Measuring Energy Efficiency Behavior: Perspectives and Methods from Psychological Science

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ABSTRACT

Many programs exist to increase the purchase and installation of energy-efficient technologies (e.g., rebates for energy-efficient appliances), while programs designed to influence other types of behaviors (e.g., unplugging devices when not in use) are much less common. This is in part because implementers are not sure how to measure these energy-efficient actions and their associated energy savings. However, in order to meet the increasing emphasis on climate change and rising energy efficiency goals, measuring non-purchase-related energy efficiency behavior will be necessary.

Luckily, a variety of research methods can be drawn from psychology to reliably measure behaviors, and these methods can be applied to measure behaviors associated with energy efficiency programs. Specifically, a variety of "real-time self-report" methods use diary techniques to assess the frequency of a behavior. Participants can be asked to record their actions on a regular time-interval, after some event occurs, or at a random time determined by a signaling device such as a PDA. These methods are systematic and reliable, and they are useful for increasing accuracy of self-reports because they are less reliant on memory. Furthermore, these same methods can be used to determine the longevity of behavior-based programs; i.e., how long do behavior changes last, and thus how long they can be counted towards energy efficiency goals? This paper provides a discussion of a variety of behavior measurement techniques from the psychology field and suggestions for how they might be applied to behavior-based energy efficiency programs.

Why Do We Need to Measure Energy Use Behavior?

Traditionally, energy efficiency programs have focused on increasing the adoption of energy-efficient appliances and technologies such as clothes washers or compact fluorescent lamps (CFLs). With recent increases in energy efficiency goals stemming from both local and state policies (Kushler, York and Witte 2009) and greater political and customer awareness of climate change, it is becoming increasingly important to look beyond technologies. One element of energy use that has been largely overlooked is the behavioral aspect, or the interaction of people with the appliances and devices that draw energy. That is, the manner in which people use devices is an aspect of energy efficiency that has been largely un-tapped by programs aimed at decreasing energy use; however, interest in behavior-based programs is increasing.

Behavior-based programs inherently involve the measurement of behavior. Before designing a program aimed at changing behavior, we need to know what the current behavior is and the potential for change. And, in order to evaluate energy savings resulting from a behavior-based program, we must know what effect, if any, the program has had on energy use. Furthermore, we need to know how long any behavior-change associated with the program will persist, so that we can tailor programs that create long-lasting changes or can be repeated at

empirically-derived intervals. Establishing reliable measures of the behavior(s) we are trying to influence is fundamental to answering these questions. For example, if we want to influence consumers to unplug electronics devices when not in use, we need to know 1.) how often they currently keep devices plugged in when they are not in use, 2.) how much energy these devices draw), 3.) how often they keep devices plugged in after participation in our behavior-change program, and 4.) for how long the new un-plugging behavior is sustained. One obstacle to implementing behavior-based energy efficiency programs involves the uncertainties surrounding the measurement of energy-use behaviors. These uncertainties likely arise because, with few exceptions (e.g., Quantum Consulting & KEMA-Xenergy 2003; Research Into Action 2009), surprisingly little publicly-available research has been conducted regarding the frequency of energy-use and energy-conservation activities. Without precedent, program designers may be unsure of how to go about measuring behavior.

One obvious approach to measuring energy-related activities involves intensive data-logging of each outlet, appliance, or piece of equipment in use. The methods discussed in this paper do not supersede this approach; rather, they have the potential to work together. Data-logging of outlets or devices allows one to know exactly how much energy each device is using and when it is being used. The methods discussed in this paper allow one to conduct a more fine-grained analysis on the individual-level, so that the preceding conditions that precipitate an energy-use event can be determined. Furthermore, they allow us to understand the characteristics of people who are using particular devices so that we know how to design and market programs to best meet our goals. In short, the methods in this paper allow us to better understand the use of energy so that we can then change it for the better; these methods are essentially a way of conducting data-logging of *people* and their energy-use behaviors.

Why Psychology?

