Home, Habits, and Energy: Deconstructing Domestic Interactions and Energy Consumptions

[author names withheld for blind review]

ABSTRACT

This paper presents findings from studies investigating people's everyday interactions with energy-consuming products in the home. Complementary qualitative and quantitative methods were employed. Home visits with qualitative interviews and self-logging activities were conducted with 15 participants. Initial results from a large online survey are also considered. This research focuses not only on "conservation behavior" but importantly investigates interactions with technology that may be characterized as "normal consumption" or "over-consumption." A novel framework for analyzing and designing energy-conserving interactions is proposed, including: *cutting*, *trimming*, *switching*, *upgrading*, and *shifting*. Using the proposed framework, and informed by theoretical developments from various sustainability and design literatures, this paper demonstrates ways in which everyday interactions with technology in the home are performed without conscious consideration of energy consumption but rather are unconscious, habitual, and irrational. Implications for the design of more energy-efficient interactions with technology and broader challenges for HCI research are proposed.

Author Keywords

Energy, design, sustainability

INTRODUCTION

Virtually every interaction within the home directly or indirectly involves the use of energy-consuming devices and systems—increasingly *digital* devices and systems. Put another way, energy consumption can be characterized as *"the routine accomplishment of what people take to be the 'normal' ways of life."* [28]:117, as discussed by Elizabeth Shove. This characterization emphasizes the insidious and problematic nature of reducing our consumption of energy: How are we to significantly curtail our energy consumption if it constitutes our normal ways of being?

In this paper, we attempt to directly address this critical yet seemingly paradoxical question surrounding energy conservation by (i) undertaking a fine grain analysis of everyday interactions with and perceptions of domestic energy-consuming products and systems through a series of field studies, interviews, and surveys; (ii) categorizing and discussing our findings; and (iii) presenting an operational design framework influenced by our results.

We present empirical findings from qualitative fieldwork and an online survey investigating how people currently interact with and think about energy-consuming devices and systems in their homes and everyday lives. Such interactions and decisions include what is commonly characterized as energy conservation, *e.g.*, turning off lights when not in use; however, as we will demonstrate in detail, the majority of everyday interactions are performed without any consideration of energy. Further, interactions for which conscious considerations of energy consumption *are* made are often irrational, a phenomenon that has been referred to as the *"efficiency paradox"* of energy consumption [6]. As we will describe, a major finding of our work suggests that much of everyday energy consumption behavior is *not* the result of conscious and motivated action. Rather, everyday consumption behaviors appear to be strongly shaped and enforced by the micro-level systems (*e.g.*, thermostat interface) and macro-level systems (*e.g.*, HVAC infrastructure and standards) that create our everyday material environments. In this paper, we focus on the relationships among micro-level design decisions, user interactions, and energy consumptions.

Our work builds on a number of empirical studies of residential energy consumption within HCI [3, 4, withheld, 30, 36] and various other fields [*e.g.*, 15, 20]. Our work differs from this body of work by its novel emphasis on (i) *routine domestic practices*—with as much, if not more, emphasis on "normal" and "wasteful" practices; (ii) *particular interactions with specific devices and domestic areas of practice*; and (iii) *a unique operational framework to capture and explore future conservation design efforts.* Our work complements existing work in this area by emphasizing the habitual, irrational, and "wasteful" behavior that people exhibit in their daily interactions with energy-consuming products and systems in the home—highlighting a pervasive set of practices that interestingly contrasts the conscious and strongly motivated conservation behaviors described in prior empirical studies of residential energy consumption.

The remainder of this paper is structured as follows. First, we propose a framework for analyzing and designing energy-conserving interactions with technology. Next, we offer a review of theoretical perspectives and prior work related to energy and sustainability. We then report our findings and conclude by drawing out (i) implications for the design of more energy-efficient interactions with technology—including a set of design strategies resulting from the application of our framework to our findings, and (ii) broader implications for HCI research related to energy, sustainability, and conservation.

VOCABULARY OF ENERGY CONSERVING ACTIONS

In order to speak more precisely about the types of energy-conserving actions we intend to understand and design for, we propose a framework consisting of a vocabulary of low-level energy-conserving actions. This vocabulary provides a language both for analyzing current interactions and designing future energy-conserving interactions. The set of actions we present may be considered a refinement and extension of the three categories of conservation strategies proposed by Kempton *et al*., namely (i) management, (ii) curtailment, and (iii) investment strategies [20]. We have drawn from these themes with a focus on HCI applications and interaction design. Our vocabulary is a set of operational terms that capture the actions and strategies of energy conservation efforts and/or opportunities and are summarized as follows:

cutting—*powering-off or putting in an extremely low-power state*, *e.g*., powering off the television or putting it in a standby state.

trimming—*using a "lower" setting* (*i.e*., more energy-efficient setting) when using a product, *e.g*., lowering the thermostat setting, or washing clothes on "cold" rather than "hot" temperature wash cycle.

switching—*using a more energy-efficient product* in place of product with similar but different functionality, *e.g*., using a ceiling fan instead of an air conditioner.

upgrading—*acquiring a more energy-efficient product* to replace a product of the same type, *e.g.,* replacing an old refrigerator with a more energy-efficient model.

shifting—*shifting use to a different time or place*, without necessarily reducing the total energy consumed by that product (but reducing energy demand; see, *e.g.*, [9]), *e.g.*, washing clothes at night during off-peak hours of low energy-demand.

We further define important subclasses of several of the above terms. **Cutting** can be further nuanced as **cutting *when not in-use*—***e.g*., turning off the television when it is not being used; or **cutting *normal-use*—***cutting to use less frequently*, and without replacing with a similar product, *e.g.*, watching less television. Similarly, **trimming** can be further refined as **shaving—***trimming without noticeable effects,* or with only trivial effects, in terms of perceived quality-of-use, *e.g.*, lowering the thermostat by one degree without discomfort; or **extending**—*trimming but extending use-time* in order to achieve the same or similar results, without necessarily reducing the total energy consumed by that product, *e.g.*, baking a dish in the oven at a lower temperature for a longer period of time.

In what follows, we apply our energy-conserving vocabulary to ground, frame, interpret, and present findings from our fieldwork and survey data, as well as propose opportunities for sustainable interaction design and HCI.

