterns of household energy consumption. The following section introduces a new categorization scheme that serves to classify different types of energy-saving behaviors into nine distinct categories of action. The third section explores evidence from each of the three types of feedback, describing the types of behaviors that have been induced by each and assessing the amount of variation in the sets of behaviors that correspond to each type of feedback. The paper concludes with a discussion of lessons learned and future research directions.

The Invisibility of Energy Resources and Characteristics of Residential Energy Consumption

Most modern energy resources (electricity and natural gas in particular) are largely invisible to residential energy consumers. This makes energy management and conservation practices both difficult and unusual. When compared to the use of wood and coal, the more modern energy resources provide an increasingly *invisible* means of meeting demands for heating, cooling, lighting, refrigeration, food preparation and entertainment. Today, both natural gas and electricity supplies flow seamlessly and silently into our homes, fueling our furnaces, powering our air conditioners and other equipment, and meeting our demands for a wide variety of energy service demands without any notable trace of their presence.

For most people, the only measure of their energy consumption is the bill that they receive up to 45 days *after* consumption. Unfortunately, the monthly bill is often an inadequate tool for managing energy resources. Monthly bills may report the number of kilowatt-hours (kWh) of electricity consumed and the costs that are incurred, but they don't indicate which end-uses are demanding the most energy, how energy intensive or energy-efficient existing appliances might be, and how changes in our own choices and behaviors can either enhance or offset energy demands associated with changing weather patterns, new appliances, and other electronic equipment. As a result, most people in the United States are unable to understand or manage our energy consumption patterns.

The invisibility of modern energy resources also impedes the establishment of social norms concerning "appropriate" levels of energy consumption. Not only are most energy consumers blind to their own level of energy consumption, but they are also equally unaware of the level of energy resources consumed by others. Without an appropriate frame of reference, individuals and households have a hard time determining whether their patterns of energy consumption are excessive or moderate and whether some type of change is warranted.

The residential sector accounts for a large and growing proportion of US energy demand. U.S., homes are responsible for approximately 21 percent of the nation's energy demand or roughly 22 quads of energy in 2010. Notably, total residential energy demand has grown by roughly 30 percent since 1978 despite a much more rapid growth in the prevalence and use of energy consuming technologies. During the past 30 years, efficiency-oriented, and technology-focused efforts have been the primary driver of the majority of the energy savings that have been

achieved. Nevertheless, many of the recent efficiency gains have been offset by three countervailing trends: an increase in the number of households, larger residences, and an increase in energy service demand associated with changing behaviors and lifestyles.

In addition to these broad trends, there is a large amount of variation in residential energy use across households. This variation is not simply the result of differences in design or technology but is also a function of socio-demographic differences (household size, member's ages, income, ethnicity and race) as well as differences in values, beliefs, norms and habits. In fact, non-physical factors have resulted in variations of as much as 3 to 1 in homes with similar construction (Hackett and Lutzenhiser 1991).

Better energy management offers the possibility of reducing energy consumption through both better technologies and improved energy use practices. For example, according to Gardner and Stern (2008), readily available technologies provide the opportunity to reduce current residential sector energy demand by more than 25 percent:

Upgrading Potential Technology-Based Efficiency Gains:

Action	**Savings**
Intallation of attic insulation	Up to 7%
Purchase of more EE heating, ventilation and cooling systems	Up to 5%
Use of CFLs	Up to 4%
Caulking/weatherstripping	2.5%
Purchase of more EE refrigerator	1.9%
Purchase of more EE water heater	1.5%
Purchase of projection versus plasma TV	1.3%
Purchase of an EE clothes washer	1.1%

However, it is also important to recognize that technology adoption doesn't occur in a social vacuum. Social and behavioral considerations are important because they both shape and constrain technology adoption decisions, technology choices, and the operation and everyday use of technologies. In addition, behavioral approaches can also reduce energy consumption more directly by changing habits, lifestyles and everyday energy use practices.