Psychology, at its core, is the study of human behavior. As social scientists, psychologists have developed and implemented a variety of methods for measuring behavior that may lend themselves well to the domain of energy use. This type of cross-pollination between psychology and areas of study focused on conservation and environmental concerns has been identified as a high priority in psychology (Price 2009). Indeed, recent work in psychology has examined ways to influence energy use (e.g., Abrahamse et al. 2005; Schultz et al. 2007) as well as the potential of energy conservation behaviors for reducing carbon emissions (e.g., Dietz et al. 2009; Gardner & Stern 2008).

Measuring behavior is particularly useful to psychologists seeking to understand and influence behaviors. In social psychology, behavioral measurement helps one to understand the causes and consequences of social or socially-influenced behavior. In clinical psychology, it is crucial to evaluate problem behaviors, implement treatments that may impact these behaviors, and then measure whether the treatments are successful. These goals parallel the goals of energy efficiency researchers, who seek to measure energy use, implement programs to lessen energy use, and evaluate the success of these programs. Therefore, behavioral methods developed and used in psychology have direct applicability to energy efficiency.

In particular, the methods most commonly used by psychologists to assess behavior are self-report and observation. Psychologists often rely on self-report methods, which, as the name implies, asks the person whose behavior you are interested in studying to report on his or her own behaviors, attitudes, values, etc. This commonly includes a wide variety of methods,

including surveys and in-depth interviews, which can be conducted in person, on the telephone, or can be self-administered. They can include both open- and closed-ended questions to collect data on a variety of research questions. These methods are well-suited to assessing energy use and energy efficiency behaviors, and are currently widely-used in the energy efficiency field and utility industry, particularly in program evaluation. Because of their widespread use, this paper will not focus on survey/interview methods, but will instead refer the reader to Visser, Krosnick, and Lavrakas (2000) for a comprehensive review of the uses, issues, and practical considerations with these methods.

Observational or ethnographic methods are useful when behavior is clearly defined and observable (Bakeman 2000). Studying behavior within the setting that it normally occurs is crucial for making valid conclusions about the frequency and nature of any behavior. Thus, observation may seem to be preferable for understanding people's energy use. However, gaining consent to enter someone's home or workplace may be difficult, and observation can be resource-intensive. Given the limitations of observational methods, this paper focuses on real-time self-report methods, which are not currently widely used in the energy efficiency field or the utility industry.

Real-Time Self-Report Methods

Real-time self-report methods are a special type of survey, questionnaire, or interview that has benefits with regard to the validity of data that are collected, compared to standard self-report approaches. These techniques allow the researcher to measure behavior in the context in which it occurs, based on self-report rather than direct observation (Reis & Gable 2000). These methods are used frequently in psychology to assess the frequency of baseline behaviors, causal triggers for certain behaviors, and to assess change in behavior over time. The person participating in the research is asked to respond to particular questions related to the frequency and circumstances surrounding particular behaviors at set or random intervals, usually once to multiple times per day. These methods have been referred to using a number of different names, including "everyday experience methods" (Reis & Gable 2000), "experience sampling" (Hektner, Schmidt & Csikszentmihalyi 2007), "ecological momentary assessment" (Shiffman, Stone & Hofford 2008), and "structured diary methods" (Delongis, Hemphill & Lehman 1992).

What these methods have in common is that the research subject completes the requested information closer in time to the event one is interested in, making their report less reliant on retrospection. For example, rather than asking research subjects, "How many days during an average summer week do you use an air conditioner?" one can ask participants to log their use of air conditioning daily or as it occurs. In addition to describing their energy use, subjects can be asked to describe the surrounding context (e.g., if they are making dinner, if they have friends over, etc.) that can then be used to determine what precipitates the greatest energy use. This can help determine how and when to most effectively influence energy use.

Another example of these methods comes from research conducted by SmartPower (2008), which asked research participants to record their activities any time they were carrying out various energy efficiency behaviors (i.e., unplugging/turning off electronics, taking shorter showers, and reducing car idling). In this study of 81 adults and teens, researchers collected over 1,000 diary entries over a two-week period. One of the key takeaways from this research was

that unplugging was the best behavior to target because research participants had the most success in carrying out this efficiency behavior, compared to shortening showers and reducing idling.