THEORETICAL PERSPECTIVES AND RELATED WORK

In an excellent review of various approaches to understanding decision making in the context of residential energy use, Wilson and Dowlatabadi outline four major perspectives: (i) conventional and behavioral economics, (ii) technological adoption theory and attitude-based decision making, (iii) social and environmental psychology, and (iv) sociology [35]. Each tradition is founded on different assumptions; for example, some assume rationally informed individuals, while other emphasize the influence of broader social contexts on behavior [35]. The sheer abundance of literature related to sustainable consumption and residential energy consumption in particular precludes us from reviewing large and relevant areas of work. Instead, we refer the reader to several excellent reviews of approaches to sustainable consumption [19], (residential) energy consumption [11, 22, 35], and selectively focus on several prior works most relevant to this paper.

Much of the research on sustainable (energy) consumption hinges on a critique of the rational choice approach [19]. Research has demonstrated that ordinary people in ordinary situations rely on a range of entirely irrational methods of dealing with cognitive demands of choice, including heuristics and "rules of thumb" [31]. Evidence from social psychology also suggests that not only are some behaviors *not* the results of attitude or intention, but that people sometimes incorrectly infer attitude and intention in order to explain their own behavior [*e.g.*, 5, 19]. Importantly, this suggests that *behaviors can be changed without necessarily first changing attitudes* [19]. The important role of habit in guiding everyday consumption behaviors has also been brought to attention [*e.g.*, 15, 28, 29]. Integrated approaches have attempted to synthesize various perspectives and models. [*e.g.*, 29, 35].

Sustainability as a central area of concern for HCI has been proposed broadly by Blevis [2], and within HCI there have since been a number of studies investigating home energy consumption [3,4,withheld,30,36] and sustainability more generally [withheld,8,12,16,17,23,withheld,withheld,33]. Prior studies in HCI have drawn primarily on psychological perspectives that emphasize the importance of people's motivations, values, and attitudes with respect to conservation behavior. A variety of artists, designers, and other practitioners have also explored interactive systems that aim to promote more sustainable consumption of energy [*e.g.*, 23,withheld]. Outside HCI, empirical studies have emphasized the role of habit as well as broader social structures in mediating everyday energy consumption [15].

Situating our approach

We rely on various theoretical frames and empirical findings discussed previously to frame and interpret our results. However, we found social-psychological and sociological approaches most useful in interpreting and explaining our results. Furthermore, our analysis is strongly informed by theoretical developments from design theory and philosophy of technology that emphasize the ways in which everyday actions and perceptions are subtly mediated by technology [*e.g.*, 21,32]. Additionally, our approach is influenced by design-oriented perspectives within HCI including those articulated by Fallman [10] and

Zimmerman, Forlizzi, and Evenson [37]. Further, our work is inspired by Blevis' notion of design as "*choosing among or informing choices of future ways of being*" as a foundation for sustainable interaction design [2]:503.

It should be made clear that our goal in this paper is not to validate existing approaches or propose new models and theories for explaining behavior and decision-making with respect to residential energy consumption. Rather, our goal is to collectively draw on existing approaches in order to describe and explain our findings as a means to inform design theory and practice.

PARTICIPANTS AND METHODS

Two studies were performed to provide converging qualitative and quantitative evidence on home energy use practices and preferences: (i) in-home interviews (with supplemental activities) and (ii) an extensive online survey.

Home interviews and activities

15 participants from 12 households (in California, Illinois, and Indiana) were recruited online (craigslist.com) and through personal acquaintances. They varied widely in demographics (*e.g.*, age, gender) and living arrangements (*e.g.*, single-family homes, in-law apartments, studio apartments). Degree of participation varied. Extended home interviews (~1-3 hrs) were conducted with all participants. Eight of them also participated in a preliminary home visit and interview session and a 3-10 day logging exercise prior to the final, extended interview. Home interviews were semi-structured and focused on everyday energy use practices. Participants gave a tour of their homes, walking through and demonstrating their typical use of various appliances and devices, and answering questions exploring their rationales for specific settings and temporal patterns of use.

Additional activities supplementing the interviews for many participants included reviewing a recent monthly utilities bill, a think-aloud card-sorting task (Figure 1), and a logging activity. For the logging activity, *consumption placards* with information about cost per use at various times of day were placed on or near specific appliances; participants indicated their use on a *daily log form* (Figure 1). Note that the goal of the activities was not to generate data per se, but rather to promote participant engagement and informed reflection during interviews. In addition, a commercial product ("Kill-a-Watt") was made available to participants to help them monitor their use if they so chose.

Figure 1. *Daily log forms* [left] for small kitchen appliances (leftmost log) and refrigerator (rightmost log); a *card-sorting activity* ("willingness to lower settings") [right].

Online survey

A extensive survey (~50+ questions) was designed to obtain data from a large sample of people in various cities across the US (*e.g.*, San Francisco, Chicago, Boston) on their energy consumption patterns with various appliances, how habitual and flexible their patterns might be, the importance of price, convenience and other factors, awareness of the cost of using specific appliances, and related topics. A variety of response methods were used, including forced-choice, numerical estimation, subjective ratings and open-ended text. The survey was conducted online, and participants were recruited primarily through craigslist. Data were collected from over 800 respondents.

FINDINGS

The results given below stem primarily from observed consumption practices and explanations of them from our home visits. These are supplemented in part with initial findings from analyses of a subset of survey responses.

Energy literacy

For most people, the monthly utilities bill provides the most accessible, specific and reliable information available on home energy consumption. Yet a number of interviewees could not accurately estimate their monthly utilities bills. None knew the cost of 1 kilowatt-hour (kWh) of electricity, or even their cost rate structure (*e.g.*, tiered, flat rate, time-of-use); they seemed to simply pay the "amount due" and move on. The survey data shows that although 80.5% of respondents personally paid their monthly bills, only 25.8% claimed to be "very sure" of even roughly how much they paid each month; 24.1% "had no idea" or were "just guessing". When asked if they knew roughly how much 1 kWh of electricity costs, 5.1% were "very sure", while 83.8% "had no idea"/"were just guessing." Not surprisingly, people seemed even more uncertain of the amount of energy consumed by individual appliances. Most interviewees understood that heating and air conditioning (HVAC) must be relatively very expensive, since their monthly bills spike with seasonal increases in use. With the exception of HVAC, most participants appeared to have little understanding of the cost of using appliances. Still (as discussed below), cost estimation is not always the primary factor in determining patterns of use.

