Crowdsourcing Behavioral Incentives for Pervasive Demand Response

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1 Introduction

Demand response (DR) refers to a set of dynamic demand mechanisms that aim to manage electricity consumption in response to supply-side signals. DR can be used for the purpose of demand regulation (e.g. to maintain voltage and frequency within safety limits) as well as for energy balance (e.g. to shift demand to off-peak periods, to curtail demand during emergency situations, or to offset fluctuations caused by less predictable energy sources such as wind or solar). DR is often carried out through direct load control (DLC), in which case it is called direct DR or dispatchable DR. Nevertheless, consumer behavior can also be influenced by using indirect methods of DR such as incentives, real-time information, or dynamic pricing. This second type of DR is called indirect DR or reactive DR.

Direct DR has the advantage that the expected outcome of a DR signal is measurable and quantifiable. For this reason, commercial and industrial energy consumers are today's preferred candidates for participation in DR programs; they are able to contribute large reductions in demand through direct control of thermal loads (e.g. heating or refrigerators), higher predictability, lower user discomfort and relatively low installation costs. Although the residential sector makes up 20% of total energy demand and 60% of peak load demand, it still remains a relatively untapped DR resource.

There are multiple reasons behind the residential sector's limited involvement in DR programs. Privacy and security are two of these. Concerns about the possibility of an external entity—whether it is legitimate or not—controlling appliances and energy consumption in private homes deterred the widespread involvement of residential consumers in DR programs. As an example, in 2008, a German

civil rights and privacy campaign group awarded Yello Strom GmbH with the “Big Brother Award” due to the company's plans to introduce smart meters to its customers. Keeping data storage and the control of appliances on the household premises therefore seems to be a preferable path towards the involvement of residential consumers in DR.

Another reason for the failure to engage the residential sector in DR programs is that the financial incentives for their participation (e.g. savings on the monthly bills) are not great. In most countries, electricity is generally a small percentage of consumers' total expenditure. For example, in the U.S., electricity expenditure represents 2.8% of total income. Given that the savings made from participation in DR programs represent between 2% and 30% of total electricity expenditure, the total potential savings for participating households range from 0.056% to 0.84% of total expenditure. These figures look even more unimpressive if the installation and operation costs of DLC devices are factored in.

For all the above reasons, indirect DR seems to be most appropriate for the residential sector. In fact, this type of DR implies neither external control of appliances nor the complex DLC devices that drive installation and operation costs up. However, indirect DR is not free of drawbacks and challenges. The outcome of indirect DR is generally less predictable, as it depends on the consumer’s behavioral response. Furthermore, reduced consumer responsiveness (i.e. ‘demand fatigue’) is another concern. Indeed, most real-world trials of indirect DR have been designed in an effort to bring about load reductions (from large, industrial consumers) over a limited number of days or hours per year, in order to minimize the likelihood of any exit from the DR program.

A common indirect DR approach aimed at energy consumption behavior is using priced-based programs (PBP). PBP are based on dynamic pricing rates in which electricity tariffs are not flat, but fluctuate over time. Examples of these rates are Time of Use (TOU), Critical Peak Pricing (CPP), Extreme Day Pricing (EDP), Extreme Day CPP (ED-CPP), and Real Time Pricing (RTP). Incentive-based programs are another variant of indirect DR where customers receive benefits for participation in the program: these can be bill rebates or a discount rate when an amount of load reduction can be attributed to the customer during critical periods.

Although the two approaches are different in their design and operation, both rely on financial stimuli to affect consumers’ energy consumption behavior. As described above, financial incentives for residential consumers do not involve great sums. Indeed, practical experiments in energy conservation methods found that informing a household about how energy usage compared to that of their

neighbors' was much more effective in prompting them to conserve energy than informing them about the financial savings of lower energy usage.

In order to initiate widespread adoption of DR in the residential sector and eventually make it pervasive, future behavioral incentive mechanisms for indirect DR will need to be enticing for residential consumers, effective at promoting the desired energy consumption behavior, and able to maintain long-term consumer engagement. In this work, we present our findings from a crowdsourcing experiment aimed at discovering effective behavioral incentive mechanisms for indirect DR. The experiment was performed in November 2013 and collected 55 ideas from 27 different participants. We then analyzed and classified them according to Fogg's Behavior Model.

