Designing Persuasive Technology to Manage Peak Electricity Demand in Ontario Homes

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ABSTRACT
When it comes to environmental sustainability, the time that electricity is consumed matters. For example, using an air conditioner on a hot summer afternoon as the power grid is strained necessitates the use of more polluting sources to meet demand. In this paper, we analyze end-user response to two utility-driven conservation programs in Ontario, Canada: Time-of-Use pricing and the peaksaver program. We find that time-of-use pricing encourages shifting some electricity demand, but only when it is convenient. We also find that while potentially effective at a larger scale, the peaksaver program in its current form is unattractive to participants. These results are discussed in the context of Fogg's Behavior Model for Persuasive Design, which allows us to explore the design space for improvement to these programs and ground our design implications for the design of technologies to encourage reduction of peak electricity demand.

Author Keywords: Sustainability; Peak Electricity Load; Persuasive Technology; Design

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
One area of interest to HCI researchers has been the study of tools, interfaces, and devices that can encourage a reduction in electricity consumption. In this area, we find studies of in-home displays [8,12], prototypes of the smart grid [7] and use of smart thermostat control [21,34], among others.

Alongside research deployments to encourage reduced electricity use, electrical utilities are also very concerned about when electricity is consumed. On a daily basis, the demand for electricity varies from low during overnight hours to higher during the day. Summer heat waves can cause extremely high demand to be placed on the electrical grid, with residential cooling account for nearly 22% of the peak demand [17]. Failure to meet this peak demand can cause disruptions in electricity availability – brownouts, rolling black outs, or even wide-spread power outages. In order to avoid this, utilities manage supply to ensure that they meet peak demand. There are side-effects and trade-offs from the possible solutions. One option is to simply have larger power plants with surplus generating capacity. The downside is that power plants are most efficient when they are being run consistently at their full capacity. Alternatively, special generating plants can be constructed solely to be used during times of particular need – which could be as infrequently as a few hours per year [35].

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To reduce the varying demand for electricity and the attendant financial and environmental costs of that varying demand, several electrical utility companies have devised programs to encourage more optimally timed consumption of electricity. The two specific program types we focus on in this paper are:

- **Variable pricing schemes**, where electricity rates vary consistently depending on time-of-day. The goal of variable pricing is to encourage behavior change on the part of the consumer, to use less electricity at daily peak times.
- **Critical peak load programs**, where participants opt-in and allow the utility to selectively control their home air conditioning units. This allows the utilities to lower the demand for electricity at critical peak times.

The end goal of both research-led and industry-led programs is to persuade consumers to change their habits with respect to the consumption of electricity. In the HCI research community, we are familiar with technologies to encourage behavior change, such as BJ Fogg's work on persuasion and behavior [9]. Many designers and researchers have explored how deployed technology can be leveraged to encourage positive action in communities of end-users [e.g. 6].

This paper presents a set of design implications for persuasive technology to encourage or enable a reduction in electricity demand from households at these peak times. To develop these, we conducted interviews with 18 people who were automatically enrolled or opted in to the versions of the industry-led programs in Ontario, Canada, in order to understand the impact of these programs on their day to day practices. These findings were then analyzed using Fogg's Behavior Model for Persuasive Design [11], along with consideration of other models of behavior change to see where these programs are missing opportunities and how they can be improved. Along with the widespread availability of smartphones and internet-enabled thermostats, we begin to explore ways that programs can evolve to better satisfy end users and lead to reduced demand at peak load times.

The remainder of this paper is organized as follows. In the next section, we discuss related work. We then describe the methodology of the study and present results of the interviews. We conclude by presenting a series of design recommendations that arise from our interview findings and existing knowledge of behavior change.

BACKGROUND AND RELATED WORK

Behavior Change

In his exploration of persuasive technology, Fogg introduced a Behavior Model for Persuasive Design (FBM) [11]. FBM proposes that in order for a target behavior to take place, three criteria are necessary. Firstly, the person must be sufficiently *motivated*. Secondly, the person must have the *ability* to execute the behavior. Thirdly, if the first two criteria are met, there must be some sort of *trigger* to actually suggest the behavior at an opportune moment. Fogg places the first two aspects as axes demonstrating a tradeoff between *motivation* and *ability* (see Figure 1).

Even if a person's *motivation* is low, if you can make the target behavior very easy to do (high *ability*) then it is likely a *trigger* will succeed in prompting the desired behavior. Successful persuasive design will increase the position on of the axes, or will provide opportune *triggers*. FBM allows for a structured analysis of programs and technologies.