Energy indifference and (over-)consumption

To our surprise, most interviewees did not express much interest in the cost information we provided them in the form of placards (for the logging activity) and price charts (estimating cost for typical use of various appliances per day, month, year), even when probed: *"*[**Q:**] *Is that* [prices for specific appliances on chart] *more or less than you thought?* [**P5**:] *Well… I don't know… you never think about these things. Until someone like you pops up.*"; and "[**Q:**] *Is that more or less than you thought it'd be?* [**P14**:] *Um, it's cheap enough."* Even when "shocked" by high prices, participants did not seem motivated to change behavior: *"*[**P8**] *The dehumidifier, we have that on all day long! Two of them! That's a shocker!* [**Q:**] *Are those prices enough to* *make change your behavior?* [**P8**:] *Well, no. No. Not enough to change."*

In fact, we were hard-pressed to find any alteration in appliance use patterns resulting from the cost information we provided in the logging exercise. To our surprise, the two participants in our study who routinely took major steps to conserve energy ("conservers") showed no real engagement with the cost information or the power monitoring devices we provided. Not one participant ever used the Kill-A-Watt power monitor we provided. Some participants even indicated they did not want to know costs associated with using appliances: "*I know I'm not gonna change anyway, so I don't really wanna know."* (**P13**); [**Q:**] *Are these* [costs] *what you expected…?* [**P6**:] *I didn't pay much attention to these, because I have to pay them anyway.* [**Q:**] *You have to pay them anyway?* [**P6**:] *Yeah, I have to use them anyway. ...um.. like, to keep my life to a certain level of convenience."*

Awareness of relatively low costs of appliance use may actually be a disincentive to conserve. This was suggested in many instances; for example, regarding computer use: "*Oh, good, it only costs a few cents to use my computer, so I don't have to worry about that."* (**P1**); "*Oh, it's cheap to leave my computer on all day* [~$0.25/day]!" (**P14**).

Still, there were some cases in which the logging activity prompted participants to become more aware of patterns of waste and over-consumption. For example, **P2** realized that she turned on extra lights at home—even in vacant rooms—during her husband's frequent business trips. **P5** became aware that she often left her therapeutic heat lamp on when not in-use. Other common examples include getting a sense of the frequency with which refrigerator doors were opened and closed, and lights turned on and off. However, only rarely did this increased awareness translate into consumption-curtailing behavior. Worse, even in those cases, strong ambivalence was expressed about whether such behavioral changes could be sustained over the long-term—for example: "[**Q:**] *Did you turn the lamp off more or not...?* [**P5**:] *Um... a little. Sorta middle of the road on that one. If I could <u>remember</u> I would go and turn it off."*

Clearly, awareness of the cost of energy consumption does not imply significant changes in practice. Cost factors alone (up to some fairly high threshold) do not seem to outweigh the effort and intentionality required to change long-held routines. While some studies have shown significant effects of feedback on residential energy consumption—in some cases up to 20% (see [11]), our results suggest that awareness of costs and even cumulative savings over time may not provide sufficient incentive for long-term change for many people. Even **P2**, a research ecologist, was not incentivized by small savings: "[**Q:**] *So…why didn't you change your behaviors?* [**P2**:] *The specific amount of money I would save seemed insignificant… I wouldn't start to care until I saved $20 or more per month, say… Maybe you could just use colors to suggest high, medium and low energy consumption; I think that would work better for me.*"

The power of habit

It's easy to overlook or forget just how influential the role of habit is in guiding our everyday interactions with technology. Prior research has identified the important role of habit in guiding energy-consuming behavior—and the challenge of altering habitual consumption [*e.g.*, see 15,19,29]. Our observations of domestic appliance use suggest that many if not most daily interactions with energy-consuming devices or systems can be characterized as unconscious or habitual rather than the result of rational decision-making. Survey data lend support to this view: When respondents were asked how well (on a 5-point scale) the word "routine" characterized their patterns of use for various appliances, modal responses hovered between "quite well" (4) and "very well" (5) in all cases.

It was clear from the home visits that slight alterations in seemingly arbitrarily developed routines could substantially reduce consumption and yield large savings. Two examples around washing machine use illustrate this point: (i) "[**Q:**] *So how come you put this on warm and not cold for this kind of stuff* [non-white loads]? [**P6:**] *Um… because I'm thinking its better for dirt. And to get all the things out… If hot water doesn't shrink I would use hot. But I think it will shrink. And the colors stays better. I don't know if it's true. But I just do it this way. Once I read an article on the Internet; it says cold water is okay for everything; it doesn't need hotter temperature. But I keep doing it because it's working.* [**Q:**] *Oh, you don't believe it?* [**P6**:] *Yeah.* [Laughs]. [**Q:**] *You don't believe it's okay…?* [**P6**:] *Um... Actually, maybe it's because I've been doing this for a long time, so I didn't change because I read that*."; and (ii) "[**Q:**] *How did you decide on 'regular 9'* [setting]*?* [**P10**:] *My mother told me to do that. ... I don't think 'regular 9.' Like, I've never said to myself, hmm: 'regular nine', nine o'clock.' I just know it goes to here* [demonstrating setting]. *I don't consciously think about the 9.* [**Q:**] *Is there any reason why you've never changed it or altered it?* [**P10**:] *I've never needed different results. I've never had any reason to want to change what I do."*

In each of these examples, the participant acknowledges that routine use of the washer is not the result of a conscious and deliberate decision to perform a certain way each time but rather is habitual, and done with little or no conscious consideration. Both participants readily offered that their routines were not necessarily the most common or the only acceptable one. Indeed, with slight alterations in their routine washer settings, both *could* significantly curtail their energy consumption. Each participant's maintenance of habit with respect to the clothes washer—and appliances in general—often appeared to be explained by a simple heuristic: "if it works, why change it?" Our fieldwork uncovered similar patters of habitual behavior surrounding the use of many common everyday appliances.