2 Behavioral Framework

To analyze and classify the behavioral incentives proposed by our crowd, we used Fogg's Behavior Model (FBM). According to this model, three factors must converge at the same time for a particular behavior to occur: *motivation*, *ability*, and *trigger*. The FBM asserts that a person must: (1) be sufficiently motivated to perform a target behavior; (2) have the ability to perform the behavior, and; (3) be triggered by some stimulus in order to actually perform the behavior (see Figure 1). FBM was introduced in 2009 to analyze and design persuasive technologies.

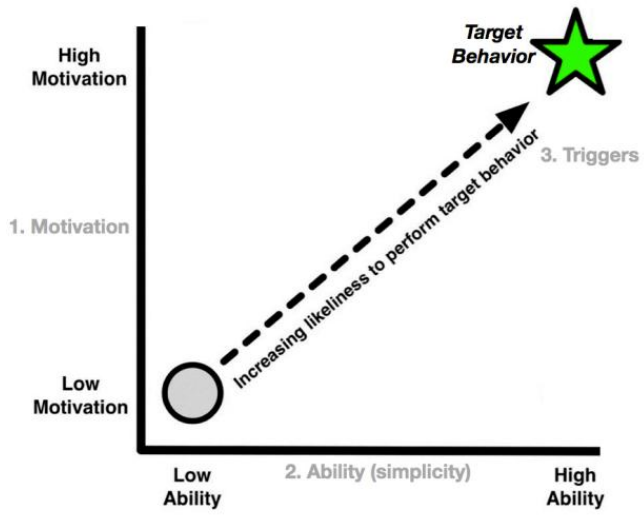

Figure 1 Fogg's Behavior Model (source: Fogg, 2009)

Motivation is a factor that can take various forms depending on the specific context of the target behavioral change. Fogg defined three different types of motivators:

- *Pleasure/pain*. This type of motivator is immediate and requires almost no thought, anticipation or planning. The response to this motivator is basically instantaneous, similarly to the response to hunger, sex or other activities related to biological self-preservation.
- *Hope/fear*. The second type of motivator requires a certain level of anticipation. The occurrence of a desired/undesired outcome is projected into the future, but makes the person experience the feeling of hope/fear in the present. For example, an energy conservation behavior can be motivated by the hope of reducing CO_2 emissions or by the fear of receiving an expensive electricity bill.
- *Social acceptance/rejection*. The third type of motivator is the social dimension. People are affected by social pressures which lead them to behave in ways that increase social acceptance and avoid social rejection. This motivator is highly present in virtual social networks, such as Facebook, where people actions (e.g. posting pictures, comments, etc.) are significantly driven by the desire for social acceptance.

Ability, or simplicity, is the factor of a persuasive mechanism that should reduce the effort needed to perform the target behavior. People are generally resistant to performing actions that require excessive effort, thus simplicity must be the guiding principle of any persuasive design. To be considered simple, a target behavior should be quick, cheap, require little physical or cognitive effort, should not violate social norms and conventions, and should easily become part of a person's normal routine. Of course, the absolute level of simplicity differs depending on the context of the persuasive mechanism to be put in place and users' profiles: some people have more time, or more money, or are more eager to perform non-routine actions than other people.

Triggers are a very important factor of any persuasive mechanism. They can have various forms, use different communication channels, and must be recognized and associated with the target behavior. The FBM describes three types of triggers.

- *Spark*. This trigger is designed in combination with a motivator. Examples of sparks are text messages that highlight a fear, or videos that inspire hope.

- *Facilitator*. This trigger suits users who have high motivation but lack of ability, i.e. it is designed to improve the user's ability. The facilitator aims to trigger the behavior by making it easier to do. Examples of facilitators are software update messages that require only one click to install the update, or an address book uploading function on a social networking website that automatically builds an initial network of acquaintances on the user's behalf.
- *Signal*. This trigger is intended to work best when people have both the ability and the motivation to perform the target behavior: the signal is therefore a reminder. Examples of signals are automatic SMS or email messages that remind users to perform the target behavior, or traffic lights, which do not motivate the user but simply indicate when a behavior (i.e. crossing the intersection) is appropriate.