In summary, substantial amounts of potential energy savings continue to be left unrealized in the residential sector. Feedback provides a promising mechanism for unlocking these savings by both encouraging people to adopt more energy efficient technologies and by helping people to shift their technology use practices and everyday behaviors.

Categories of Energy-Saving Behaviors

While efforts to reduce energy consumption require a well-researched understanding of existing energy end-uses and everyday practices, they also benefit from an understanding of the malleability associated with these actions. By recognizing which behaviors are the most malleable, policymakers and program managers can determine which behaviors and interventions are likely to yield the most energy savings and can target their efforts appropriately. However, feedback initiatives are different from standard efficiency programs in several important ways. 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. One way to simplify this very long list of behaviors is a categorization scheme that assesses the relative economic cost of each behavior along with the frequency with which people need to engage in the behavior (see Laitner et al. 2009). This categorization scheme has been found to be useful because cost often represents an important barrier that inhibits many people from engaging in a particular purchasing behavior, while behaviors that require frequent repetition present potential barriers associated with habit formation. Figure 1 illustrates the typology of energy behaviors as a function of both the frequency of the action and its economic cost. This categorization scheme reveals three distinct categories of energy behaviors: Energy Stocktaking, Routine Behaviors, and Investment Choices.

Figure 1. Energy Behaviors as a Function of Frequency and Cost

Frequency of Action	**Infrequent**	**Frequent**
Low-cost or 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	**Investment Choices and Purchasing Decisions**	
	Purchase new EE Appliances Purchase new insulation Purchase a new EE Furnace Purchase new EE Windows Purchase new EE electronics	

(Adapted from Laitner et al. 2009)

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 *Investment Choices*, or

Purchasing Decisions and involve the purchase of more energy-efficient products and appliances (Laitner et al. 2009).

While the typology presented above is useful for paring down the more than 100 types of energy-saving behaviors that people might choose to engage in, it also masks important distinctions in the types of practices that people must engage in to reduce their energy consumption. For example, while it's useful to know the frequency and cost associated with different types of practices, it is also useful to understand whether people are curtailing their demand for energy by substituting one type of technology for another, by changing appliance settings, through better equipment maintenance, or by remembering to turn things off. As such, this paper suggests a more nuanced categorization scheme that expands on the one presented by Laitner et al. (2009). As presented in Table 1 below, this new categorization scheme maintains the investment choices category but identifies eight distict types of no-cost or low-cost behaviors (rather than the two identified by Laitner et al. 2009) for a total of nine categories of energy-saving behaviors.

Table 1: Categories of Energy-Saving Behaviors

	Behavior Category	**Type**	**Description**
1	Alternative Technology Choice	Prac.	Chosing between 2 technologies to achieve the same goal but w/ different energy implications (ex: using a window fan instead of air conditioning, or a CFL instead of an incandescent light bulb)
2	Conservation Behavior	Prac.	Doing things differently in ways that save energy (for example: washing and drying full loads of laundry, taking shorter showers)
3	Conservation Setting	Prac.	Changing the settings on lights, appliances and electronics (for example: changing the thermostat setting, changing computer settings, reducing refrigerator and hot water heater settings)
4	Enhanced Control	PP	Purchasing and using special equipment that allows for enhanced control (ex: using power strips, timers, & program. thermostats)
5	Investment Decision	Purch.	Purchasing more energy-efficient technologies that cost $200 or more (for example: purchasing attic and wall insulation, a new furnace or AC unit, new kitchen appliances)
6	Low Cost Investment	Purch.	Purchasing relatively inexpensive things (<$200) that don't need to be replaced often with the goal of reducing energy consumption (for example: insulation for a hot water heater, low-flow shower head)
7	Maintenance	PP	Maintaining existing equipment in ways that reduce energy consumption (for example: cleaning furnace filters, cleaning dryer filters, replacing refrigerator seals)
8	Turning Off	Prac.	Turning off appliances, electronics and any energy using device.
9	Unplugging	Prac.	Unplugging appliances, electronics or any energy using device.

These nine categories of behaviors can also be characterized as falling into one of three types of action: purchases, practices, and a middle grouping that often involves both purchases and practices. This third type of behavior is designated in Table 1 with PP indicating that both purchasing decisions and related practices are often involved.

