Home, Habits, and Energy: Examining Domestic Interactions and Energy Consumption

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ABSTRACT
This paper presents findings from a qualitative study of people's everyday interactions with energy-consuming products and systems in the home. 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 vocabulary for analyzing and designing energy-conserving interactions is proposed based on our findings, including: *cutting*, *trimming*, *switching*, *upgrading*, and *shifting*. Using the proposed vocabulary, and informed by theoretical developments from various 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 energy-conserving interactions with technology and broader challenges for HCI research are proposed.

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ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Human Factors

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."* [25]: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 investigate the relationships among "normal" domestic interactions with technology, energy consumption, and the design of everyday products and systems in order to suggest ways that "normal" interactions with and practices around technology could be designed to be more sustainable. 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 are 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 appear to be performed without conscious 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 [7]. 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 standards and infrastructures) that compose our everyday material environments. In this paper we focus on the relationships among micro-level design decisions, user interactions, and energy consumption.

Our work builds on a number of empirical studies of residential energy consumption within HCI [4,5,8,27,33]. Our work differs from this body of work by its 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 resulting from our study consisting of a vocabulary of terms used to analyze, discuss, and design specific types of energy-conserving interactions with technology. 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 many prior empirical studies of residential energy consumption.

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

THEORETICAL PERSPECTIVES AND RELATED WORK

The sheer abundance of literature related to residential energy consumption and sustainable consumption in general precludes us from reviewing large and relevant areas of work. Instead, we refer the reader to several excellent reviews of approaches to sustainable consumption [16], residential energy consumption [11,32], and selectively focus on several prior works most relevant to this paper.

Much of the research on sustainable consumption hinges on a critique of the rational choice approach [16]. 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" [28]. 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., 6,16]. Importantly, this suggests that *behaviors can be changed without necessarily first changing attitudes* [16].

Sustainability as a central area of concern for HCI has been proposed broadly by Blevis [3], and within HCI there have since been a number of studies investigating home energy consumption [4,5,8,27,33] as well as the consumption of material products [14,21,30]. A variety of artists, designers, and other practitioners have also explored interactive systems that aim to promote more sustainable consumption of energy [e.g., 2,22].

Situating our approach

In this paper we rely on various theoretical frames and empirical findings to frame and interpret our results. We found sociological perspectives particularly useful in interpreting and explaining our results [e.g., 13,23-25,31], as well as social-psychological approaches [e.g., 6]. Furthermore, our analysis is strongly informed by theoretical developments from philosophy of technology, science and technology studies, and design theory that emphasize the ways in which everyday actions and perceptions are mediated by technology [e.g., 1,19,29] as well as work that applies and develops such theoretical ideas specifically in the context of sustainable consumption [e.g., 17,26]. Additionally, our approach is influenced by design-oriented perspectives within HCI including those articulated by Fallman [10] and Zimmerman, Forlizzi, and Evenson [34]. 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 [3]: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 means to inform design theory and practice.

PARTICIPANTS AND METHODS

Two studies were conducted simultaneously to provide qualitative and quantitative data related to home energy practices and preferences: (i) in-home interviews (with supplemental activities) and (ii) an extensive online survey. For the in-home interviews, 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 (approximately 1-3 hours each) were conducted with all participants. 8 participants from 8 households also participated in a preliminary home visit and interview session and a 3-10 day logging exercise prior to the final extended home interview. Home interviews were semi-structured and focused on everyday interactions with energy-consuming products. Participants gave a tour of their homes, demonstrating and describing their typical use of various appliances and devices. Additional activities supplementing the interviews for many participants included reviewing a recent monthly utilities bill, a think-aloud card-sorting task, and a logging activity. For the logging activity, *consumption placards* with information about the energy and monetary costs of using various appliances were placed on or near the respective appliances; participants indicated their use on a *daily log form*. The goal of the logging activity 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. Interviews were audio recorded and relevant portions transcribed. We reviewed transcriptions and field notes and organized them into emergent themes.

An extensive online survey with a total of 72 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. Data were collected from 646 respondents.