3 Crowdsourcing Experiment

3.1 Crowdsourcing

Crowdsourcing refers to the practice of requesting a large group of people (the crowd) to contribute to the accomplishment of a specific task. Crowdsourcing is usually offered by online services and platforms, and can be used for *cloud labor*, *crowd creativity*, *crowdfunding*, *distributed knowledge* and *open innovation*.

Cloud labor consists on leveraging a distributed virtual labor pool on-demand to complete tasks of different complexities, from translating text to coding pieces of software. Amazon Mechanical Turk (www.mturk.com), MobileWorks (www.mobileworks.com), or Crowdflower (www.crowdflower.com) are well known platforms for this type of crowdsourcing. Crowd creativity is similar to cloud labor, but focuses on tapping pools of creative talent to develop art and media content, such as photography, video production, or graphic design. Crowdfunding seeks to raise financial contributions from a large number of stakeholders, sponsors, or donors to fund initiatives or enterprises. Kickstarter (www.kickstarter.com) is one of the most well-known platforms for starting a new business or enterprise. Distributed knowledge can be developed, aggregated, and shared through open questions and surveys, by using websites such as Epinions (www.epinions.com), for example. Finally, open innovation refers to the generation, development, and implementation of ideas though brainstorming sessions. The best ideas are typically rewarded with some sort of prize or award. Websites that focus on this type of crowdsourcing are Ideascale (www.ideascale.com) and Atizo (www.atizo.com).

Crowdsourcing is gaining acceptance in the innovation toolkits of many corporations and governmental agencies. A well-diversified crowd is composed of individuals with varied skills, experience, and perspectives, and can operate at a scale that often exceeds that of the biggest corporations. This means that the crowd can often solve problems more efficiently. For example, many corporations post predictive modeling and analytics competitions on Kaggle (www.kaggle.com) so that statisticians and data scientists from all over the world can compete to produce the best models. This type of crowdsourcing approach is very effective for an exploration of the huge number of possible predictive models and techniques, given that it is usually impossible to know beforehand which ones will be most effective. Furthermore, crowdsourcing platforms are becoming cheap, powerful and easy to use, facilitating management of the task and interaction with the crowd members.

3.2 The Experiment

In November 2013, we performed a crowdsourcing experiment for open innovation and we asked the crowd for new ideas for effective incentive mechanisms for indirect DR. The challenge was posted on the Atizo website, the leading Swiss open innovation platform for the development of creative ideas and innovative concepts. On Atizo, a user (typically a corporation) can pose a challenge to be solved by others. A challenge comprises a description (short, catchy, and easy to understand), evaluation criteria, and reward.

Our challenge was entitled "Convince consumers to reduce peak hour consumption. How can electricity suppliers encourage consumers to reduce their electricity consumption during peak hours?" To drive the *originality* and *applicability* of the ideas submitted, we used these factors as the principal evaluation criteria. The two best ideas were rewarded CHF 100 each. Figure 2 shows a screenshot of our challenge's home page.