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 nine 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 change

appliance settings, find ways to enhance their control through the use of timers and smart strips, or simply turn things off or unplug them. The following section introduces the three types of feedback that are the focus of this paper, assesses the distribution of reported behaviors across the nine categories of behaviors for each type of feedback, and assesses the relative contribution of each category of behavior to total energy savings.

Preliminary Evidence of Feedback-Induced, Electricity-Saving Behaviors

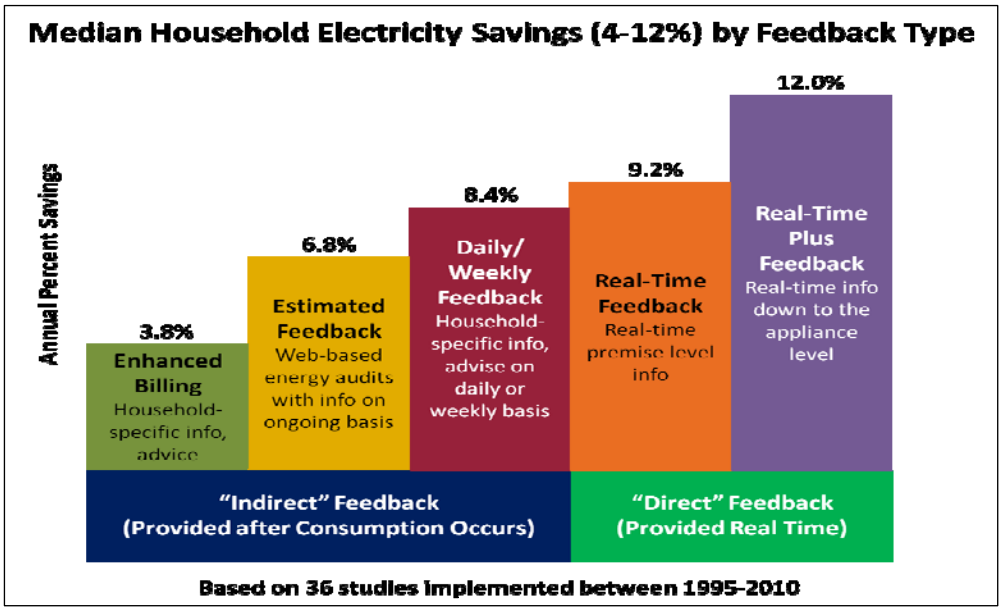
Feedback about energy or electricity consumption can be provided to households in several different ways – from enhanced billing programs to appliance-level real-time feedback that typically relies on in-home displays. In a 2009 report on the topic, EPRI identified and defined the following six distinct types of feedback:

- Standard Billing (indirect) – An energy bill that displays the monthly kilowatt-hour (kWh) of consumption and the unit rate ($/kWh), the corresponding total cost and other billing charges, as well as the total amount due. This form of feedback generally lacks comparative statistics or any detailed information about the temporal aspects of consumption
- Enhanced Billing (indirect) - Provides more detailed information about energy consumption patterns, and often includes comparative statistics – either comparing the most current monthly electricity usage and expenditures together with historical consumption and/or a comparison to other households.
- Estimated Feedback (indirect) – This approach uses statistical techniques to disaggregate the total energy usage based on a customer's household type, appliance information, and billing data. The resulting feedback provides a detailed account of electricity use by major appliances and devices. These most commonly take the form of web-based "home energy audit" tools, offered by a utility to its customers.
- Daily/Weekly Feedback (indirect) – These reports use averaged data and often include consumer self-read studies (in which individuals read their meter and record the energy usage themselves) as well as studies in which individuals are provided with daily or weekly consumption reports from the utility or research entity.
- Real-Time Feedback (direct) – In home energy display devices that provide real-time or near real-time energy consumption and energy cost data at the aggregate household level.
- Real-Time Plus (direct) - In home energy display devices that provide real-time or near real-time energy consumption and energy cost data disaggregated by appliance.