Simply causing a person to reflect and offering information on "better" alternatives does not directly produce changes in long-standing habitual practices. As mentioned above, expressions of any real interest in modifying routine use were the exception, not the rule, with our participants. Even cost savings were apparently insufficient to motivate small behavioral changes. Ingrained habits appear to be more powerful than clear evidence that even small changes can yield cost benefits.

Importantly, the power of habit can also be seen in some common conservation practices (*e.g.*, *cutting* lights, TV, computers when not in-use, *trimming* by closing refrigerator doors) performed *even by people who lacked strong motivations*—either intrinsic (*e.g.*, environmental values) or extrinsic (e.g., financial incentive)—to conserve energy. For example, **P8** describes her routine of *cutting* basement lights when not in-use: "[**P8**:] *We're constantly turning* [lights] *on and off and we leave them on only for at most maybe less than 15 minutes at a time. But it's kinda crazy because after we come down the stairs we turn 'em off and then on again. And we just turn them on and off at least 50 times a day.* [**Q:**] *Is there a reason you turn 'em on and off?* [**P8**:] *Because we think it saves energy. Yeah.*"

Upon reflection, "saves energy" seems more like a rationalization than a reason for **P8's** routine practice of turning off lights. Given her clear pattern of "over-consumption" in most other domains, it seems "kinda crazy" even to her. She and her family own a large home, with typical energy bills of $400/month, and show little motivation to conserve energy for financial, environmental, or other reasons. She claimed *"we make enough money that we don't need to worry about that* [conserving energy]", but appeared surprised when we asked *why* she turns off lights, as if it were a common and unquestioned practice. In fact, this seemed characteristic of participants' explanations of other such habitual (but not most effective) conservation routines: *"I believe it saves energy"* (**P1**); *To save energy* (**P5**)*"; "Because we think its saves energy"* (**P8**); *"Just to save energy."*(**P3**); *"Well…I mean it just makes sense: to save electricity"*(**P15**)*; "I feel like I'm paying for it."*(**P13**).

In context, these seemed like post-hoc rationalizations of ingrained habits, perhaps from childhood, since these participants were largely unmotivated to conserve and did not demonstrate conservation behavior with respect to most other appliances and devices. The one exception to this rule is in the case of temperature control. Most people realized that heating and AC dramatically affects their energy bills, and when conservation measures were taken in this domain, they seemed more intentional and well-considered.

Conservation: failed attempts and unwitting routines

Several instances of *failed conservation attempts* were discussed in our home visits. For example, consider **P6**'s reports of repeated attempts to use the space heater less: "[**P6**:] *Cuz, like, in the winter my* [energy] *bill usually doubles… After I found out my bill doubled, I try to use the heater less—every day or two. But then I couldn't stand the cold. And then I was using the space heater for long hours again.* [**Q:**] *So you tried?* [**P6**:] *It was because the bill was just double. If it was triple, or more, I might—I might* [laughs]*—try something else. I will try to use it* [space heater] *less often, just to save on the energy bill. And because sometimes I'm too lazy to put on a jacket. And it's just easier to turn on a switch then go in the room, open the closet, and put on a jacket* [laughs]*."*

Even with a 100% increase in her energy bill (which she attributed to overuse of the space heater)—and despite living in a fairly warm Californian climate—**P6** seemed unwilling or unable to routinely reduce her space heater use. Comfort (*"I couldn't stand the cold"*) and convenience (*"it's just easier to turn on a switch"*) appear to be the strongest contributing factors. Related results were found for other appliances in the survey data. For example, respondents rated how much (on a 5-point scale) 4 specific factors impact how they use their dishwasher. The modal response for price/cost was "not at all" (1), for Comfort was "quite a bit" (4), for Convenience was "very much" (5), and for Environment was "somewhat" (3).

Several other participants described attempts to lower consumption with only a vague sense that it might save them money or was otherwise worthwhile. In most cases, these were failed attempts involving *cutting when not in-use*: turning off lights, televisions, computers and other devices. Inconveniences were described that prevented them from routinely *cutting* these devices when not in use. As an illustrative example, consider **P8**'s *cutting* practices with her computer monitor but not computer: "*I have* [the computer] *on pretty much all day, about noon until nine. I hate restarting it up again. It's a headache to restart it again. So I just leave everything on…It's a headache to go down there a press that button and try to restart it, so I just turn the screen off, and then I'll turn the screen on*." (**P8**)

Note that in our discussion with **P8** it was apparent that she *did* habitually *cut* the monitor yet *did not cut* the computer because it seemed too inconvenient. In this case, the difference between pressing a button at *eye-level* and waiting *several secon*ds to power on or off (computer monitor) and *reaching down* to press a button and waiting *almost a minute* to power on (computer) apparently allowed the former and not the latter to become a conservation routine. This finding is worth highlighting because in our fieldwork (i) many people appeared to have an inclination to *try* to *cut* devices when not in-use, but (ii) all too often, they eventually determined that it was too inconvenient to regularly do so. In other cases it was not apparent that other conservation options were even possible (*e.g.*, *trimming* dishwasher and refrigerators by reducing temperature settings). This finding implies that if products are designed such that they can clearly and conveniently be *cut* and *trimmed* then people *will*; otherwise, many most likely will not.

In contrast to failed conscious conservation attempts, we also uncovered some "successful" but *unwitting conservation routines*. For example, several participants described *cutting* computers at night because they made too much noise, making it difficult to sleep. (In one case, a participant described changing her routine to leave the computer on at all times *only* after the computer was moved out of her bedroom.) One participant (**P2**) even unplugged her refrigerator at night because of its noise—the only example of *cutting* we uncovered with respect to routine refrigerator usage. Several participants who did not own air conditioners mentioned *cutting normal-use* with the oven in the summer due to the heat, or *switching* by instead using the toaster oven. In each case, participants were successfully motivated to conserve energy not by an intention to lower costs or conserve energy but rather by a desire to *avoid inconvenience and discomfort*. None of these participants mentioned making the connection between these practices and conservation.

Along related lines, several participants felt motivated to conserve in order to avoid inconvenience associated with our logging activity. For example, **P1** described how and why the logs prompted him to *cut normal-use* of lights and *trim* refrigerator door-openings: *"a few cents doesn't matter to me… The time it takes to fill out the thing is a bigger deal than the cost. What actually happened is I don't want to write down the thing down* [on the log form] *so I don't do it* [*e.g.*, use lights, open refrigerator *"just to look"*]*."*

These examples collectively highlight the potential impact of *seemingly* trivial inconveniences and discomforts on user behavior and, in turn, energy consumption. They further suggest that designing certain constraints (*e.g.*, making inefficient energy options *less* accessible) into device interfaces might help successfully shape energy-conserving practices.