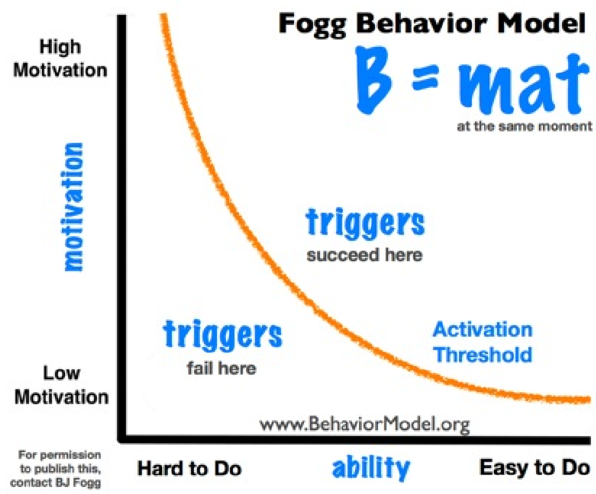

Figure 1 - Fogg's Behavior Model (© BJ Fogg) [10]

Other models of behavior change have been used in HCI research, including the stage-based, or Transtheoretical Model (TTM) of behavior change [5], and work has been done to help bridge the gap between behavior change research in HCI and established Behavioral Theory [16]. He et al. incorporate the TTM and acknowledge that it is necessary to target eco-feedback design interventions to the individual because of the different stage and unique circumstances they are in [15]. We include some discussion of targeting interventions based on TTM in our design implications. However, most HCI work using the TTM focuses almost exclusively on motivation. We argue that FBM offers a more holistic perspective, through the additional consideration of how technology can increase ability and be used as triggers.

Many other theories of behavior modification exist. Classical concepts such as operant conditioning (positively reinforcing or punishing certain behaviors) are considered throughout this work, particularly with respect to the monetary incentives. Operant conditioning is part of the larger discussion of increased motivation, ability and triggers. However, operant conditioning through positive reinforcement can lead to the "over-justification effect" [22] where the incentives or rewards reduces intrinsic motivation. Countering the over-justification effect is self-perception theory, which argues that attitudes are influenced by behavior. Other theories abound: balance theory, cognitive dissonance theory, social comparison theory, discursive practices, etc. At heart, these theories examine how attitudes and behaviors are linked, and these theories are implicitly incorporated into FBM. As Fogg notes, motivation includes pleasure/pain, hope/fear, and social acceptance/rejection, and ability includes time, effort, cognitive complexity, social deviance, and habitual vs. non-routine behaviors. Many of the psychological theories of the link between attitude and behavior or of behavior change can be mapped onto these dimensions of FBM.

Sustainability in the HCI Community

Creating a sustainable future requires contributions from a large set of disciplines – engineering, green design, and renewable generation, among others. Even within the HCI community, there is discussion of what role HCI can best serve in this research community, and how to best go about it [14,19]. Prototyping the smart grid is becoming increasingly common in recent HCI work [7,27,34], and Costanza et al. propose that HCI in particular is well positioned to prototype and study interfaces for the increasingly complicated electricity system now, while they are still being developed [7].

Going Beyond Eco-Feedback

Brynjarsdóttir et al. provide a review of HCI research in persuasive technology for sustainability from 2009 to 2011, and argue that much of the research done so far has been focused on making users "more aware" of their consumption through feedback, which is taking a limited view of the problem [3]. Pierce and Paulos express similar views in another review of HCI research that emphasizes electricity consumption feedback [25], and also suggest that investigating demand response technologies could be particularly interesting from an HCI perspective, given the deeper behavior change that would be required. With a few exceptions [2,32], this area has been relatively unexplored.

Focus on the Human and Everyday Practice

Strengers gives a name to the practice of designing for increasing awareness: designing for "Resource Man" [33]. This fictional character is interested in technology, educated, motivated to manage his resource consumption in a fully rational way, and stereotypically male. She argues that design geared toward Resource Man will ultimately fail because it neglects lived experiences. Brynjarsdóttir et al. [3], similarly, note that much research in sustainability has been grounded in a "modernist" approach, i.e. the assumption that once quantified and provided with expert-level advice, individuals will act rationally to improve their practices. They also argue that we need to refocus on lived experiences both with respect to the individual and to the collective. Some recent research (e.g. [18,26]) has explored domestic interactions as a mechanism for understanding constraints on behaviors within households. Our goal, similarly, is to examine the lived experiences of households subject to both variable pricing schemes and critical peak load programs as a first step to a broader perspective.

FBM and Sustainability

Brynjarsdóttir et al. [3], in their survey of sustainability in HCI, note that much HCI research in sustainability leverages Fogg's ideas of persuasion and technology to encourage sustainability. However, they also note that, of the papers that they surveyed, *"almost half"* had no evaluation, and that the *"typical duration of a field study is 3-4 weeks, which is likely not long enough to go beyond novelty effects"*.

