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Preparing for smart grid technologies: A behavioral decision research approach to understanding consumer expectations about smart meters

Tamar Krishnamurti [a,b,*], Daniel Schwartz [c], Alexander Davis [c], Baruch Fischhoff [a,c], Wändi Bruine de Bruin [a,c], Lester Lave [a,b], Jack Wang [a,b]

[a] Department of Engineering and Public Policy, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, USA
[b] Tepper School of Business, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, USA
[c] Department of Social and Decision Sciences, Carnegie Mellon University, 5000 Forbes Avenue, Porter Hall 208, Pittsburgh, PA 15213, USA

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ABSTRACT

With the enactment of the 2009 American Recovery and Reinvestment Act, U.S. President Obama made a public commitment to a new approach to energy production and transmission in the United States. It features installing smart meters and related technologies in residential homes, as part of transforming the current electrical grid into a "smart grid." Realizing this transformation requires consumers to accept these new technologies and take advantage of the opportunities that they create. We use methods from behavioral decision research to understand consumer beliefs about smart meters, including in-depth mental models interviews and a follow-up survey with a sample of potential smart meter customers of a major U.S. mid-Atlantic electricity utility. In both the surveys and the interviews, most respondents reported wanting smart meters. However, these preferences were often based on erroneous beliefs regarding their purpose and function. Respondents confused smart meters with in-home displays and other enabling technologies, while expecting to realize immediate savings. They also perceived risks, including less control over their electricity usage, violations of their privacy, and increased costs. We discuss the policy implications of our results.

1. Introduction

1.1. Policy context

In February of 2009, U.S. President Obama enacted the 2009 American Recovery and Reinvestment Act (ARRA); a stimulus package of approximately $787 billion intended to promote U.S. spending in response to an economic recession (United States Government Accountability Office, 2009). A significant portion of this funding was allocated to developing more advanced approaches to energy production, transmission, and consumption (Executive Office of the President of the United States, 2010). The current grid consists primarily of a mechanically operated system with over 9200 electric generating units connected to over 300,000 miles of transmission lines. The ARRA promotes a *smart grid,* which utilizes two-way digital communication technology to provide utilities with rapid, detailed information about electricity use, blackouts, and power quality (United States Department of Energy (U.S. DOE), 2009a). For residential customers, the first step towards the smart grid is the installation of a *smart meter,* allowing remote meter reading on a daily or even continuous basis (Federal Energy Regulatory Commission (FERC), 2010).

Based on continuous smart-meter readings, electric utilities can implement *demand response* programs, offering electricity prices sensitive to changes in consumer demand, rather than the flat rates common to U.S. utilities. Indeed, demand–response programs seek to reduce electricity use during peak use hours. Currently, 15% of generation and transmission capacity in the Mid-Atlantic States is used less than 1% of the time to meet that peak demand (Spees and Lave, 2008). Moreover, during peak demand, the system may be over-taxed, producing blackouts and brownouts. As a result, successful demand response programs can provide consumers with more reliable service and decrease the need for new generation, which in turn could reduce energy waste and subsequent carbon emissions (Siddiqui et al., 2008).

Moreover, demand–response programs are expected to decrease utilities' *capacity costs* paid to energy suppliers to ensure availability during peak demand times (Pratt et al., 2010). At present, approximately 91% of residential customers in the United States pay a fixed rate for electricity use (FERC, 2008), even though the utility typically pays more when demand is high (Eyer and Corey, 2010; U.S. DOE, 2006, 2009b). Average U.S. residential demand is 50–100% higher in the early evening than

* Corresponding author at: Department of Engineering and Public Policy, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, USA. Tel.: +1 412 268 6837; fax: +1 412 268 8548.
E-mail address: tamar@cmu.edu (T. Krishnamurti).

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at 3 AM, with the highest levels of demand peaking during hot summer afternoons. Smart grid technology would allow utilities to charge more during those peak-demand periods—offset by lower charges during off-peak hours. Conversely, this same technology would allow utilities to decrease prices in order to increase demand during high supply periods.

To date, there is little evidence of how effective widespread demand–response programs would be. Demand–response programs are relatively rare in the U.S. (FERC, 2008) and the situation is similar internationally. Although smart meter penetration is 85% in Italy, most European countries have less than 8% (Carbon Trust, 2007; European Regulators' Group for Electricity and Gas, 2007; Haney et al., 2009). Our own review (Davis et al., in preparation) found that the majority of demand–response programs were located in the U.S. Exceptions included Korea, the UK, Denmark, Japan, France, Norway, and Australia (Choi et al., 2009; Faruqui et al., 2010; Gaskell and Pike, 1983; Jensen, 2003; Mansouri and Newborough, 1999; Matsukawa, 2004; Ueno et al., 2006; Wood and Newborough, 2003). California's Statewide Pricing Pilot is currently the most extensive program for implementing demand–response and it showed significant peak reductions among the residential customers enrolled in the demand–response pricing programs (Haney et al., 2009).