Unconsidered options

Our home visits further revealed that many conservation options—including energy-saving settings on devices, even when explicitly labeled as such—seemed entirely unknown to or unconsidered by participants. While this may hardly be surprising given the complexity of many user interfaces—even for common everyday products [24]—we were struck by the impact that these *unconsidered options* had in terms of energy consumption. Failure to use energy-saving options was especially common with the following products: clothes washer and dryer (*e.g.*, did not consider *trimming* by reducing temperature or cycle length in terms of saving energy), dishwasher (*e.g.*, did not consider *trimming* by using air dry setting or reduced wash/rinse cycle), refrigerator/freezer (*e.g.*, were unaware of options to *trim* temperature setting or had not considered in terms of saving energy), hot water (*e.g.*, did not make the connection between *cutting* hot water consumption and saving energy; had not considered *trimming* by adjusting setting on hot water heater), cooking appliances (did not consider *switching*, *e.g.*, using toaster oven instead of oven in order to save energy), and computers, televisions and other electronics (*e.g.*, did not *completely cut* by completely powering off, but instead left on or in low-power standby mode).

Responses from our survey further support our finding of a common lack of awareness of certain energy-saving options. For example, when respondents were asked for their usual settings on specific appliances, typically about 25-30% claimed they simply "had no idea" or "were just guessing". Two exceptions to this rule may be informative: Almost 67% of respondents "had no idea"/"were just guessing" on the settings on their water heaters, but 75.2% felt "fairly" or "very sure" of those for the AC. Interestingly, 37.5% of survey respondents claimed to "have no idea"/"just guessing" their refrigerator/freezer settings. While almost every participant we interviewed had adjusted the temperature of their refrigerator/freezer, only in two cases had the adjustment resulted from a conscious effort to conserve electricity. For the remaining participants who had adjusted their refrigerator/freezer temperature, the adjustment process was roughly as follows: First, it is noticed at some point that food in the refrigerator either freezes or starts to spoil; second, the temperature adjustment setting is located and adjusted, typically over the course of several days, until a temperature is reached in which food neither spoils nor freezes; finally, the person forgets about the setting and it is not adjusted again.

As mentioned previously, participants rarely mentioned or displayed examples of conservation behavior related to *cutting normal-use*, *trimming*, *switching*, or *shifting*. Energy conservation did not appear to strongly motivate *upgrading* products—yet factors like style did (*e.g.*, **P3**, a "conserver", did not upgrade to an Energy Star refrigerator because it was not available in the stainless steel finish he wanted.)

In the remainder of this section, we focus on set of specific examples around washer and dryer usage to further illustrate *unconsidered options*. However, we could have chosen similar examples from a number of other appliances and devices to illustrate these points as well.

Many participants did not use and/or were not able to explain all of the settings on the clothes washer or dryer they use. Instead, they often described finding settings that achieved acceptable results, at which point they did not further consider other options—for example: (i) "[**P10**:] *I've also never ever, ever turned this dial to anything but here.* [indicating "normal" cycle]. *… But yeah, as far as that goes* [other interface options]*, I have no idea at all as to what those things would do. I've never, ever not done this.* [**Q:**] *How come?* [**P10**:] *'A', I've never read them. 'B', I don't feel the need.",* and (ii) "*We mainly just use this one. Because I don't know what this is and I don't know what that is. So I just mainly put it on 60 for towels and stuff. And it's nice in there. And I put in there cuz delicate is too cold. And then we just press the start button. Yeah."* (**P8**).

Clearly both of these participants did not know of or consider *trimming* by using more energy-efficient settings (*e.g.*, shorter wash/rinse/dry cycles). However, as discussed previously, simple awareness of more energy-efficient options does not ensure that people will try—and continue—to use them. Analysis of participants' interactions with appliances, such as the washer and dryer, suggests that such an unwillingness to change may be attributed in part to the particular details of the interface. For example, **P15** described unwillingness to wash white loads on cold in terms of the interface options provided: "[**Q:**] *What would it take for you to wash them* [clothes] *on cold…?* [**P15**:] *I don't know… I guess, if they started making washing machines with only that option, because everything was alright with cold… They must include those there for a reason… They must be giving you these options for a reason. Now, I suppose if I bought a washing that only had a cold cycle on it, then that's what I'd do."*

Here, **P15** justifies her use of higher temperature settings by noting that since they *are* available options, it must be expected that they will be used. Further, we note that "hot", "warm", and "cold" settings on clothes washers are not simply *available* options, but the interface layout and design tend to hold specific assumptions about user interaction with these options: (i) they have high priority (*e.g.*, they are large and accessible options compared with, say, a "hold rinse" option) and (ii) they are used with similar frequency (*e.g.*, hot, warm and cold are often given buttons of equal size, grouped in-line in order of increasing heat). The extent to which appliance interfaces shape and reinforce behavior is suggested more subtly in the ways in which participants map available interface options onto their behavior. For example, **P3**, (one of two "conservers" in our home study), describes his use of the clothes washer interface: "[**P3**:**]** *And then these are for the temperature of your water. So hot, cold, warm. So depending on my clothes, I'll change it*. [**Q:**] Can you give me an example? [**P3**:] *Yeah, so if something's white and its really dirty I'd use more of a hot/cold* [hot wash/cold rinse] *setting. And if something's not that bad I'll go warm.* [**Q:**] *Not too bad…?* [**P3**:] *Yeah, regular. Just like regular laundry.* [He uses cold for 'delicates'].*"*

For **P3**, the three available temperature settings map neatly onto three distinct categories of wash loads: *"really dirty"*, *"not that bad"*/*"regular"*, and *"delicates."* It is interesting to consider how **P3**'s practice may have differed if clothes washer interfaces were designed differently: What if "cold" were the default ("regular") setting and temperature adjustments were made less salient or accessible (*e.g.*, relegated to another section of the interface) or labeled "advanced temperature settings"? What if temperature setting were continuously adjustable? Or the washer did not even have a "hot" setting?