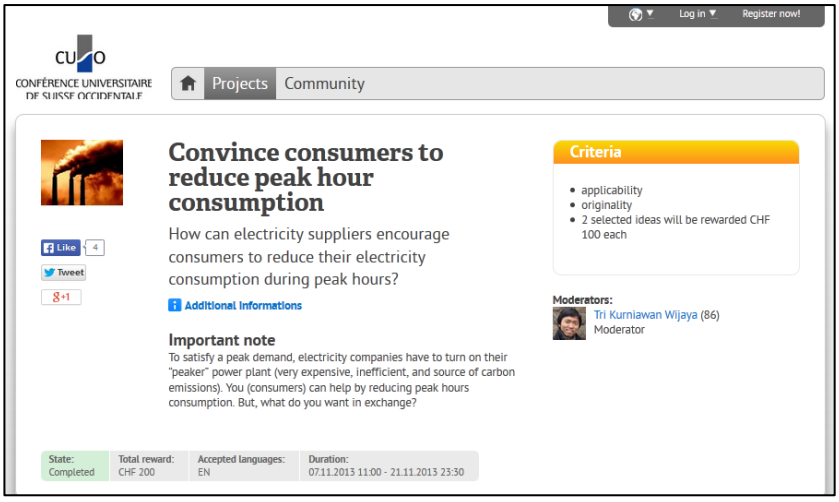

Figure 2 Home page of our crowdsourcing challenge

4 Analysis of Results

4.1 Submission Statistics

The crowdsourcing experiment collected 55 ideas from 27 different participants. The number of ideas submitted by each participant is shown in Figure 3. The histogram follows a power law distribution[1], with the top three participants having provided 50% of all ideas. The campaign went almost unnoticed until Nov. 11th 2013, when 27 submissions from 18 different participants were received. From that date onward, the crowdsourcing campaign steadily received an average of 3 new ideas per day (see Figure 4). The word cloud generated from the submissions (Figure 5) shows that they were indeed consistent with the challenge's main topic.[2] In the next sections, we provide an analysis of the submissions with respect to the three factors: motivation, simplicity, and trigger.

[1] The best fit, showed as a solid line, is $f(x) = 8.7394x^{-0.7622}$

[2] The complete list of the submissions is available at `https://github.com/tritritri/behavioral-dr`