According to a meta-analysis of 57 different feedback initiatives by Ehrhardt-Martinez et al. (2010), certain types of feedback tend to be associated with higher or lower levels of associated electricity savings. As shown in Figure 2, enhanced billing programs were found to achieve 3.8 percent electricity savings, while estimated feedback programs and daily/weekly feedback programs were found to achieve 6.8 and 8.4 percent savings, respectively. Real-time feedback programs were able to achieve higher levels of savings: 9.2 percent for real-time

feedback initiatives and 12 percent for real-time plus programs. These findings are consistent with earlier studies that suggested that more frequent feedback tends to be more effective (Darby 2006, Fischer 2007, Abrahamse 2005).

Figure 2: Feedback Type and Associated Electricity Savings



Source: Ehrhardt-Martinez et al. 2010

While past studies show a clear pattern between the type of feedback and the associated energy savings, there has been little research to determine the actions and decisions that are responsible for generating those savings. In other words, how are people generating the energy savings that are being achieved? This paper seeks to shed some light on this question by looking at the actions associated with three different types of feedback: enhanced billing, monthly on-line feedback, and real-time feedback. The objective is to reveal the types of energy saving behaviors that correspond to each type of feedback and to compare how the sets of behaviors vary (or are consistent) across the three types of feedback. The assessment uses household-level data from three recent feedback initiatives.

Enhanced Billing (Monthly Paper Reports)

Survey data were collected for a total of 500 households participating in a study of one type of enhanced billing feedback program. The enhanced billing program provided households with feedback about their energy consumption on a monthly basis using paper reports that were delivered through the mail. The mailed reports provided recipients with benchmark data and suggestions for reducing their energy consumption. Among the survey questions administered to a subset of households, respondents were asked an open ended question about the actions that they engaged in to reduce their energy consumption. Table 2 shows the distribution of named actions across the 9 categories described above as well as the proportion of households who reported taking these actions. Table 3 shows the ten most frequently reported behaviors. Table 2

shows that just under 50 percent of the actions named by participants (47%) fell in the ”practices” category while roughly the same proportion (45%) fell into the ”purchases” category. When looking across the 9 types of potential actions, however, it is notable that the predominant set of actions identified by respondents were those behaviors associated with major investments – 37% of all actions identified by respondents were associated with costly investments in new technologies. The second largest category of behaviors identified by respondents were conservation behaviors such as washing full loads of laundry and dishes as well as blocking under door drafts. These represented roughly one-fifth of the energy-saving behaviors identified by respondents. Two other types of behaviors represented approximately 10 percent (each) of the behaviors reported by respondents: turning off lights, electronics, and devices; and unplugging devices, lamps, and appliances. Roughly 8 percent of respondents indentified ways of enhancing their control through the use of smart strips and timers; and another 8 percent identified low cost investments such as weatherizing, using window film and water heater blankets. Very few people reported behaviors associated with alternative technologies (i.e. window fans) or conservation settings (i.e. changing refrigerator or computer settings) and nobody specified maintenance-related behaviors such as changing furnace filters.

Columns 4 and 5 in the same table presents data on the actions that people reported to have actually taken. A comparison of action types and measures of the frequency with which households engaged in indentified actions reveals that participants chose to engage in practices rather than purchases to a disproportional degree. For example, while practices represented 47 percent of the range of energy-saving actions identified by household respondents, they represented 81 percent of actions actually taken. And while purchases represented 45 percent of the range of energy-saving actions identified, they represented only 16 percent of actions actually taken. Finally, the combined category of purchases/practices represented only 2 percent of actions taken but roughly 8 percent of actions identified.