(In)Flexibility

It is important to emphasize that overall our participants were, in most instances, very unwilling to alter their interactions with the wide variety of everyday products and systems we investigated—in order to reduce energy consumption or otherwise. This general "inflexibility" is captured in the following participant responses**:** *"I need them* [various appliances and devices]. *And I desperately need them throughout the day for entertainment and for food and for keeping cool and stuff. And so they're not that flexible. I need 'em. I need 'em to be on. I want 'em to be on all day. And I need 'em when I need 'em."* (**P8**)*;"Well the other* stuff [everything except clothes washer, dryer, and dishwasher] *is, well, if I'm gonna use it I'm gonna use it. So… yeah* [I'm 'not willing to use less frequently']." (**P3**)**;** **"***Yer gonna eat when you wanna eat. Yer gonna watch TV when you wanna watch TV. You know?"* (**P13**).

DESIGNING ENERGY-CONSERVING INTERACTIONS

In this section, we present implications for the design of energy-conserving interactions, including a set of design strategies generated using our proposed framework. We conclude by outlining broader challenges for sustainable interaction design and HCI research.

Interaction affordances and constraints

Our study highlights the importance of considering particular aspects of a product's interface in terms of forcing, shaping, and guiding energy-conserving interactions with that product. Our study revealed that (i) people are often unaware of energy-conserving options for products and, importantly, (ii) people often ignore visible options, instead relying on habit and split-second decisions. Moreover, our field evidence suggests these decisions are predominantly shaped—and enforced—by the interface itself rather than attitudes and conscious, rational decisions. The lack of strong motivations to conserve, and the fact that motivation does not imply people will actually conserve or conserve most effectively, further suggests the importance of designing affordances and constraints [24] to promote conservation behavior. Interfaces such as light switches and refrigerator doors subtly encourage conservation with "closing" affordances; similarly, certain laptop computers (*e.g.*, MacBooks) employ *forced cutting* by automatically going into a low-power state when the laptop is closed. Designers can encourage conservation by carefully emphasizing these kinds of affordances and constraints.

Material scripts; descriptive social norms

Related to affordances [24], we present two additional conceptual tools for analyzing current and designing future energy-conserving interactions with technology: (i) scripts and (ii) descriptive social norms. Latour's concept of *prescription*s [21], or simply *scripts*, is a useful conceptual tool for designers and researchers to more consciously consider the values, norms, and ethics that are prescribed to user interfaces. Scripts act as implicit users' manuals and can be conceptualized in terms of imperatives *"uttered (silently and continuously) by the mechanisms"* that compose a product's interface [21]:157. For example, a refrigerator door is scripted for *trimming* in terms of door-closing ("Close me! Don't let the cold out!"), while a wireless router is not scripted for *cutting* but rather for being "always on" ("It's okay to leave me plugged in."; "Routinely unplugging me is deviant!"). Designers can imagine alternative, perhaps extreme, scenarios in which appliances are scripted for energy-conserving interactions embodying different norms and values. For example, a refrigerator or wireless router scripted for *cutting when not in-use* (*e.g.*, a prominent "light switch" on the product exterior for powering it down); or faucets scripted for *trimming* hot water (*e.g.*, a digital system of gestural interactions to finely control water temperature/pressure). Such conceptual explorations resonate with Gaver and Martin's explorations of information appliances that *"embody values apart from those traditionally associated with* [individual] *functionality and usefulness."* [13]:233. Explorations in line with Gaver and Martin's methodology and intent should further be explored in relation to *cutting, trimming, etc.*, to advance understandings of how energy-conserving interactions may be *experienced* in terms of pleasure, engagement, *etc.*—helping ensure such interactions do not focus on shaping behavior to the neglect of individual subjective (aesthetic) experience.

Latour's concept of scripts, and more generally the notion of artifacts as social "actors", can further be related to the social-psychological concept of *descriptive social norms*, which refers to *"perceptions not of what others approve but of what others actually do."* [5]:263. Cialdini presents several compelling experiments demonstrating that *"people frequently ignore or severely underestimate the extent to which their actions in a situation are determined by the similar actions of others."* [5]:264. As an example of the power of descriptive social norms, rephrasing messages to encourage reusing hotel towels as "descriptive normative" messages was found to increase compliance by 28.4%. ([5] citing [14]). Instead of highlighting "energy efficient" settings on, for example, washing machines, designers might instead highlight a "high-energy" cycle, reversing descriptive normative messages to imply that the high-energy option is not "normal" usage. When designing for energy-conserving interactions designers should keep in mind that interfaces subtly communicate and propagate "normal" and "abnormal" user interaction; designers and designs help define what constitutes "normal" behavior.

Feedback and "awareness"

Our study has shown a general lack of "energy literacy" among participants while also suggesting limitations of motivating conservation action through general energy and price awareness alone. These findings suggest gaps in feedback research: How do various types of feedback affect *specific behaviors with respect to specific devices*? To what extent does feedback motivate behavior at a behavioral versus reflective level of cognition? Given the apparent limitations of motivating through price awareness alone, designers should continue exploring feedback for various forms of motivation—including aesthetic and experiential aspects of energy [*e.g.*, 23,withheld]—as alternatives or complements to more traditional feedback [*e.g.*, 11].

Design Strategies: Operationalizing the framework

In this section, we present a set of design strategies that we have generated by applying our framework, consisting of a vocabulary of energy-conserving actions: *(i) cutting, (ii) trimming, (iii) switching, (iv) upgrading,* and *(v) shifting.* The strategies we propose in this section further demonstrate how our framework can be operationalized to generate design insights, principles, strategies, *etc.* We want to emphasize that we consider these strategies as starting points rather than definitive strategies; indeed, they are only a sample of the strategies and concepts we have generated. It is our hope and intention that more such strategies for sustainable interaction design will be developed and employed using our framework and adaptations thereof.

Relabeling "normal." Related to our discussion of descriptive social norms, labels that highlight "energy efficient" options can be reversed to instead highlight "energy intensive" options—*e.g.*, reframing *trimming* as a "normal" and expected interaction. For example, electronic devices with batteries—such as laptop computers, mobile phones, and portable MP3 players—can highlight "short battery lifetime" management options; energy efficient options can be relabeled as "normal" or "regular" settings. Similarly, appliances like dishwashers, washing machines, and refrigerators can label "high energy" settings while labeling energy-efficient settings "normal" or "regular."