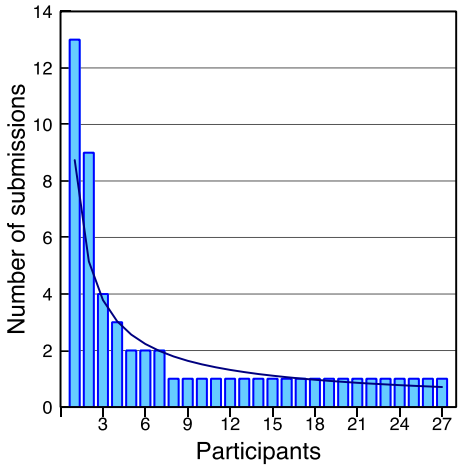

Figure 3 Number of submissions per participant

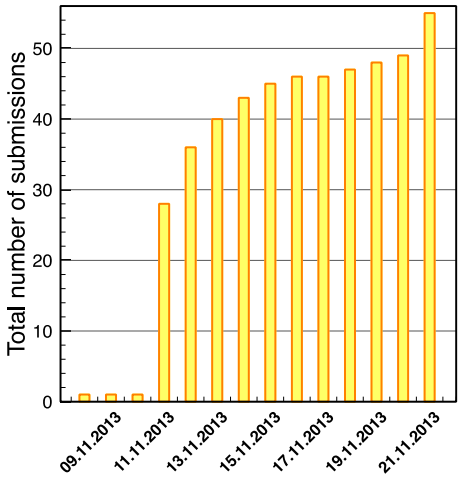

Figure 4 Submissions over time

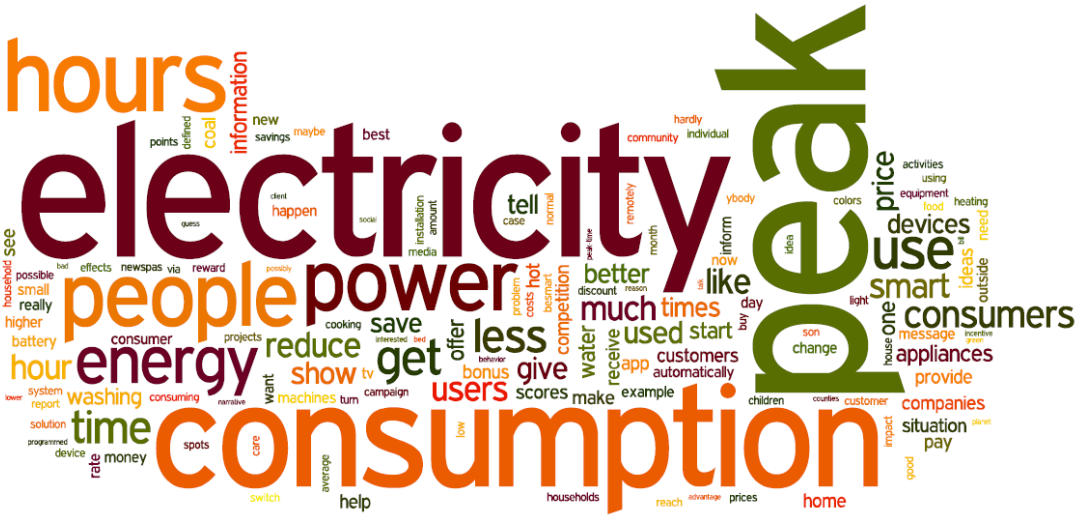

Figure 5 A word cloud generated from the submissions

4.2 Motivation

The ideas submitted by the crowd participants allowed us to extract the following types of motivation that might drive energy consumers to reduce peak consumption:

- *Money* (FBM category: Pleasure/pain). This motivation can take various forms, such as different tariffs between peak and off-peak consumption, discounts, bill rebates, redeemable points to use electricity at later time or to purchase energy efficient appliances.
- *Green awareness* (FBM category: Hope/fear). People who care about the environment should be informed about the impact of their peak electricity consumption on CO_2 emissions and non-renewable resource usage.
- *Green cooperation* (FBM category: Hope/fear). This motivation is similar to green awareness, but is enriched by a social component. Residential energy consumers are not aiming to reduce their personal carbon footprint, but rather they are members of a bigger community aiming at more challenging goals, such as reducing peak consumption over an entire district and thus removing the need for an entire CO_2-intensive peak power plant. Consumers can also be motivated by the fact that the rewards for their collaborative effort are ploughed back into the community in the form of projects such as road maintenance or new parks.
- *Energy awareness* (FBM category: Hope/fear). When consumers actually see how much they are consuming, a visual representation acts as the feedback to make them understand how and when they use energy. The understanding of their own energy behavior leads consumers to improve their peak energy consumption.
- *Social pressure* (FBM category: Social acceptance/rejection). This motivation type refers to the pressure exerted by any type of social comparison or competition, including with oneself. For instance, the peak-shaving performance of energy consumers can be compared to that of other people in their neighborhood or shared within their social network using social media such as Facebook. This motivation can also take form of self-comparison, in which case people exert pressure on themselves.

A categorization of the motivational ideas submitted is shown in Figure 6. Money and energy awareness were identified as the strongest motivations. Protecting the environment, either as a personal challenge (green awareness) or as a collective effort (green cooperation), also represented a strong driver for behavioral change. Surprisingly, social pressure was not seen as a strong motivation, in

contrast to the results of recent behavioral experiments. For example, Opower (www.opower.com), a company that partners utility providers in the promotion of energy efficiency, reported that leveraging competition between consumers was a strong driver in shaping energy consumption behavior; by showing them how their energy efficiency performance compared to that of their neighbors and other consumers with similar characteristics.

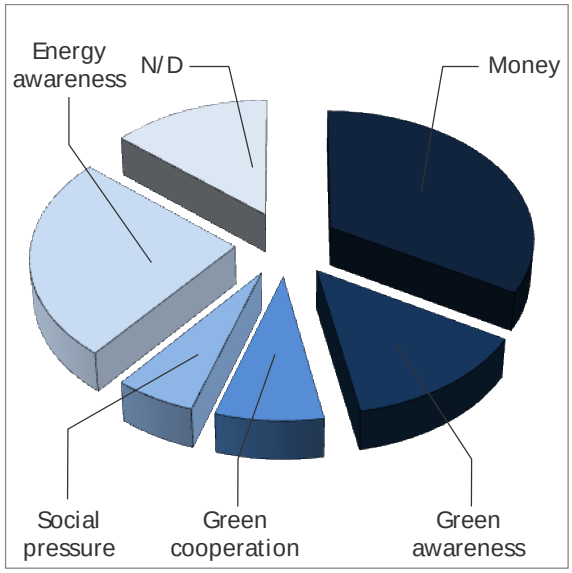

Figure 6 Motivation

4.3 Simplicity

With regards to simplicity, participants in the crowdsourcing experiment highlighted the fact that energy consumers might need assistance to reduce the effort needed to reduce peak consumption. From their ideas, we extracted the following *effort* elements that consumers would like to have simplified (or minimized) in order to carry out the desired peak energy saving behavior:

- *Time*. The consumer often has both the motivation and knowledge to perform peak energy saving actions, but would like to spend the minimum amount of time on discovering when and which appropriate and specific actions should be carried out.
- *Physical effort*. All the ideas that require supportive devices such as smart appliances, programmable thermostats, electricity storage systems, home control systems and backup power generators, fall within a simplification of physical effort. All these devices reduce the physical effort required to carry out certain peak energy saving actions such as lowering the

heating thermostat or rescheduling the use of appliances such as washing machines and dishwashers.

- *Cognitive effort*. In order to become savvy energy consumers, users must be educated. Any incentive that comes with informative content to help the user become an expert in energy management falls within this category.

A categorization of the ideas for *simplicity* submitted is shown in Figure 7. Although a considerable number of the submissions implicitly assumed that consumers were fully capable of carrying out the desired behavior, the majority of submissions recognized that helping consumers to reduce the cognitive and physical efforts necessary to carrying out that behavior was important for the incentive mechanism. Most residential energy consumers are neither tech savvy nor familiar with the their energy consumption, therefore educating them in their management of energy usage or teaching them to schedule appliances through easy-to-use control tools is a good way to increase their ability to perform the desired behavior.

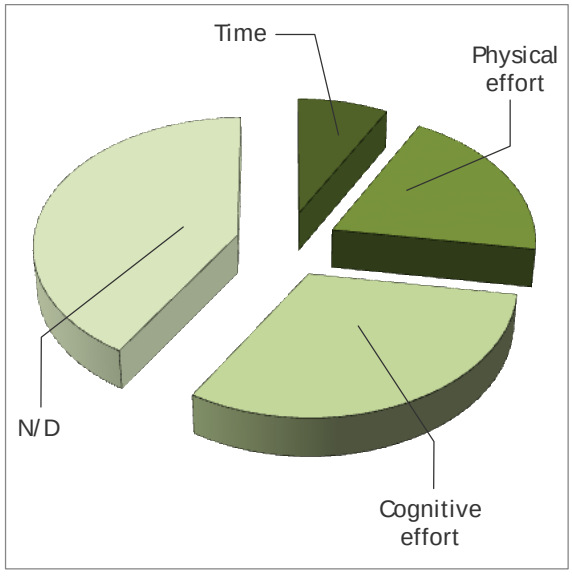

Figure 7 Simplicity

4.4 Trigger

Finally, some of the ideas defined mechanisms aimed at triggering the desired consumer behavior. These triggers were classified into the following types:

- *Media* (FBM category: Spark). Many participants suggested the use of videos, documentaries,

movies, text messages, radio announcements, and social media in order to instill motivations such as environmental and energy awareness.

- *Information* (FBM category: Facilitator). This trigger aims to improve the consumer's ability to carry out the desired behavior by using appropriate graphical interpretations of peak energy consumption and possible actions to diminish it.
- *Alarm* (FBM category: Signal). This category includes all types of reminders to carry out the desired behavior, and can be delivered via home displays, social media such as Twitter and Facebook, smartphone apps, and SMS messages.

A categorization of the trigger ideas submitted is shown in Figure 8. Almost half the contributions did not specify any sort of activation mechanism for triggering peak energy saving behavior. For the half that did consider triggers to be an important factor in any incentive mechanism, information dissemination campaigns using various media to encourage consumer motivation were considered the most effective. Furthermore, displaying information visually, using an appropriate graphical interpretation, was recognized as an important trigger to increase consumers' ability to carry out the desired behavior. Finally, only a small percentage of the submitted ideas specifically defined signaling triggers such as SMS alarms or reminders, sent through emails or social media such as Twitter and Facebook.