In this paper, FBM is leveraged to guide the analysis and re-design of two demand management programs that have been deployed for several years. In our analysis, we find that FBM frames data on these programs' successes and failures while retaining a link to past research in designing new persuasive technologies to promote conservation. As a result, it serves both as a reflective tool on the efficacy of existing programs [13] and as a tool to guide redesign of different aspects of these programs.

CASE STUDY CONTEXT

The research presented in this paper is based on a case study of two specific programs that are currently implemented in Ontario, Canada. Currently, the baseline electricity needs of Ontario are met by nuclear and large hydroelectric power stations. The peak demand is generally met with natural gas powered plants, as well as some smaller hydroelectric plants [36]. Thus, reducing peak demand in Ontario can directly lead to reduced greenhouse gas emissions. The existing programs are a variable pricing scheme for electricity, i.e. time-of-use pricing (TOU), and a program for mitigating the severity of critical peak usage, the peaksaver program (peaksaver).

These specific programs in Ontario, Canada were chosen as a case study in addressing power consumption for a number of reasons:

- Ontario experiences notable peaks in electricity consumption – both daily and at critical times;
- There exist specific programs that are well defined to address these peaks, and these programs have existed for a number of years;
- Other researchers have used these programs and the Ontario context to perform quantitative analysis of the costs and benefits of these programs, which provides complimentary data to our analysis.

Beyond the pragmatic reasons outlined above, there are issues of social sustainability surrounding power generation in Ontario. In 2013, political decisions to relocate new power plants to pacify voters during an election campaign resulted in almost $1 billion in costs to Ontario taxpayers. Essentially, power consumption in Ontario is an issue of active public discourse, increasing public awareness of both the environmental, economic, and social problems surrounding electricity production and consumption and programs designed to address these problems.

INTERVIEWS

While in this work we build from existing models of behavior change, we first need to know more about the existing practices surrounding shifting electricity consumption to off-peak times. While studies have focused on electricity consumption as a whole [15,26], peak demand and shifting usage has not been a major focus.

Method

The study consisted of 18 semi-structured interviews that took place in person, by phone or by Skype. Participants received a $20 gift card to an online retailer for their time.

Participants were recruited through email lists, online classified ads throughout Ontario, word of mouth, and posters at local community centers and libraries. Participants were pre-screened before being interviewed in order to ensure a variety of participants with respect to age, who they live with, what type of dwelling they inhabit, whether they have central air conditioning, the type of thermostat they use, and involvement and knowledge about the peaksaver program. See Table 1 for a summary.

Table 1 - Background Data of Interview Participants

Age	20s: 6 30s: 7 40s: 5
Gender	Female: 13 Male: 5
Air Conditioning	Central Air Conditioning: 14 Portable or window: 4
Lives with	Partner only: 6 Partner and children: 5 Parents (with or without siblings): 3 Roommates: 3 Alone: 1
Peaksaver	Enrolled: 3 Previously enrolled: 1

The interviewer had a set of topics and some starter questions to discuss, but the interviews were also open ended in order to learn more about specific habits, devices and programs of the participants. The topics included:

- Usage of air conditioning;
- Control of the thermostat;
- Awareness and consideration of TOU pricing when making consumption decisions;
- Awareness and consideration of peak load times
- Thoughts about various existing demand response programs and pricing schemes; and
- Awareness and consideration of the peaksaver program.

Interviews lasted between 30 minutes and 1 hour. All interviews were audio recorded and then transcribed for analysis. Affinity diagramming done by two researchers, using incremental, open coding was used to group codes into 95 clusters. A cross cutting analysis linked these clusters into 4 themes. A subset of these themes and clusters are presented in this work in the context of the two Ontario programs.

TIME-OF-USE PRICING

Details and Related Work

While many variants of differential pricing of electricity exist, Ontario's TOU pricing scheme varies the price of electricity throughout the day at three different levels (off-peak - 7.5 ¢/kWh, mid-peak - 11.2 ¢/kWh and on-peak - 13.5¢/kWh as of Sept. 2014) on a consistent schedule. This schedule changes twice per year (summer versus winter). Overnight (7pm to 7am) is always off-peak, as are weekends and holidays. In practice, the overall financial benefits for many consumers from shifting usage due to TOU pricing are small, particularly when considering that paying for electricity makes up only about 1.8% of average total household expenditure in Ontario [28]. As of May 2014, 95.9% of households and small business paid these variable rates for electricity in Ontario [24].