Defaulting. Energy-inefficient default settings and presets can be removed and even replaced with energy-efficient default settings and presets in order to encourage energy-conserving interactions. For example, a washing machine can *default to trim* by defaulting to "cold." A new generation of appliances designed for energy demand-response [9] might *default to shift* or *default to extend*. For example, a clothes washer could default to *shift*ing the start of a wash load to an off-peak period or *extend*ing a load during a peak period.

Foregrounding efficiency options. Our study revealed many unconsidered options with respect to *trimming*, *cutting*, *etc.,* which participants did not use, understand, or even realize were available. The low visibility and accessibility of these unconsidered options make them difficult to use and further sends an implicit message to users that these options are less important and less "normal." Efficiency options can instead be foregrounded while *backgrounding inefficiency options*. For example, designers can *foreground trimming* by making temperature adjustments on refrigerators more accessible and salient, such as by moving the setting adjustment to the product exterior; an "off" option can be included on the temperature setting in order to encourage *cutting when not in-use* (*e.g.*, *cutting* an empty refrigerator when on vacation).

"1-click" cutting. While most participants were largely unmotivated to conserve, they still engaged in *cutting when*

not in-use when it was obvious and convenient; otherwise, they often did not *cut* lights, computers, televisions and other devices. Similar to Amazon.com's "1-click" shopping, energy-consuming products could be designed with *"1-click" cutting*, making various cutting options (*e.g.*, power-off, standby) as simple and convenient as possible.

Upgradeable interfaces. Upgrading, as we have defined it in this paper, can be considered in terms of upgrading parts or modules of a product. In particular, we can consider upgrading the interfaces of products in order to reflect current "best practices" in energy conservation—such as the types of interface redesigns we have proposed thus far. For example, appliances with digital interfaces (*e.g.*, touch-screens) can automatically update via wireless Internet connection, similar to software upgrades on computers. Designers can also then iteratively evaluate the conservation effectiveness of interfaces in-context. *Upgrading* entire products may save users' energy, but the manufacture and disposal processes that accompany the replacement of electronic devices also consume energy and further produce e-waste pollution [16,17,withheld]. Upgradeable interfaces are one way to continually update interfaces for energy-conserving interactions while minimizing product obsolescence and disposal.

BROADER IMPLICATIONS FOR HCI RESEARCH

While our research has suggested opportunities for designing more energy-conserving interactions, it also suggests broader challenges, opportunities, and areas for criticism. It is well beyond the scope of this paper to engage with these issues in detail, but we nonetheless raise them as matters for future engagement from the HCI community.

Interaction / Automation. Increasingly there is a drive to automate home systems to be more energy-efficient, as well as comfortable and convenient. User interaction will necessarily play a vital role, although this interaction may be quite different than traditional interaction with home appliance interfaces. For example, individuals may interact with "homes-as-interfaces" so smart devices and systems can learn dwellers' patterns and preferences over time. A range of usability and user experience issues must be considered, and we argue that it is important for designers to keep interactions such as *cutting*, *trimming*, *etc.* in mind when designing such interactions. Our findings suggest that *cutting when not in-use* is a commonly understood, although not necessarily routine, part of users' everyday interactions. Designers need to ensure that interactions like *trimming*, *shifting*, *etc.* enter into our everyday vocabulary in the context of future "smart" products and systems.

Low-tech / High-tech. Are high-tech solutions always most appropriate? For example, a simple relabeling of buttons may be more appropriate than a novel high-tech feedback system in certain cases. More generally, HCI research can and should explore systems that challenge underlying assumptions about what is necessary and desirable with respect to energy consumption—for example, by considering *"minimum feasible power"* [18] as a principle to guide design. We have proposed *cutting* as one type of energy-conserving interaction to design for; how might we also consider designing for the special, more radical, case of *relinquishing*: permanently powering off a device?

Technical change / Individual change / Socio-cultural change. While "smarter" and more "efficient" products and systems promise to offer technical and interactive solutions in terms of reducing energy consumption, these systems also make various assumptions about how we can and should live, *e.g.*, individuals will live in homes with (large) HVAC systems, entertainment centers, refrigerators, *etc.* As discussed by social anthropologist Harold Wilhite, *"The replacement of one technology with a more efficient one may reduce the energy input but not the total amount of energy demanded for the energy service…behaviour and household technology are mutually implicated in the demand for these services."* [34]:29. As suggested by sociological perspectives on sustainable consumption, *"intervention designers need to recognize critical moments when sociotechnical regimes are openly changing and can be most easily influenced."* ([35]:188 citing [27]). Rising interests in energy demand-response and dynamic pricing [9] are creating new opportunities for radically reforming the relationship between energy consumers and producers; for example, *"interruptible loads challenge the established norm that a utility company's role is to provide electricity to meet demand."* [35]:188. HCI and interaction design should, and will, play a role in shaping new paradigms of energy consumption: What will the *shift* and *extend* buttons on appliances of the future look like? What types of new social norms and expectations can arise regarding "normal" everyday interactions with respect to *trimming, shifting*, *etc.*?

In this paper, we have uncovered and articulated ways in which energy consumption behaviors are strongly shaped by seemingly small, easily overlooked design decisions—rather than clearly following from informed, intentional, and conscious actions. As our analyses have revealed, our everyday domestic environments are simply *not* designed to promote and sustain energy-conserving interactions—*cutting, trimming*, *switching*, *upgrading*, *shifting, etc*. That is, our everyday interactions are unsustainable owing largely to products and systems that *are themselves unsustainable*. HCI and interaction design must consider this as we (re)design our future interactive products and systems, which in turn will (re)shape and (re)define our future ways of being. We believe the framework and strategies presented in this paper are one important step towards a future in which our "normal" ways of being truly are sustainable ways of being.