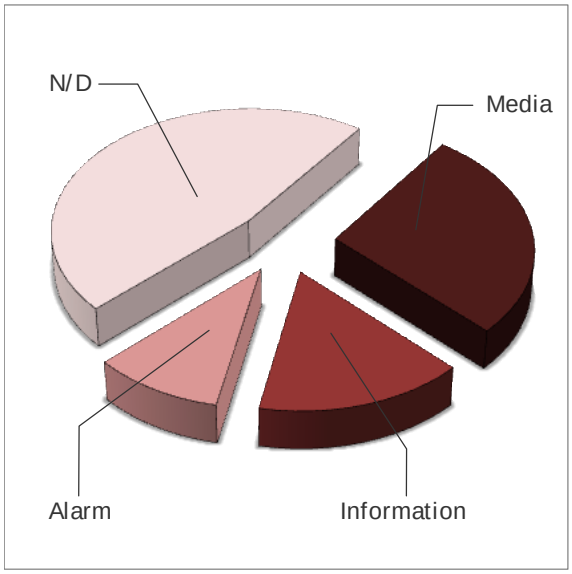

Figure 8 Triggers

5 Generating New Solutions

One of the advantages of carrying out an innovative crowdsourcing experiment is that aspects of the different ideas submitted can be combined to generate new solutions. Given that some ideas may be attractive to certain communities, but not others, new or hybrid solutions can be tailored specifically to suit the target community. Furthermore, in order to move towards a more sustainable planet, behavioral change *per se* is not enough: new behavior should be sustainable in the long term. Below, we offer an example proposal that also aims to sustain change. More specifically, we combined several crowdsourced ideas into one in order to define a behavioral incentive for DR which leverages both the participants' green awareness and their cooperative spirit as they collaborate to reach a long-term goal. The overall objective is intentionally framed as a long-term endeavor in order to keep motivation high for the long run.

> *An advertizing campaign is run using TV ads and social media. People are asked to sign up for a challenging collaborative endeavor with the objective of reducing peak hour consumption at the scale of a community or even an entire city. A certain number of participants must be enrolled before the campaign can start, similarly to crowdfunding projects and companies. For a better mental image and intellectual grasp of the overall objective, it is set out as such a radical and definitive change in peak hour consumption that an entire CO_2-intensive peak power plant becomes unnecessary. The title of the campaign itself could be provocative, for example: "Let's Cut that Peak Power Plant!" Participants should be able to join the campaign despite different levels of automation in their homes; from completely manual energy use management to programmable appliances, batteries, or even direct load control. The participants should receive easily understandable information about how to reduce consumption at peak time. Progress by the participants should be part of an appealing visual narrative (not exclusively charts or numbers) and could be deployed on several interfaces, from web-based applications to smartphone apps. Animated interpretations of progress, such as variably sized smoke clouds over the city, or animals and people in various states of health, could give a rapid emotional feedback to the participants in order to trigger further actions.*

6 Conclusions

The challenge of influencing users to consume energy differently—to avoid peak energy consumption through demand response (DR), for example—must be met using elements of knowledge from power systems, information and communication technologies, economics, and behavioral science. Overcoming the multiple barriers to widespread adoption of DR in the residential sector will require advances in the design of behavioral incentive mechanisms that: (1) boost consumer motivation; (2) promote the desired energy behavior effectively, and; (3) maintain long-term consumer engagement. The analysis of the ideas collected in our crowdsourcing experiment showed that monetary incentives, albeit important, were not the only potential sources of consumer engagement. Consumers are indeed keen to protect the environment, either through individual acts or as part of a collaborative effort. Furthermore, a considerable percentage of the participants in our experiment clearly suggested (and validated the common belief) that consumers need mechanisms that reduce the cognitive and physical burdens of managing their energy consumption, such as through smart appliances, appropriate graphical interpretations of data, or decision support systems. Last but not least, whilst the Fogg Behavior Model (motivation, ability/simplicity, and trigger) can be used to model behavioral change, guaranteeing a more sustainable energy supply and environment also requires that the design of a DR program takes into account the long-term sustainability of the target behavior.

Acknowledgement

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