The scope of Ontario TOU pricing has led to research on the programs as a whole. At a macro level, Strapp et al. found that TOU pricing does encourage some shifting, and there is often a small net conservation effect when the shifted consumption is less than the peak period reduction [31]. Rowlands and Furst found that bills changed by less than 5% in either direction as a result of the adoption TOU pricing in Ontario [29]. Adepetu et al. criticize the existing distribution of hours and prices as being neither optimal nor effective at reducing the mean peak-to-average ratio of demand [1].

Outside of the Ontario context, Strengers examined smart metering demand management programs in Australia [32], which included the use of In-Home-Displays (IHDs) along with a critical peak/TOU pricing scheme. She notes that the decisions people make about using resources for the comfort and cleanliness of their homes is much more complex than a rational decision about optimizing resource consumption or cost. Specifically, programs and technologies that seek to foster behavior change should allow for the tensions between convenience/comfort and cost [32]. Many of our findings echo this.

There are a variety of technologies that support consumers in adapting to TOU pricing. Research on programmable thermostats indicates that the challenge of programming these devices limits their impact [23]. Direct feedback through IHDs can reduce overall consumption by 5-15% in the short term [8].

Findings

Money Incentivizes Easy Shifting

There was a common sentiment of why not shift usage if it saves a bit of money and is convenient. The consensus was that the off-peak times are a convenient time to do laundry and run the dishwasher for those with a regular weekday working schedule.

On the other hand, many participants noted that, without the potential to save money, they might not consider load shifting, and that the money causes them to act. For P4, *"if it works in your schedule, any money is worth it"*, since *"money is a tangible thing, where you're like 'I'll wait that extra hour'"*. Although we probed, we found little evidence that participants were motivated by sustainability, or other concerns when shifting day to day usage.

Not all Shifting is Easy

The ease of shifting any one activity varied across participants. P17 worked from home, and found it convenient to do laundry at lunch time. She was fully aware that it cost a little more, but felt that *"I'm also like, I don't want to do this tonight, when I'm tired, so, I'll pay the extra"* combined with justifying the small expense by saving money in other ways. Cooking was an interesting example for participants too, and behavior fell on a continuum which varied from never shifting despite TOU pricing (P2), to saving long roasting for the weekends but using the stovetop on weeknights (P10, P11, P5), to P7 who stated that *"I've actually sat there like ok we're going to make dinner. Ok like I could start cooking at 6, but I'll just wait until 7"*. A number of our participants had gas ranges, so this discussion did not apply.

Considering TOU in Home Cooling is Uncommon

One of the most important aspects of peak electricity demand is the use of air conditioners during hot, humid summers in Ontario. Only two participants directly mentioned making explicit changes in home comfort using the thermostat because of TOU pricing or consideration of daily peaks. These included purchasing a programmable thermostat for use with both air conditioning and electric heat (P10) and pre-cooling the house to avoid using the air conditioner during peak hours (P2). Other participants had programmable thermostats, but either did not program them or did not consider TOU in the process. Most focused only on the overall cost of using their air conditioner. Many also noted that they were more concerned about the temperature in their home for the comfort of family members - children and older parents at home during the day - or guests and pets, as opposed to themselves. This resonates with Fogg's inclusion of social acceptance as an important contributor to the motivation axis [11], as well as Strengers' findings [32].

The Impact of Shifting is Unclear

P5 explains she has *"a hard time visualizing what my little impact of not doing my load of laundry in the, during the day has on the broader system, although I recognize that if everyone was doing their laundry during the middle of the day it might be a bit of an issue"*. Without some awareness of the broader impacts of collective action, our participants, instead, weigh the cost versus inconvenience to them.

PEAKSAVER PROGRAM

Details and Related Work

The peaksaver program [37] is an opt-in program, designed to address critical peaks in electricity consumption. Residents of single-family homes with central air conditioning are offered a free internet-connected, programmable thermostat. In exchange, the utility installs a controller on the air conditioner. During critical peak load times, the target temperature of the air conditioner is either increased by up to 2ºC or cycled off for 15 to 30 minutes every hour for up to four hours of the day. These occurrences are limited to weekdays, and a maximum of 10 times per year.

Examining specifically the peaksaver program in Ontario, Singla and Kehsav suggest that there are not enough people participating in the program on a voluntary basis to significantly impact consumption [30]. They devise a scheme that would pay participants up to $2 per degree hour that they increased the setpoint of their thermostat in the summer (for central air conditioning) and demonstrate that this scheme would still reduce operating costs in Ontario by $688 million in the next 20 years, by reducing the need for the construction of new power plants.

