Perceptions of Electricity Use Communications:

Effects of Information, Format, and Individual Differences

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Abstract

Electricity bills could be an effective strategy for improving communications about consumers' electricity use and promoting electricity savings. However, quantitative communications about electricity use may be difficult to understand, especially for consumers with low energy literacy. Here, we build on the health communication and graph comprehension literature to inform electricity bill design, with the goal of improving understanding, preferences for the presented communication, and intentions to save electricity. In a survey-based experiment, each participant saw a hypothetical electricity bill for a family with relatively high electricity use, covering information about (a) historical use, (b) comparisons to neighbors and (c) historical use with appliance breakdown. Participants saw all information types in one of three formats including (a) tables, (b) bar graphs, and (c) icon graphs. We report on three main findings. First, consumers understood each type of electricity use information the most when it was presented in a table, perhaps because tables facilitate simple point reading. Second, preferences and intentions to save electricity were the strongest for the historical use information, independent of format. Third, individuals with lower energy literacy understood all information less. We discuss implications for designing utility bills that are understandable, perceived as useful, and motivate consumers to save energy.

Keywords: electricity use information; graphs; energy literacy

Introduction

To curb the risks of climate change, the Intergovernmental Panel on Climate Change (IPCC 2014) posits that global carbon dioxide emissions from the energy supply sector must be reduced to 90% below 2010 levels between 2040 and 2070. In 2011, the U.S. produced 17% of all carbon dioxide (CO_2) emissions worldwide (EIA 2011), with approximately 14% of that coming from U.S. residential energy consumption alone (EIA 2012). It has been estimated that residential energy consumption could be reduced by approximately 20% in 10 years through energy efficiency and conservation strategies (Dietz, Gardner, Gilligan, Stern, and Vandenbergh 2009; Pacala and Socolow 2004). Unfortunately, consumers face several barriers to saving electricity, including a lack of understanding about which behaviors use the most or the least electricity (Attari, DeKay, Davidson, and Bruine de Bruin 2010; Owens and Driffill 2008; Gardner and Stern 2008).

In a review of 26 bill-based interventions, Fischer (2008) suggests that clear, frequent, and detailed feedback can help residential consumers to reduce their electricity consumption. Because most people pay at least some attention to their electricity bills, improving the communications provided via their bills could be an effective strategy for enhancing their understanding of their electricity use and increasing their intentions to save electricity. Consumers who are concerned that their electricity use is relatively high tend to be especially interested in receiving electricity use information (Fischer 2008; Karjalainen 2011). At present, however, electricity bills provide no information about whether consumers' electricity use is high or low, or what appliances contribute most to their overall use (Fischer 2008). Moreover, when electricity providers do add quantitative electricity use information to bills, the effectiveness of those communications is often not evaluated. The few papers that have been published on this topic lack a theoretical foundation, and remain qualitative in nature (Fischer 2008). Hence, relatively little is known about which types of information or communication formats best improve consumers' understanding, their preferences for the materials, or their intentions to save electricity.

Formative research on consumers' responses to hypothetical electricity bills is needed to convince electricity companies to invest in electricity bill re-design and field trials examining resulting effects on their consumers' actual behavior over time. Indeed, convincing organizations to design and test new communications is no easy feat (Keller-Cohen 1987). Handbooks of communication design also recommend first conducting formative research that presents consumers with hypothetical communication materials, before investing in expensive field trials (Fischhoff, Downs, and Brewer 2011; Morgan et al. 2002).

Only a few formative studies have been conducted to test people's response to hypothetical electricity bills (Egan, 1999; Karjalainen 2011). However, those studies have ignored variables identified as relevant in related domains. Here, we build on formative research in the domain of health risk communication, as well as cognitive theories of graph comprehension, which highlight that it is important to test the usefulness of presentation formats for different types of information, and for recipients varying in background knowledge (Friel, Curcio, and Bright 2001; Lipkus 2007; Peters, Hart, and Fraenkel 2011; Shah, Freedman, and Vekiri 2005; Shah and Hoeffner 2002; Shah and Freedman 2009). Below, we discuss how insights from these domains can inform the re-design of electricity bills, while considering types of electricity use information, proposed formats, and individual differences in background knowledge (i.e., 'energy literacy'). Before doing so, we first highlight the communication goals for improved electricity bills.