Table 2: Distribution of Identified and Actual Actions for Enhanced Billing Feedback

	Identified Actions		Actual Actions		Difference
Type of Action	**#**	**%**	**#**	**%**	
Practice	18	47%	388	82%	+35%
Purchase	17	45%	78	16%	-29%
PP	3	8%	10	2%	-6%
Alternative Tech. Choice (ATC)	1	3%	118	25%	+22%
Conservation Behavior	8	21%	10	2%	-19%
Conservation Settings	1	3%	53	11%	+8%
Enhanced Control	3	8%	10	2%	-6%
Investment	14	37%	63	13%	-24%
Low Cost Investment	3	8%	15	3%	-5%
Maintanence	0	0%	0	0%	0%
Turn Off	4	10%	166	35%	+25%
Unplug	3	10%	41	9%	-1%
TOTAL	38	100%	476	100%	

A comparison of the nine categories of action reveals that there was a disproportionately large number of people engaged in two types of behaviors: alternative technology choices and

turning off devices, lights and electronics. In this case, a large proportion of people reported installing CFLs as well as being more consciensious about turning thinks off when not in use. A surprisingly small proportion of people reported engaging in other conservation behaviors (especially when compared to the findings from other feedback initiatives – see below). While conservation behaviors represented 21 percent of the behaviors mentioned by respondents, they only represented 2 percent of the actions taken. Similarly, while respondents mentioned many investment-related behaviors, a disproportionately small number of respondents actually reported having engaged in these behaviors. In the conservation settings category, only one behavior was identified by respondents (turning back their home's thermostat), however a disproportionately large number of people reported engaging in this particular energy-saving behavior. The use of smart strips, timers, weatherization and other low cost measures were less frequently reported by respondents.

Table 3 shows the 10 most common actions that respondents reported to have engaged in. Half of the top ten actions are practices while four out of ten are purchases (either low cost purchases or more costly investments). Only one of the top ten actions fall into the purchases/practices category which includes maintenance and enhanced control devices such as timers, sensors, and smart strips and – in this case – programmable thermostats.

Table 3: Ten Most Popular Actions for Enhanced Billing Feedback

	Action	Type	Freq	% of HHs
1	Turn off lights	Prac.	132	26.4%
2	Replace incandescents with CFLs	Prac.	118	23.6%
3	Change thermostat setting	Prac.	53	10.6%
4	Unplug devices and electronics	Prac.	41	8.2%
5	Turn off devices	Prac.	34	6.8%
6	New EE appliances (washer, fridge, unknown)	Invest.	12	2.4%
7	Install Insulation (attic, basement, crawl space, garage)	Invest.	10	2.0%
8	Plastic window covering	LCI	10	2.0%
9	New EE Windows	Invest.	9	1.8%
10	Install Programmable Thermostat	PP.	6	1.2%
	Number of HHs taking one or more actions.		**425**	**100%**

On-line Feedback

A total of 4105 households were engaged in a study a monthly online feedback feedback program. Through their online participation, households provided information about the types of behaviors that they were engaging in as part of the program. Participants could chose from just over 100 energy saving actions. Table 4 shows the distribution of potential and actual actions across the 9 categories described above. Table 5 shows the ten most frequently reported behaviors. Table 4 clearly shows that the majority of actions available to participants (65%) fell in the ”practices” rather than ”purchases” category. When looking across the 9 types of potential actions, however, it is notable that roughly 40 percent of potential actions consisted of conservation behaviors, followed by 23 percent in the investment category, 11 percent were alternative technology choices and 8 percent were lost cost investments.

Columns 4 and 5 in the same table presents data on the actions that people reported to have actually taken. A comparison of potential and actual actions reveals that participants chose to engage in practices rather than purchases to a disproportional degree. For example, while practices represented 65 percent of potential actions, they represented 78 percent of actions actually taken. And while purchases represented 31 percent of potential actions, they represented only 10 percent of actual actions taken. Finally, the combined category of purchases/practices represented nearly 12 percent of actions taken but only 4 percent of potential actions. A comparison of the nine categories of action reveals that both large investment decisions and low cost investments are underrepresented while people are disproportionately more likely to turn off electronics, install and use devices that enhance their control over energy-consuming equipment, and engage in conservation behaviors.