Strengers' studied critical peak pricing in Australia, with day ahead notice by email or phone call [32]. In this scheme, prices increased by 10 to 20 times on hot weekday afternoons, to better match the real time price of electricity at those times. She found that those who participated in the critical peak pricing program were more likely to sacrifice comfort in the short term specifically because of the high cost of power at critical peaks.

The option of paying consumers for signing up has been leveraged by Nest through a program called "Rush Hour Rewards" [38]. These "Rush Hours" are simply an analogy for peak load times. With this enabled, the Nest thermostat pre-cools the home, then ensures that the air conditioner runs only intermittently during peak times. The user can override the Rush Hour if desired.

Findings

Few Understand Critical Peak Load

Having some awareness of critical peak load times and their significance is the first step towards having some non-zero motivation to reduce usage at times of critically high demand for electricity. For our participants, even this awareness is missing. Some participants were able to identify that peak load times correspond to heat waves, but did not make the connection to the impact on electricity demand in the moment.

Taking Action is Hard

When asked directly about taking action or changing behavior at peak load times, there was a common sentiment among many of the participants that they were already doing the best they could to reduce electricity consumption at all times (generally because of cost), and there was not much that they could change and still live their life comfortably at critical peak times. Some were aware of the environmental impact and the small monetary cost from TOU, but comfort in their home took priority. P11 explains that *"I realize that I probably shouldn't be and I realize that you know, there's probably, every other person in this apartment building is probably doing the same thing, but I do want to be comfortable"*. For P8, *"being so hot, like it kind of trumps, like the amount, or the cost that you know you'll have to pay later"*. Some participants did take action as required: P5 and P7, who had only portable air conditioning units, discussed going to work in order to be in the air conditioning there.

One issue that arose during our discussions with participants is that many people do not have any control over the temperature at work, and the choices made by their workplace did not correspond with what they might choose in their own home, either for comfort or financial reasons. P7 suggests that even at critical peak times, *"I don't change any of my habits at work"* because it's *"totally financially motivated, which makes me kind of sad"*. P4 laments the lack of control at work, and was frustrated that it makes her own efforts at conservation seem negligible. P15 recalls *"I hated it going in to work and I had to dress like it was winter inside. It doesn't need to be that cold"*. Some participants expressed similar feelings of preferring open windows or a higher temperature in the home, but were overruled by roommates or family members.

Others May Not Do Their Part

This idea of collective action was also significant when we discussed rolling blackouts or brownouts because of insufficient supply. P9 noted that *"we would try to reduce [consumption] but then we'd also probably get kind of annoyed when other people don't [...] we'd want that conservation to go on not just from us, we'd want it to be everybody"*. Similarly, P11 suggested that *"if only one person changes their behavior and no one else does, then it really doesn't help"*. The perceived threat and inconvenience of blackouts was a much bigger motivator for some more than others. For example, P17 explained that a previous blackout *"certainly put a monkey wrench in my day to day existence"*. On the other hand, P18 figured *"we're not going to be the only ones in the blackout, so it wouldn't really affect our usage"*, and says *"to me a blackout wouldn't be such a big deal"*.

A number of participants also commented on the practices of neighbors or relatives being noticeably inefficient in general. One participant knew others who had *"a really bad habit of running their air conditioning and leaving their windows open"*. The question then becomes how to design solutions that reach those people too.

Peaksaver

Three of our participants were currently a part of the peaksaver program: P1, P3 and P17. P16 participated but when she switched energy providers, that provider did not offer the peaksaver program. P1 learned about peaksaver through an ad in the newspaper promising a free programmable thermostat, but it became clear in the interview that he was not aware of the fact that the utility had the option to cycle down his central air conditioner during peak times. P1 was actually quite averse to the idea of utility being able to control his home air conditioning unit. The others learned about the program through the mail - either an insert with the electricity bill or a separate flyer. They had a much stronger grasp of what the program entailed, and joined for the purpose of putting less strain on the grid. As P3 put it *"it didn't seem like a big sacrifice"* and she suggested that *"I don't even think it really should be optional"*. We also found that, with the exception of P16, participants were unaware of changes to their air conditioning, and noticed no difference to their comfort level, which supports claims made in advertising materials. P16 noticed it was a little warmer in the house, but *"I totally understood that, made a lot of sense"*. This difference was likely because she set the air conditioning to 24 or 25 degrees, which was a higher baseline temperature than the others.