Data using real-time self report methods are advantageous for several reasons (Delongis, Hemphill & Lehman 1992):

- The data are more valid because they are collected in the environment in which they take place,
- They enable one to examine contextual events they may contribute to energy use behaviors,
- They allow one to take multiple measurements over time, which can increase the validity of the data, and
- They can increase the reliability and validity of self-report data because the data is collected closer in time to when events occur, rather than asking people to recall events that occurred long ago.

How Are Data Recorded?

With each of these techniques, data can be recorded by the research subject either on paper or electronically (online or otherwise entered into a computer or handheld device). Mobile phones offer an array of data collection methods, including telephone surveys, text messaging, and web reporting with Internet-enabled phones (Boschen & Casey 2008). If filled out on paper, the participant can be provided with booklets that are turned in, mailed in, or picked up by the researcher at specific time points, such as once per week throughout the study period (DeLongis, Hemphill & Lehman 1992). Whether via paper or some electronic device, the research subject is asked to report a variety of information, depending on the behaviors one is interested in studying and the hypotheses regarding the correlates or causes of those behaviors.

When Are Data Recorded?

Research subjects are instructed to record data at certain points during the day, and are often cued by an alerting device. “Experience sampling” is the term for the particular type of research method that uses a remote signaling device to cue research subjects to complete information, typically several times per day for several days or weeks (Hektner, Schmidt & Csikszentmihalyi 2007). Signaling devices can be pagers, preprogrammed stopwatches, phone alerts, or any other systematic way to cue a response. A phone call from the research team can even be a cue to complete a diary entry, and data can then be collected over the phone via telephone survey (Delongis, Hemphill & Lehman 1992). This way, the signaling cue and the method of entry are one and the same. The possibilities are becoming seemingly endless with the prevalence of mobile phones; one could imagine signaling via text-message or utilizing a smart phone application to signal research participants to enter data online.

A variety of options exist for determining when the individuals one is studying are to record their behavior. The method the researcher chooses depends on the goal of the research, and these options are outlined below.

Time-based recording. Time-based recording occurs when the person is asked to record their behavior at prescribed intervals. This could be once per day, every eight hours, once per week, or any other regular time period. In determining the time interval, the researcher must consider:

- When the behavior normally occurs,
- When it is convenient for the person to report on their behavior, and
- How often the person should report on his or her behavior.

For example, to test the possibility that plug loads represent a great potential for reducing demand, one might ask participants to record which devices are plugged in when they get home from work each day. Researchers may want to collect information more frequently during certain parts of the day or year (Shiffman, Stone & Huffard 2008), for example, when a study of air-conditioning or heating use is conducted.

Randomly-signaled recording. Instead of describing their current behavior at fixed intervals or time periods, this method requires the person to record their behavior when they are cued by an alerting device. Random signaling has the benefit of capturing behavior when subjects are not expecting to be observed. In randomly-signaled recording, electronic hand-held devices (e.g., personal digital assistants or PDAs; Reis & Gable 2000) and pagers can be particularly useful. Devices can be programmed to provide random signals at a particular frequency (e.g., three times per day) or during particular parts of the day (e.g., during typical waking hours) while maintaining randomness within these constraints. For example, one might wish to ask research subjects to report all the appliances or devices that are in use during a particular time when demand is high to determine which actions a conservation campaign might target in order to realize the greatest benefit in terms of demand reduction. A PDA could alert participants once per day, at a random time during the peak demand period (e.g., once per day between 2 and 6 pm) and ask them to report which devices are being used, what temperature the thermostat is set at, whether the person is at home or at work, etc. The PDA is both the alerting device and the data collection device. A free download of The Experience Sampling Program is available (ESP 2010), which enables the user to construct and run questionnaires or surveys for use with a PDA.

Event-based recording. This method asks participants to describe certain events whenever they occur. For example, a study of diet might ask people to report their actions just after eating a full meal. An energy study might wish to test the hypothesis that meal times might be especially energy-intensive, asking participants to record which appliances or devices are in use when they cook a meal. Another study might have participants record how long a shower takes each time they take a shower.