A variety of social, cultural, economic, and regulatory factors would likely play a role in the success of demand response in individual countries. Yet the common first step for demand–response programs to move forward is consumers' acceptance of smart meters in their residences. Some U.S. locations have experienced customer backlash to smart meters. For example, Pacific Gas and Electric's attempts to deploy smart meters in Northern California have been opposed by customers who fear threats to privacy, health effects from smart meters' radio-frequency radiation (Barringer, 2011), and increased electricity bills (Sullivan and Kahn, 2011). Other major utilities have also experienced customer protests, including Oncor, Dayton Light and Power, Central Maine Power, and San Diego Gas & Electric (Hoey and Maine, 2011; Nesbitt, 2011; Soto, 2010). Both Pacific Gas and Electric and Oncor have faced class-action civil suits claiming that customers were overcharged after smart-meter installation (PG&E Denies Lawsuit Allegations, 2009; Tweed, 2010).

Although public concerns are a legitimate and important input to policy making, they may sometimes arise from misunderstanding the technologies. Smart grid technology could be needlessly delayed if customers underestimate its benefits or overestimate its problems. Alternately, it could be deployed too quickly, if customers have unrealistic expectations of its benefits or are unaware of problems that require resolution. To design policy appropriately, it is crucial to understand consumers' concerns and preferences as well as bridge those gaps in knowledge that may prevent consumers from making a fully informed decision.

2. Studying public perceptions of smart meters

Here, we use methods from behavioral decision research, to more systematically examine public perceptions of smart meters. Behavioral decision research studies individuals' decision making in terms that can be compared to a formal (or *normative*) decision model. Among other things, that comparison identifies which decision-making tasks people have mastered and which they have not, and suggests strategies for improving their decision making (Edwards, 1961; Einhorn and Hogarth, 1981; Fischhoff, 2010; Hastie and Dawes, 2001; Kahneman et al., 1982; Payne et al., 1992). Hence, behavioral decision research involves three interrelated approaches: (a) *normative analysis* of the decision context under consideration; (b) *descriptive research* into how individuals actually view and make those decisions; (c) *prescriptive interventions* attempting to bridge the gaps between the normative ideal and the descriptive reality (Fischhoff, 1992, 2005; Hastie and Dawes, 2001; von Winterfeldt and Edwards, 1986). Behavioral decision research complements other studies of consumer behavior by suggesting the basic decision-making processes contributing to it (e.g., Gardner and Stern, 2002, 2009; Madlener and Harmsen van Hout, 2011; Scholz, 2011).

The next section offers a normative analysis of the expected outcomes to consumers of implementing residential smart meters. It is followed by descriptive findings from in-depth interviews of residential electricity consumers who may soon receive smart meters. We then test hypotheses generated from these interviews with survey data from a larger sample of residential electricity consumers, from which we develop a model of customer responses designed to inform attempts to provide better information.

3. Existing normative data on smart meters

Here, we summarize research into the potential effects of smart meters for utility customers. We consider both direct effects, from the smart meter itself, and indirect effects that arise from implementing those enabling technologies, which require smart meters. Subsequent sections contrast these analyses with consumers' perceptions.

3.1. Benefits of smart meters

One main benefit of smart meters is that they can improve the operational efficiency of the grid and allow for proactive maintenance. For consumers, the benefits of this improvement might be realized through the reduction of such adverse events as blackouts. According to Pratt et al. (2010), automation enabled by smart meters can reduce blackout times from hours to seconds by identifying faults and compensating remotely. Indeed, without smart meters, customers must notify their utility about outages, whereas smart meters allow for immediate outage detection.

Another potential benefit of smart meters is that they may help customers to save money. There are several ways in which smart meters may directly contribute to customer savings. Specifically, smart meters are expected to increase energy efficiency and improve operational efficiency and reliability, as mentioned above, as well as reduce labor costs (Siddiqui et al., 2008), all of which would accrue savings to the utility that may or may not be passed on to consumers. For example, after U.S. penetration in 2009 almost doubled that in 2007 (8.7% vs. 4.7%) (FERC, 2010), Faruqui and Wood (2011) estimated the savings in labor costs alone to be up to $24 per meter over a 20-year horizon, from no longer needing to have an employee physically read the meter.

Additionally, indirect benefits may arise if consumers purchase or are provided with *enabling technologies* that respond to smart meter signals. Most likely, one or more of the following options will be made available to at least some consumers: (a) Central Air Control, (b) Direct Load Control, and (c) In-Home Displays (Ehrhardt-Martinez et al., 2010). First, Central Air Control may be provided by some utilities, and would involve a *smart thermostat* or *smart switch* that responds to user settings (e.g., turning off the air conditioner when no one is home), to time (e.g., turning off the air conditioner on summer afternoons), or to price information (e.g., turning off the air conditioner when prices are high in a demand–response program). Second, Direct Load Control may be provided by some utilities, and would involve allowing the utility to exert remote control over energy use (FERC, 2009), by turning