Participants who were not enrolled in peaksaver may have heard something about the program, but, because of limited motivation, had not bothered to learn more. For these participants, we described the program and gauged their reactions, finding a continuum of opinion from being actively averse to the idea of someone else controlling some aspect of their home, to not having a direct problem with utility control but not seeing enough benefit to themselves to bother making the effort to join. Many participants noted that there was some aspect of "big brother" that they found distasteful. With more appropriate incentives, even those who were extremely opposed to the idea of someone else having control over their home might consider it. P12 suggested if a rebate occurred *"that would be a different story"* and would *"relax my concern of someone else being able to control it"*. P9, who was quite concerned initially, expressed *"if it was going to save money, then definitely"*.

With two days' notice, participants can opt out of peaksaver for a 48 hour period. We probed the issue of control and opt out with our participants. Some participants indicated that if they were to join, they would fully commit to the program, such as P4 who states that if she joined, *"I wouldn't want to go through the hassle of like opting out"*. On the other hand, being able to opt out in the moment, or in some way override the system in the moment, would be absolutely required for others to even consider joining. P9 would want ultimate control out of concern for her family *"maybe somebody has a kid who as a fever [...] as long as it's like, in the end, I've got the ultimate control over it, then that would be ok"*.

One positive aspect that interviewees brought up about the peaksaver program was that it supports collective action. P5 says she likes that it works on *"a collective rather than an individual basis"*. Additionally, P8 thinks it makes sense since *"it's not guaranteed that I or another person would make the changes"* and it *"at least guarantees some action taken"*. P17 likes that the change is done for her - "*I don't have to think about it. Just one more thing off my list"*.

DESIGN IMPLICATIONS (DI)

There are a number of design implications that we identified from our findings, which are supported by relevant related work. The intertwined concepts of motivation, ability and triggers from FBM were used to develop these. Specifically, we considered each theme identified from the affinity diagram and analyzed what our participants were telling us about their habits, and whether it effectively increased or decreased ability or motivation, or whether it was indicative of existing or missing triggers. We gathered what we could learn from existing practices (e.g. shifting usage as a result of TOU pricing) and what barriers were in place to making more dramatic shifts in behavior at critical peak load times.

Motivation

The core motivators identified by Fogg are:

- Pleasure/pain: which focuses on the immediate response;
- Hope/fear: which focuses on the anticipated future outcome of the behavior; and
- Social acceptance/rejection: which focuses on social norms.

DI: Communicate the Impact of Peak Load

It is clear from our interviews that most people are rarely aware of the times that the electricity grid is strained, and are even less aware of the impact that peak load demand has on neither the construction of new power plants nor the environmental consequences. One potential area for persuasive technology to help is in increasing this type of knowledge. These should build from existing knowledge of motivational techniques [20].

This design implication targets the core motivator of hope/fear. Ideally one could instill a hope for a better world, and that should be the focus. On the other hand, in reality, many of our participants were especially motivated by the fear of imminent blackouts. This DI targets those in the early stages of the TTM, who are not yet aware of the benefits of taking action.

DI: Harness Collective Action

Our participants noted both not being able to comprehend the impact of their individual behavior (such as shifting laundry) and the worry that they would be the only ones making sacrifices during peak load times. Both of these impacted their motivation to make changes, and could be addressed by demonstrating collective action. For daily peaks, this could be communicated at the time of making a decision to use an appliance. As the internet-of-things expands to include common household objects, these objects could communicate information about current consumption.

Collective action can particularly be harnessed to address critical peak times. Social media tools can be used to communicate who is making cutbacks within a social circle. They can be used to anonymously communicate the net effect of cutbacks to the masses. They can be used to allow occupants of a large building to collaborate to increase the temperature during times of acute demand. In our work, we found the lack of awareness of collective participation and collective effect sapped motivation. Participants cannot always make extreme efforts to conserve, but for those infrequent critical peaks, collective action holds the promise to both motivate and serve as a trigger. The work of Boucher et al. capitalizes on this need [2].

DI: Give Consumers Ultimate Control

We found a number of participants who were not opposed to the small or imperceptible reduction in comfort from peaksaver, but the specific implementation details turned them off – specifically the idea of an outsider having control, with limited ability to opt out in the moment. Giving consumers ultimate control over adjustments and thus the ability to opt out in the moment using the thermostat would reduce this fear. One concern of the designers of peaksaver was that people could in theory opt out en masse at the times when changes were most needed. However, in practice, peaksaver participants were unaware of the changes, so this is unlikely to be the case.

Nest is already working with a limited number of utility companies to offer rebates, or even a free Nest thermostat for signing up for their Rush Hour Rewards program, which does not preclude opting out in the moment.

DI: Allow Flexibility and Customization

As others have noted, it is essential to target behavior change interventions to what stage the participant is in the TTM [5,15]. Even beyond this, there is a need for further flexibility and ability for customization tailored to the individual, since they have different thresholds for comfort and willingness to contribute to the greater good, as well as perceptions of social norms.