Validity of Real-Time Self-Report Methods

Studies using the methods described above have had success with a large range of age groups and have been used to study individuals with various psychological disorders, substance abuse, and physical disabilities (Csikszentmihalyi & Larson 1987; Shiffman 2009). For studies that use a signaling device, the vast majority of subjects appear to respond immediately or within 10 minutes of signaling (Csikszentmihalyi & Larson 1987). Compared with traditional measurement approaches such as questionnaires that rely on recall, real-time self-report methods

generally show more accurate data, in that the information that is captured is more intricate (Shiffman 2009) and contains less missing data (Boddy & Smith 2008). A study of water use in Bolivia compared diary methods with traditional methods relying on recall, concluding that a diary-based approach was more accurate (Wutich 2009). When asked via free recall (relying on memory alone with no prompting), research participants said they used approximately 19 liters of water per day, per person, while diary methods revealed usage averaging 41 liters of water per day, per person. Participants appeared especially likely to underestimate water used for clothes washing when asked to freely recall this information. Using electronic data-collection methods can bolster validity by time-stamping the data entry, which can help ensure that data is entered on a regular, real-time basis, as opposed to retrospectively recalled (Bass et al. 2007).

It is always possible that the mere act of measuring a person's behavior will inadvertently alter the very behavior one is trying to measure. There is some evidence that "reactivity," as it is called, may be more likely under two conditions: 1) when people are trying to change the behavior you are measuring, and 2) when the measurement takes place before the activity occurs (Korotitsch & Nelson-Gray 1999, as referenced in Shiffman, Stone & Huffard 2008). Thus, if a program designer is interested in measuring baseline energy use behaviors, he or she might pay special attention to whether the subjects of the research are interested in using less (or more) energy. Measurements occurring before the research subjects are using an appliance or device might be subject to bias as well. On the other hand, research has generally shown little effect of reactivity outside of these conditions (Shiffman, Stone & Huffard 2008).

There have been some concerns of research subjects filling out daily diaries at times other than what was specified by the researcher (Shiffman, Stone & Huffard 2008). For example, a person might skip two days, and on the third day fill out three diaries entries. This obviously defeats the purpose of using real-time self-report methods, as in this case, the subject is either completing the information from recall or is falsifying the information. This is of concern for the validity of data one collects from such studies. However, various precautions can be taken to prevent this from happening (Shiffman, Stone & Huffard 2008) by providing a time-stamping mechanism (e.g., postmarks if returning by mail, electronic time-stamping if submitting online, etc.). Shiffman, Stone and Huffard (2008) note that determining the proper completion of event-based entries is difficult at best. However, signal-based entries are easier to verify.

The amount of burden placed on a person participating in a research study is one factor that could contribute to less valid, or simply incomplete, data. Because real-time self-report methods ask research subjects to record data at least once per day for several days, "subject burden," as it is called, is a potential issue. Real-time self-report methods are reported to be burdensome for 20 to 30% of research subjects (Csikszentmihalyi & Larson 1987). However, 80 to 90% of subjects feel that their self-reports are accurate, and 75% say they would participate in a similar study again (Csikszentmihalyi & Larson 1987). Participants have found PDAs easy to use, convenient, and more private compared to paper-based assessments (Bass et al. 2007), suggesting that electronic-based approaches may lessen subject burden. In general, compliance with signaled assessments increases when the number of signals per day is decreased (Csikszentmihalyi & Larson 1987).

Longitudinal Measurement

If behavior-based programs are to claim energy savings, then we will need to know whether the energy actions targeted by the program are sustainable: How long does the behavior-

change last after the initial "intervention," program participation, and point of contact with the customer? Another way of putting this is: When will additional follow-up be required to sustain the behavior change? Repeatedly measuring energy-related actions using the methods discussed above can help to answer these questions.