One important potential limitation of our approach that should be acknowledged is the difficulty in understanding people's routine and habitual everyday interactions and practices and how these might change over time and with context. Especially given the limited time we spent with participants during the home visits (typically 1-3 hours per household), we run the risk of relying too heavily on our participants' descriptions and demonstrations of their own consumption practices, which may differ from their actual, day-to-day consumption practices. However, significant steps were taken to understand people's actual rather than self-described energy consumption practices and experiences related to energy consumption. We combined ethnographic interview and contextual inquiry approaches rather than relying solely on self-reported survey or interview data. Importantly, participants physically demonstrated and discussed in context their use of most major appliances, helping ensure our findings were accurate reflections of what people actually do. Many participants kept daily log forms intended to prompt reflection on routine use of appliances prior to contextual interviews. We were also careful to minimize our mention of "conservation", "the environment", etc., instead focusing on the more values-neutral notion of "appliance use" in order to encourage candid responses concerning actual consumption practices.

FINDINGS

Before presenting our findings in detail, it is worth noting the complexities of determining what may or may not be "sustainable." At times our interpretations of our field data assume that a certain interaction is more "energy-conserving" than another and hence is more sustainable. However, assessing the long-term effects of a given interaction systemically in terms of energy efficiency and environmental sustainability is rarely if ever a straightforward task with a definitive outcome. This challenge must be acknowledged in general, and the validity of our specific assumptions, implicitly or explicitly communicated, about what constitutes an energy-conserving or sustainable interaction cannot and should not be uncritically accepted. Indeed, a primary goal of our work described here is to promote more careful and critical examinations of routine and taken-for-granted interactions with products and systems in terms of energy consumption and sustainability. As our analysis will suggest, our selves, our things, and the designers of our things assume a great many things about how we can and should act; it is these things that we argue can and should be examined in terms of energy consumption in particular and sustainability in general.

The results reported below stem primarily from observed consumption practices and self-described participant explanations of these practices ellicited during home visits. These are supplemented in part with initial findings from an analysis of survey responses.

A vocabulary of energy-conserving interactions

An important general outcome of our work is a vocabulary of energy-conserving interactions, which emerged through carefully analyzing the specific types of interactions we did and did not encounter during our fieldwork. This vocabulary provides a more precise way of understanding and describing interactions with technology in terms of energy consumption, and we propose its general applicability as a framework for both analyzing current energy-consuming interactions and designing future energy-conserving interactions. The set of interactions we present may be considered a refinement and extension of the three categories of conservation strategies proposed by Kempton et al., namely management, curtailment, and investment strategies [18]. We have drawn from these themes with a focus on HCI applications and interaction design. The vocabulary is a set of operational terms that capture the actions and strategies of energy conservation efforts and opportunities and are summarized as follows:

1. **cutting—***powering off or putting in an extremely low-power state*, e.g., powering off the television or putting it in a standby state.
2. **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.
3. **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.
4. **upgrading**—*acquiring a more energy-efficient product* to replace a product of the same type, e.g., replacing an older refrigerator with a more energy-efficient model.
5. **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., [9,27]), 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 refined 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. *Trimming* can be further refined as **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 draw on our proposed vocabulary to present and interpret more specific findings from our studies. We then later apply the vocabulary to develop and discuss design recommendations and broader implications in the concluding sections of the paper.

Energy indifference and (over-)consumption

Many interviewees, especially those that did not pay the utility bills themselves, did not know the cost of their recent or typical monthly energy bills. None of our participants knew the cost of 1 kilowatt-hour (kWh) of electricity, or their cost rate structure (e.g., tiered, flat rate, time-of-use). The survey data show that although 80.5% of respondents personally paid their monthly bills, only 25.8% claimed to be "very sure" of 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." Participants 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 specific appliances.

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 participants did express surprise at high prices, they still 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."*

Only in several cases did participants appear to alter appliance use patterns in response to the cost information we provided in the logging exercise. Even the two participants in our study who routinely took major steps to conserve energy did not demonstrate or describe any significant engagement with the cost information or the energy monitoring devices we provided. Not one participant ever used the Kill-A-Watt energy monitor we provided. Several participants 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* [roughly $0.25/day]!" (**P14**).