While in general our participants understood that a small change in temperature would not have a large impact on their home comfort, the primary motivation for cooling the home was for the pleasure of being cool on a hot day. Further flexibility would allow users to cycle down their air conditioning only to the extent that they are comfortable with it, for a proportionally smaller reward. If this increased flexibility means that more people would sign up, even if the individual impact was small, collective impact would still have an important impact on peak load.

Ability

According to Fogg, lowering any of time, money, physical effort, mental effort, social deviance or non-routine aspects of an action increases its simplicity and therefore increases the ability of a person to perform the task. If any one of these elements are lacking for a specific person, then the behavior is not simple for that person. The simplicity of the behavior is assessed at the time that it is triggered, based on these criteria.

DI: Allow Users to Set it and Forget It, or Customize and Optimize

Even the simple implementation of TOU pricing was not fully understood by most of our participants. Many people were unable or unwilling to invest the time or "brain cycles" in learning the details of this program, including the actual price differential, or the mid-peak and on-peak hours, beyond the 7pm threshold to off-peak. On the other hand, some made very deliberate choices about running home comfort systems and appliances with respect to these prices. New appliances are increasingly coming with timers in order to make it easy to consume at off-peak times. In a fully connected future, these appliances could even connect to the grid directly and run at the best time given the constraints of the user.

In the same vein, the fact that peaksaver made the changes automatically was appealing to a number of our participants, since they did not have to think about making the changes themselves. There are also those who have demonstrated a desire to be more actively engaged in managing their resource consumption and home comfort, and be able to customize systems to their individual needs. While Strengers cautions us of designing *only* for Resource Man, designers should be careful not to alienate these users.

DI: Use Appropriate Incentives

Many participants were reluctant to forgo the comfort of air conditioning on hot days. In these cases, the small monetary savings of TOU pricing were particularly ineffective. For some, no feasible amount of money would be enough to convince them, but others were willing to make changes for appropriate monetary incentives. Still others indicated that the hypothetical financial reward was not necessary, and they were happy to do their part. An additional concern is how to handle the problem that putting a monetary value on a behavior can actually have negative spillover on other environmentally conscious activities because of putting a price on it [20].

The existing one-time gift of a thermostat for the long-term commitment of participation in peaksaver seemed disproportionate to many of our participants. While different participants have different levels of price-sensitivity, in order to expand the reach of utility driven air conditioning demand response programs, more appropriate incentives are required.

DI: Offer Suggestions of How to Reduce Consumption at Peak Times (And Make These Easy To Do)

Our participants simply did not know of reasonable ways to reduce their consumption at critical peak times, which correlated with [32]. In order for behavior change to occur, it is necessary for them to not have to think too hard about what to do, or work too hard to do it, or in Fogg's words, decrease the brain cycles and physical effort required. Thus, easy to do suggestions are required, such as:

- Using the barbecue to avoid heating up the house (and causing the air conditioner to work harder);
- Cooking in advance of a heatwave and using the microwave or toaster oven to reheat;
- Spending time in larger groups at places that are already air conditioned instead of at home.

These behaviors were gathered from those who do not have central air conditioning at home, as necessities for keeping cool. Admittedly, they do have higher motivation to find ways to keep cool since they do not have the simple option of turning on the air conditioning. But there are alternative ways to keep cool that could help reduce peak demand, including closing windows blinds, the use of ceiling, circulating or portable fans which were mentioned by a number of our participants to reduce their need for air conditioning in order to save money. Making these suggestions of other ways to keep cool without much discomfort, and with lower cost, may be beneficial to those who did not take these actions already. Exploring the automation of some of these lower tech solutions in order make them easy for those that do have the option is one path going forward.

Taking these suggestions to the next level, families could plan a group barbeque and consolidate their need for air conditioning, with the added benefit of increasing a sense of community and social action at these critical peak times. Issues of sustainability around food preparation has also been studied within the HCI community [4]. Making this behavior part of accepted social practice and pitching in to help with this problem is where the design challenge lies. Taking more intensive action at the more infrequent critical peak load times is where efforts should be directed, given the increased impact [30]. This could also help overcome the fatigue noted by our participants.

Triggers

Fogg describes three types of triggers:

- Spark: Trigger with a motivational element;
- Facilitator: Trigger that also makes the behavior easier to do;
- Signal: Notification or reminder.

These types of triggers should be used appropriately to help increase whichever of the elements is lacking.