Table 4: Distribution of Potential and Actual Actions for On-line Feedback

	Potential Actions		Actual Actions		Difference
Type of Action	**#**	**%**	**#**	**%**	
Practice	66	65%	28,046	78%	+13%
Purchase	31	31%	3,552	10%	-21%
PP	4	4%	4,235	12%	+8%
Alternative Tech. Choice (ATC)	11	11%	4,927	14%	+3%
Conservation Behavior	41	41%	19,352	54%	+13%
Conservation Settings	4	4%	1,126	3%	-1%
Enhanced Control	2	2%	1,351	4%	+2%
Investment	23	23%	2,472	7%	-16%
Low Cost Investment	8	8%	915	3%	-5%
Maintanence	5	5%	1,767	5%	0%
Turn Off	3	3%	2,346	7%	+4%
Unplug	4	4%	1,577	4%	0%
TOTAL	101	100%	35,833	100%	

Table 5: Ten Most Popular Actions for On-line Feedback

	Action	Type	Freq	% of HHs
1	Replace incandescent bulbs with CFLs	PP	2871	70%
2	Use blinds during summer days	Prac.	2704	66%
3	Wash larger loads of dishes	Prac.	2699	66%
4	Turn off computer when not in use	Prac.	1832	45%
5	Turn off coffee maker when not in use	Prac.	1639	40%
6	Use microwave instead of conventional oven	Prac.	1292	31%
7	Raise AC thermostat	Prac.	1183	29%
8	Use a drying rack for clothes (instead of dryer)	Prac.	1177	29%
9	Turn off extra lights	Prac.	1150	28%
10	Use a smart strip to reduce standby electricity use	PP	832	20%

Table 5 shows the 10 most common actions that respondents reported to have engaged in. All but two of the top ten actions are practices while two of the actions fall into the combined practice/purchase category. None of the top ten actions include investment choices.

The actual energy savings across all households be action type is shown in the last column of Table 6. The proportion of electricity saved as a result of changes in energy use practices (68%) far exceeded that of purchase-related behaviors (9%), while savings from the purchase and use of CFLs, smart strips and other devices comprised 22 percent of total electricity savings.

Table 6: Energy Savings by Action Type for On-line Feedback

	Potential Actions		Actual Actions		Electricity Savings
Type of Action	**#**	**%**	**#**	**%**	**%**
Practice	66	65%	28,046	78%	68%
Purchase	31	31%	3,552	10%	9%
PP	4	4%	4,235	12%	22%
Alternative Tech. Choice (ATC)	11	11%	4,927	14%	25.7%
Conservation Behavior	41	41%	19,352	54%	49.9%
Conservation Settings	4	4%	1,126	3%	0.3%
Enhanced Control	2	2%	1,351	4%	3.4%
Investment	23	23%	2,472	7%	8.2%
Low Cost Investment	8	8%	915	3%	1.0%
Maintanence	5	5%	1,767	5%	5.4%
Turn Off	3	3%	2,346	7%	1.5%
Unplug	4	4%	1,577	4%	4.6%
TOTAL	101	100%	35,833	100%	100%

Real-Time Feedback (In-home Displays)

A total of 81 households were engaged in a study of real-time feedback. Participants received feedback through in-home displays that also provided information via the web. In order to participate, households were required to access an online account which they used to set energy saving goals, make commits to certain energy saving actions, and obtain tips and ideas about ways of reducing their consumption. Participants could chose from 122 energy saving actions. Table 7 shows the distribution of potential and actual actions across the 9 categories described above. Table 8 shows the ten most frequently reported behaviors. Table 7 clearly shows that the majority of actions available to participants (59%) fell in the ”practices” rather than ”purchases” category. When looking across the 9 types of potential actions, however, it is notable that the category with the largest selection of potential actions was investments (24%), followed by conservation behaviors (16.5%) and conservation settings (14%). The remainder of the categories captured 6 to 10 percent of the potential actions.