Still, there were some cases in which the logging activity prompted participants to become more aware of patterns of perceived 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 appear to result new conservation behavior. When conservation behavior was attributed to new knowledge gained through our interventions, ambivalence was typically expressed about whether such behavioral changes would 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 is easy to overlook or forget 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

13,16,24]. 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. 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 example, the participant acknowledged that routine use of the washer was not the result of a conscious and deliberate decision to perform a certain way each time but rather was 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 possible. Indeed, with slight alterations in their routine washer settings, each participant *could* significantly reduce 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.

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.*"

Interestingly, **P8** 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. According to **P8**, *"we make enough money that we don't need to worry about that* [conserving energy]." However, she 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 conservation routines, which typically involved *cutting* lights and other products when not in use: *"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**). It may be that participants in these cases incorrectly inferred a rationale or intention to save energy in order to explain an unconscious or habitual behavior [see, e.g., 6,16]

Conservation: failed attempts and unwitting routines

Participants discussed several instances of *failed conservation attempts* during 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 that she attributed to overuse of the space heater—and despite living in a fairly warm Californian climate—**P6** appeared 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. Participants often described inconveniences 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 was too inconvenient. In this case, the difference between pressing a button at *eye-level* and waiting *several secon*ds to power on or off (the computer monitor) and *reaching down* to press a button and waiting *almost a minute* to power on (the 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 or uncomfortable 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 effective 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 the loud noise it made—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 the logging activity 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 it 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 interactions.

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 [20]—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. When survey respondents were asked for their usual settings on specific appliances, typically about 25-30% claimed "no idea" or "just guessing."

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 used. 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**).

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 decreasing 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 own behavior. For example, **P3**, 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 is 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 the temperature setting was continuously adjustable? Or the washer did not even have a "hot" setting?

Inflexibility

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**)*;"If I'm gonna use it I'm gonna use it* [referring to various energy-consuming products]. (**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 may be largely 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 [20] 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, we present two additional conceptual tools for analyzing current and designing future energy-conserving interactions with technology: scripting and descriptive social norms. Prior research regarding sustainable design and user behavior has employed the concept of scripting [e.g., 17,26], although the HCI and interaction design community has been slow to explicitly acknowledge, apply, and develop this concept in terms of designing sustainable interactions or otherwise. The concept of scripting is an important conceptual tool for designers and researchers to more explicitly consider the values, norms, and ethics that are prescribed to user interfaces. As described by Madeleine Akrich, designed things *"define a framework of action together with the actors and the space in which they are supposed to act."* [1]:208. Scripts act as implicit user's manuals and can be conceptualized in terms of imperatives *"uttered (silently and continuously) by the mechanisms"* that compose a product's interface, as described by Latour [19]: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).

The concept of scripting, 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."* [6]: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."* [6]: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%. ([6] citing [12]). 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.

Design strategies: Operationalizing the framework

In this section we present a set of design strategies that we have generated by applying our framework, which consists of a vocabulary of energy-conserving interactions: *cutting, trimming, switching, upgrading,* and *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 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 could be included on the temperature setting 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. Designers 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 [14,21]. Upgradeable interfaces are one way to 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 and 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 and 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, considering *"minimum feasible power"* [15] as a principle to guide design. We have proposed *cutting* as one type of energy-conserving interaction for which to design; how might we also consider designing for the special, more radical, case of *relinquishing*: permanently powering off a device?

Technical change, individual change, and sociocultural 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."* [31]: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."* ([32]:188 citing [23]). Rising interests in energy demand response and dynamic pricing [e.g., 9,27] 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. Yolande Strengers has specifically discussed opportunities for HCI to contribute to the reconfiguration of comfort and cleanliness expectations and practices in the context of water and electricity smart metering demand management programs [27]. 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 redesign our future interactive products and systems, which in turn will reshape and redefine 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.

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