DI: Integrate Triggers

To provide some small trigger, some participants did post the TOU schedule in the kitchen or laundry room to remind themselves of peak times. Additionally, certain IHDs do provide feedback about the current price level. However, these IHDs require the user to engage with the display to be informed, i.e. they are separated in space from the location of the instantaneous decision. An alternative trigger could be a set of small displays attached on or near the controls of electricity-intensive appliances that signal whether it is an appropriate time to use the appliance, combined with an increasingly common delayed-start feature. Such ubiquitous devices would be more appropriate triggers as they are in-the-moment, localized awareness mechanisms that are visible as a decision is being made.

Participants were often unaware of critical peak times, and so lack any form of trigger to alter their behavior in-the-moment. The most obvious trigger, particularly for critical peaks, is some form of simple notification such as an email or text message. While we had difficulty finding scientific studies on the effectiveness of basic email of text message notifications, it is also worthwhile to note that the use of a generic notification is sufficiently undirected that it may be ineffective as a trigger if motivation and ability are not high enough [11]. Utilities are proficient at predicting demand days in advance of critical peak periods, and could easily notify customers in advance to increase consumers' ability to plan, which has been shown to be feasible for some [7].

DI: Consider Sparks and Facilitators

Critical peaks are particularly amenable to sparks and facilitators, because they are sufficiently infrequent that the spark or facilitator will not become so commonplace that they become irksome.

Networked thermostats could be used to spark behavior change in a variety of ways. Given the ability of utilities to pay up to $2 per degree hour for savings during these periods [30], one could imagine using the network interface to provide significant incentives to consumers. Imagine a smartphone interface where, by leaving your house and idling your air conditioner, you obtained a free cold drink at a local cafe, as indicated by a coupon on your smartphone. If the interface included a simple button to raise the temperature, the interface combines the positive attributes of a spark and facilitator to promote high-impact, low-frequency behavior change, particularly important during critical peak periods. However, those who choose to forgo central air conditioning should not be unduly punished. Additionally, designers need to be careful that this system does not encourage excess car use, which could undermine potential benefits.

DISCUSSION

In their survey and critique of sustainability research, Brynjarsdóttir et al. [3] identify oversights in past sustainability research in its narrow definition of sustainability, its focus on the individual, its assumption of rationalism, its neglect of lived experiences, and its neglect of dynamics. While we do not claim to address all issues with past research in sustainability, we note that applying FBM to an analysis of two real-world demand management programs does provide data on the lived experiences of participants with these programs and the dynamics of behavior of participants with respect to these programs over time. In exploring experiences with these two demand management programs, our design implications – particularly the first two motivational implications – also touch on the rationalism of participants and on collective versus individual actions and decisions.

One characteristic of past research on sustainability is a strong focus on awareness mechanisms. Brynjarsdóttir et al. [3] in particular claim that most systems *"aim to provide information and raise awareness, in the hopes that this will lead in some way to altered behavior"*. Strengers [31], too, notes that individuals may frequently not be aware of possible actions they can take to conserve power in-the-moment. Within our design implications, we address these under the theme of Ability, noting that offering concrete suggestions and enabling those suggestions is an important aspect of addressing critical peaks, in particular.

While we focus on the implementation of the programs in Ontario, other regions have both similar and different problems. Many of the design implications that come out of this work could be generalized or adapted. As discussed by Boucher et al. [5] there are other reasons for occasional, more unpredictable short-term changes in demand. Inclement weather can cause damage to distribution systems, or incidents at generating facilities can constrict supply. In such cases, centralized control by the utility is the preferred solution, since there is not enough time for people to become informed and to react. Renewable energy sources, such as solar and wind power are often constrained on the supply side, so having systems and technologies for temporarily reducing demand can again reduce the need to rely on more polluting sources. We would argue that our work provides a path toward broader participation in demand management programs like peaksaver, and that the broader participation in these programs extends beyond simply addressing critical demand peaks.

It is important to consider that even air conditioning demand management programs would only be part of the solution. Some utilities have adapted the peaksaver to include cycling down pool pumps, but it could also be expanded to pool heaters, and even electric hot water heaters in homes. For very short term peaks, such as those caused by accidents, even refrigerators or chest freezers could be cycled down by a few percent without negative consequences. Other researchers in areas like engineering are working on other types of solutions including reducing waste in the grid, better efficiencies in generation, and better electricity storage.

CONCLUSION

In this paper, we use Fogg's Behavior Model to analyze conservation programs implemented by electrical utilities in Ontario, Canada. While we find that these programs do have some net positive effect, we also identify several shortcomings of existing programs. We use these shortcomings, coupled with an application of Fogg's Behavior Model to identify a series of design implications for persuasive technology. It is our belief that, by adapting programs and the design of new technologies to align with the design implications we provide, the programs can promote more optimally-timed consumption of electricity and foster the participation of more electricity consumers.

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