REFERENCES

1. Aoki, P. M., Honicky, R. J., Mainwaring, A., Myers, C. Paulos, E. Subramanian, S., & Woodruff, A. (2009). A vehicle for research: Using street sweepers to explore the

landscape of environmental community action. In *Proc. CHI '09*, 375-384.
2. Blevis, E. (2007). Sustainable interaction design: invention & disposal, renewal & reuse. In *Proc. of CHI '08*, 503-512.
3. Chetty, M., Tran, D., & Grinter, R. (2008). Getting to green: understanding resource consumption in the home, In *Proc. Ubicomp '08*, 242-251.
4. Chetty, M., Brush, A.J., Meyers, B., & Johns, P. (2009). It's not easy being green: Understanding home computer power management In *Proc. CHI '09*,1033-1042.
5. Cialdini, R. (2007). Descriptive social norms as underappreciated sources of social control. *Psychometrika*, *72*:263– 8.
6. DeCanio, S. (1998). The efficiency paradox: Bureaucratic and organizational barriers to profitable energy-saving technologies. *Energy Policy*, *26*(5): 441-454.
7. Dillahunt, T., Mankoff, J., Paulos, E., & Fussell, S. (2009, In press). It's not all about green: Energy use in low-income communities. In *Proc. of UbiComp '09*.
8. DiSalvo, C., Boehner, K., Knouf, N., & Sengers, P. Nourishing the ground for sustainable HCI: Considerations from ecologically engaged art. In *Proc. CHI '09*, 385-394.
9. Earle, R. & Faruqui, A. (2006). Toward a new paradigm for valuing demand response. *The Elec. Journal*, *19*: 21-31.
10. Fallman, D. (2003). Designing design: Design-oriented human-computer interaction. In *Proc. of CHI '03*, 225-232.
11. Fischer, C. (2008). Feedback on household electricity consumption: a tool for saving energy? *Energy Efficiency*, *1*:79-104.
12. Froehlich, J., Dillahunt, T., Klasnja, P., Mankoff, J., Consolvo, S., Harrison, B., & Landay, J. UbiGreen: investigating a mobile tool for tracking and supporting green transportation habits. In *Proc. CHI '09*.
13. Gaver, W., & Martin, H. Alternatives: Exploring information appliances through conceptual design proposals. *Proc. of CHI '00*, 233 – 240.
14. Goldstein, N., Cialdini, R., & Griskevicius, V. (submitted). A room with a viewpoint: Using norm-based appeals to motivate conservation behaviors in a hotel setting.
15. Gram-Hanssen, K. (2007). Consuming Technologies – developing routines. *Jour. of Cleaner Prod.*, *16*:1181-1189.
16. Hanks, K., Odom, W., Roedl, D., & Blevis, E. (2008). Sustainable millennials: Attitudes towards sustainability and the material effects of interactive technologies. In *Proc. of CHI '08*, 333-342.
17. Huang, E.M. & Truong, K.N. (2008). Breaking the Disposable Technology Paradigm: Opportunities for Sustainable Interaction Design for Mobile Phones. In *Proc. of CHI '08*, 323-332.
18. Illich, I. (1974). *Energy and Equity*. Marion Boyars.
19. Jackson, T. (2005). Motivating sustainable consumption—A review of models of consumer behaviour and behavioural change. A Report to the Sustainable Development Research Network. Policy Studies Institute.
20. Kempton, W., Harris, C., Keith, J., & Weihl, J. (1985). Do Consumers Know What Works in Energy Conservation? In Byrne, D., Schulz, M. & Sussman, M. (eds). *Families and the Energy Transition*. Haworth Press.
21. Latour, B. (2000). Where are the missing masses? The sociology of a few mundane artefacts. In Bijker, W. E. & Law J. (eds). *Shaping Technology/Building Society: Studies in Sociotechnical Change*. MIT Press.
22. Lutzenhiser , L. (1993). Social and Behavioral Aspects of Energy use. *Annual Review of Energy and the Environment*, *18*: 247-289.
23. Mazé R, & Redström J. (2008). Switch! Energy Ecologies in Everyday Life. *Int. Journal of Design*, *22*(3): 55-70.
24. Norman, D. (1990). *The Design of Everyday Things.*
25. Odom, W., Pierce, J., Stolterman, E., & Blevis, E. (2009). Understanding why we preserve some things and discard others in the context of interaction design. In *Proc. CHI '09*, 1053-1062.
26. Pierce, J., Odom, W., & Blevis, E. (2008). Energy Aware Dwelling: A Critical Survey of Interaction Design for Eco-Visualizations. In *Proc. OZCHI '08*, 1-8.
27. Shove E., Lutzenhiser, L., Guy S., Hackett B., & Wilhite H. (1998). Energy and social systems. In Raynor, S. & Malone, E. (eds). *Human Choice & Climate Change*. 291–326.
28. Shove E. (2004). Changing human behaviour and lifestyle: A challenge for sustainable consumption? In Reisch, L.A. & Røpke, I. (eds.), *The Ecological Economics of Consumption*. 111-131.
29. Stern, P. (2000). Toward a Coherent Theory of Environmentally Significant Behavior. *Journal of Social Issues 56*(3):407-424.
30. Strengers, Y. (2008). Smart metering demand management programs: Challenging the comfort and cleanliness habitus of households. In *Proc. OZCHI '08*, 9-16.
31. Tversky, A. & Kahneman, D. (1974). Judgement under uncertainty: heuristics and biases. *Science, 185*:1124-1131.
32. Verbeek, P-P. (2005). *What Things Do – Philosophical Reflections on Technology, Agency, and Design.*
33. Wakkary, R. & Tanenbaum, K. (2009). A sustainable identity: the creativity of an everyday designer. In *Proc. CHI '09*, 365-374.
34. Wilhite, H. (2007). "Will efficient technologies save the world ? A call for new thinking on the ways that end-use technologies affect energy using practices." In *Proc. ECEEE 2007 Summer Study*, 23-30.
35. Wilson, C. & Dowlatabadi, H. (2007). Models of Decision Making and Residential Energy Use. *Annual Review of Environment and Resources*, *32*.
36. Woodruff, A., Hasbrouck, J., & Augustin, S. (2008). A bright green perspective on sustainable choices. In *Proc. CHI '08*, 313-322.
37. Zimmerman, J., Forlizzi, J., & Evenson, S. (2007). Research through design as a method for interaction design research in HCI. In *Proc. CHI '07,* 493-502.

Contributes a framework and strategies informing the design of more energy-efficient interactions as a matter of sustainable interaction design.