Columns 4 and 5 in the Table 7 present data on the actions that people reported to have actually taken. A comparison of potential and actual actions reveals that participants chose to engage in practices to a disproportional degree. Participants also disproportionally favored

actions that fell in the purchase/practices category. Solutions that relied exclusively on purchases were underrepresented in the actions that people chose to perform. For example, while practices represented 59 percent of potential actions, they represented 71 percent of actions actually taken. And while purchases represented 31 percent of potential actions, they represented only 13 percent of actual actions taken. Finally, the combined category of purchases/practices represented roughly 15 percent of actions taken but only 10 percent of potential actions. A comparison of the nine categories of action reveals that both large investment decisions and low cost investments are underrepresented (as are decisions to unplug things) while people are disproportionately more likely to turn off electronics, use alternative technologies that use less energy, and install and use devices that enhance their control over energy-consuming equipment, maintain appliances.

Table 7: Distribution of Potential and Actual Actions for Real-Time Feedback Users

	Potential Actions		Actual Actions		Difference
Type of Action	**#**	**%**	**#**	**%**	**%**
Practice	72	59%	634	71%	+12%
Purchase	38	31%	119	13%	-18%
PP	12	10%	138	15%	+5%
Alternative Tech. Choice (ATC)	9	7%	99	11%	+4%
Conservation Behavior	20	17%	172	19%	+2%
Conservation Settings	17	14%	138	16%	+2%
Enhanced Control	9	7%	111	12%	+5%
Investment	29	24%	97	11%	-13%
Low Cost Investment	9	7%	22	2%	-5%
Maintanence	12	10%	108	12%	+2%
Turn Off	7	6%	95	11%	+5%
Unplug	9	7%	47	5%	-2%
TOTAL	122	100%	889	100%	

Table 8 (next page) shows the 10 most common actions that respondents reported to have engaged in. Five of the most popular actions involved the purchase and use of devices that enhance household control over electricity consumption or provide alternative technology options. Four of the top ten actions are practices while one of the actions involves the purchase of ENERGY STAR indoor light fixtures.

Comparison Across Three Types of Feedback

The previous sections serve to illustrate the types of actions that households engage in after exposure to different types of feedback. This section looks across the three different types of feedback to assess similarities and differences in the behavioral patterns or action choices that were catelyzed by each type of feedback.

Based on the assessment provided in this paper, households receiving ***all three types of residential-sector feedback are more likely to report changes in household practices*** as opposed to purchases of new energy efficient appliances, electronics, insulation, HVAC systems

Table 8: Ten Most Popular Actions for Real-Time Feedback Users

	Action	Type	Freq	% of HHs
1	Use power strips on home entertainment system	PP	31	38%
2	Use power strips on home computer system	PP	29	36%
3	Reduce wattage in multiple bulb fixtures	PP	26	32%
4	Power off external computer speakers	Prac.	26	32%
5	Clean your dryer lint filter	Prac.	25	31%
6	Use CFLs in indoor fixtures	PP	24	30%
7	Set dryer timer to the minimum time required	Prac.	23	28%
8	Run your dishwasher with a full load	Prac.	22	27%
9	Use lighting controls or timers	PP	19	24%
10	Install ENERGY STAR indoor light fixtures	Purch.	17	21%

or other similar purchases. As shown in Table 9, 78 to 82 percent of the actions taken by households receiving enhanced billing or online feedback were associated with different types of practices while 62 percent of the actions taken by households receiving real-time feedback were associated with energy-related practices. Households receiving enhanced billing and real time feedback were a little more likely to engage in the purchase of energy saving technologies, insulation and other types of behaviors that required cash outlays when compared to those receiving daily/weekly feedback (16%, 13% and 10%, respectively). Households receiving real-time feedback were most likely to report energy-saving maintenance behaviors as well as behaviors that allow for enhanced control such as timers, sensors and smart strips.