For example, if a program or marketing initiative focuses on decreasing the frequency that clothes are washed in hot water, one would first construct a baseline by asking research subjects to report, using the methods described above, how often they wash their clothes in hot water over a two-week period. Then, the research subjects participate in the program designed to decrease this behavior, encouraging participants to wash their clothes in warm or cold water instead. A follow-up assessment would determine how often the behavior takes place during the intervention period, and then again at various points after the intervention to determine at what point the behavior "relapses" back to washing more loads of laundry with hot water. Ideally, these data would also be compared to a control group that does not participate in the program. We would then know when to re-introduce the program content or provide new incentives to reactivate the desired behavior. A number of studies have followed up with research subjects over a numbers of years; for example, one study followed adolescents over two years using the experience sampling method (Rathunde 2001).

Applying Psychological Methods to Energy Efficiency Program Goals

The real-time self-report methods discussed in this paper can be applied in a variety of ways to design, provide ongoing program metrics, and evaluate energy efficiency programs that focus on behavior change.

For program design, it is important to first determine which energy-use actions have the most potential for change. The methods described above can be used to determine which appliances or devices are used most frequently, so that we can pair this information with the energy used by such appliances or devices, and in turn, determine which behavior should be targeted by the program to achieve the greatest impacts in terms of energy savings.

In addition to measuring the frequency of various energy-use actions, one could also assess various demographic, "psychographic" (i.e., values, beliefs, attitudes), and context-relevant (e.g., home vs. work, social occurrences) characteristics that correlate with or trigger particular energy-use behaviors. This allows one to then design a program targeted to certain sub-populations that are more likely to use particular appliances or devices. This also allows one to target the marketing, information, and incentives (either monetary or non-monetary) so that they have the intended effect on the group being targeted. For example, research could determine whether residents of certain geographic areas are more likely to do laundry with hot water or to wash clothes with less-than-full loads. Pairing the real-time self-report method with an assessment of values could determine whether these residents are more concerned with water availability, energy security, or carbon footprints, and one could use this information to effectively market a combined water/energy conservation program.

As described above, the methods discussed in this paper could also be used to follow-up with program participants and determine whether the desired behavior change is persisting over time. For example, if it is learned that participants revert back to their original patterns of energy use after three months, then at this time point, appropriate follow-up could take place, whether a reminder, additional incentive, or some other form of influence to continue the energy-efficient action(s). After follow-up, these methods could be deployed again to evaluate the impact of the

follow-up intervention. Ongoing research to continually inform the program is a keystone of successful program design (e.g., see Kotler & Lee 2008; McKenzie-Mohr & Smith 1999) and achievement of energy impacts. Without ongoing research, it is unknown whether the behaviors persist, and forecasts of energy use and demand will suffer. Likewise, traditional program evaluations that occur at the end of a program cycle can use these methods to determine the achievements of the program in terms of conservation behaviors, which can be linked with measurements of energy reduction to determine program impacts.

Summary & Conclusions

The real-time self-report methods described in this paper allow researchers to collect information about energy-use behaviors in the contexts in which they occur, using self-report mechanisms. These methods could be combined with qualitative information such as in-depth interviews or ethnographic data to form a very rich data set. Combined with meter data or data-logging of individual outlets or devices, we can get an accurate and complete picture of energy use, individuals' awareness of their energy use patterns, the potential for conservation, and the groups or types of people that may be most prepared to increase their efficient behavior. The specificity of information that is collected allows one to narrow in on a program and messaging design that will have the most impact; in short, it eliminates the guesswork from program design. With aggressive energy efficiency goals and the reality of climate change, methods such as those presented in this paper allow utilities and energy efficiency professionals to proceed with confidence.

A systematic measurement of energy-related actions is necessary in order to develop behavior-based energy efficiency programs that can successfully claim savings (Sullivan 2009). Obviously, the behavior-assessment methods described in this paper are fairly intensive ways of measuring behavior. However, they are also more accurate compared to traditional approaches. Behavior-based programs that are implemented without the necessary research may fail due to preventable mistakes, wasting limited financial resources, time, and effort. Carrying out the required research allows utilities to place more confidence in both the ability to achieve the goals of the program and as well as the utility's overall efficiency goals. Collecting information regarding customers' energy-use actions in a systematic and informed manner requires more effort up-front, but deliberate research at the outset of program planning has the potential for large paybacks in the long-term.

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