Table 9: Difference in Actions Taken by Type of Feedback

	Actions Taken		
Type of Action	Enhance Billing	Online	Real Time
Practice	82%	78%	71%
Purchase	16%	10%	13%
PP	2%	12%	15%
Alternative Tech. Choice (ATC)	25%	14%	11%
Conservation Behavior	2%	54%	19%
Conservation Settings	11%	3%	16%
Enhanced Control	2%	4%	12%
Investment	13%	7%	11%
Low Cost Investment	3%	3%	2%
Maintanence	0%	5%	12%
Turn Off	35%	7%	11%
Unplug	9%	4%	5%
TOTAL	100%	100%	100%

A comparison of actions by category also reveals interesting differences in the feedback-induced behaviors associated with each type of feedback. Of particular note, households that took action in response to online feedback were much more likely to engage in conservation behaviors, while households receiving real time feedback were much more likely to engage in using conservation settings on appliances and electronics, using simple technologies to enhance user control of devices, and performing maintenance related behaviors. Households that took

action in response to enhanced billing were slightly more likely to make investments in energy-saving technologies. Notably, this group was much more likely to turn off or uplug applicances, devices and electronics and much more likely to report using alternative technologies such as CFLs.

Discussion and Conclusions

Once people receive information about their energy consumption patterns, there are a wide variety of actions they can take to reduce the amount of energy they consume. Currently, the relationship between feedback type, household response, and subsequent energy savings remains unclear. The four primary objectives of this paper were to 1) document the range of energy saving behaviors associated with three different types of feedback, 2) explore an alternative classification scheme for understanding feedback-induced energy saving behaviors, 3) document household preferences for engaging in certain types of energy saving behaviours, and 4) examine whether feedback-induced behaviors vary as a function of feedback type.

The evidence from the feedback studies examined here indicates that there is a broad range of more than 100 potential actions that household members can engage in to reduce their energy consumption. Past attempts at categorizing these actions have often been rooted in a dichotomous categorization scheme that attributes energy savings to either the adoption of a particular technology or curtailment of use (aka behavior). This classification scheme is problematic because energy consumption cannot simply be determined by documenting the range of technologies that have or have not been adopted but must also recognize the myriad ways in which technologies are used (or not used), maintained (or not maintained), as well as the ways that technologies can be interchanged. This paper presents an alternative classification scheme that recognizes nine distinct energy-related actions that range from relatively high-cost investment decisions on one end of the spectrum to simple conservation behaviours on the other end. This categorization scheme provides a useful means of describing the *mechanisms* by which households are able to achieve feedback-induced energy savings. This approach provides a more nuanced perspective regarding the ways that behaviour and technologies work together in the realm of everyday practices and choices.

The preliminary assessment presented in this paper found that households are much more inclined to engage in a range of new energy-related practices (as opposed to technology purchases) as a result of all types of feedback studied here. These findings suggest that most households are using feedback as a means of evaluating how they can adjust existing systems to reduce their energy consumption rather than focusing on making large changes in the technologies already in place. Nevertheless preliminary evidence presented here also suggests that households that receive *enhanced billing forms of feedback* and *real-time feedback* (as opposed to online feedback) may be somewhat more likely to make investments in energy-efficient technologies. The data also indicates that households receiving *real-time feedback* may be more likely to use facilitator technologies such as smart strips, timers, and programmable thermostats to enhance their control of energy-using devices. These findings are interesting and may provide a partial explanation as to why past studies have found real-time feedback to be more effective at generating higher levels of savings at the household level. (According to Ehrhardt-Martinez et al. (2010), real-time feedback programs had average program savings of 9.2 percent compared with savings of 8.4 percent and 3.8 percent for daily/weekly and enhanced feedback programs, respectively.) Lastly, the energy savings data from the online form of

feedback studied here (see Table 6) indicates that a disproportionate share of actual energy savings were achieved through alternative technology choices – a set of behaviors that may deserve more attention. According to the assessment, 14% of actions taken fell into the category of *alternative technology choices*, but this same category of actions generated 26% of electricity savings. Such actions include: using fans instead of air conditioning, using task lighting instead of overhead lighting, and using CFLs instead of incandescent bulbs.

While more research is clearly needed to document the relationship between the type of feedback, the prevalence of different types of household actions, and the resulting energy savings, findings presented here suggest that this is an area of study that could help reveal the best means for maximizing feedback-induced energy savings. Future research should use more rigorous statistical methods to assess the strength of relationships between feedback, actions, and savings as well as the importance of other relevant variables including socio-demographic variables, building characteristics, climate and weather.

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