Proposed Communication Goals for Improved Electricity Bills

Cognitive research on the design of tables and graphs has mostly focused on improving students' understanding of quantitative information in classroom settings (Friel et al. 2001; Shah and Hoeffner 2002; Vessey 1991). However, outside of the classroom, tables and graphs may be designed for additional purposes. An electricity company may want to design information that meets consumers' preferences, with understanding being only a secondary goal (Keller-Cohen 1989). Indeed, qualitative interviews with consumers have indicated that they will throw out bills if they dislike how the information is presented (Egan 1999). A third communication goal, often promoted by policy makers, is to better inform people's decisions or inspire behavior change (Bruine de Bruin and Bostrom 2013). Hence, it is important to study the ability of tables and graphs to achieve different communication goals in real-world contexts. In summary, designers of electricity bills have the following communication goals: (1) to improve recipients' understanding of their electricity use, (2) to increase the preferences for the presented communication, so that recipients are willing to engage with it and apply it to their decisions, and (3) to increase intentions to save electricity (Egan 1999; Fischer 2008).

The health communication literature also recognizes the three goals of improving understanding, preferences, and intentions to change behavior (Ancker et al. 2006; Lipkus 2007). Unfortunately, the health communication literature has found that communications that succeed in one goal may not succeed in another. Communications that increase understanding may not actually be preferred (Ancker et al. 2006; Lipkus and Peters 2009; Miron-Shatz, Hanoch, Graef, and Sagi 2009; Schapira, Nattinger, and McHorney 2001) or even undermine recipients' willingness to implement the presented health recommendations (Stone et al. 2003; Weinstein and Sandman 1993). Additionally, relatively little is known about how specific communication features interact with each other or with recipients' ability to understand the presented information (Fagerlin et al. 2007; Lipkus 2007; Lipkus and Peters 2009). Hence, before disseminating communications to large audiences, it is important to first test their effectiveness in terms of their effect on understanding, preferences, and behavioral intentions (Hegarty, Smallman, and Stull 2012; Lipkus 2007; Spiegelhalter, Person, and Short 2011).

Proposed Information Content for Improved Electricity Bills

Proposed content for improved electricity bills includes information about historical use, neighbor comparisons, and appliance-specific breakdowns (Egan 1999).

First, information about households' historical electricity use presents how residential electricity use changes over time, including periods of peak usage and seasonal trends. Typically, historical use is presented for each month over the past year, thus allowing recipients to compare specific months within and across seasons (see Figure 1). Such communications aim to improve consumers' understanding about when their electricity use is relatively high, and increase their intentions to change the underlying behaviors. Historical information is thought to be most likely to motivate behavior change when consumers find their electricity use to be relatively high (Fischer 2008; Karjalainen 2011). In qualitative interviews, consumers have indicated that they do indeed value electricity bills that present information about how their own electricity use has changed over time (Karjalainen 2011).

[Figure 1 near here]

Second, neighbor comparisons show the household's use for one specific month, as well as that month's use for similar households in the same neighborhood (see Figure 2). Specifically, communications that present neighbor comparisons highlight whether the recipients' household uses more or less electricity than comparable neighbors. Such approaches build on theories positing that individuals are motivated to behave in line with social norms (Schultz, Nolan, Cialdini, Goldstein, and Griskevicius 2007), and are consistent with findings that people have limited awareness of how much electricity use is the norm (Attari et al. 2010). People perceive neighbor comparison information as useful, perhaps because it helps them to evaluate whether their electricity use is relatively high or low (Egan 1999). Among especially wasteful consumers, neighbor comparisons can indeed lead to the understanding that using less electricity has been the social norm among their neighbors, and promote the motivation to start saving electricity (Allcott 2011; Schultz et al. 2007). Yet, neighbor comparison information can inadvertently teach frugal consumers that most of their neighbors use more electricity, which has been found to undermine the motivation to save electricity (Schultz et al. 2007). To avoid such detrimental effects on the electricity use of frugal consumers, it is therefore important to show approval of their behavior, through for example printing a smiley face on their electricity bill (Schultz et al. 2007).

[Figure 2 near here]

A third type of information that could be included on electricity bills involves a historical appliance breakdown. It adds appliance-specific details to the historical use information for the specific household, by showing how much the use of specific appliances contributes to the overall electricity use of the recipients' household over time (see Figure 3). Adding such an appliance-specific breakdown should increase understanding because most consumers know relatively little about which of their appliance-specific behaviors contribute to higher electricity use (Attari et al. 2010). Consumers have also indicated that they want to receive more information about which specific appliances use the most electricity (Karjalainen 2011; Krishnamurti et al. 2012). Detailed information about which appliance-specific behaviors use the most electricity may also motivate consumers to use those appliances less, or to replace them with more energy-efficient appliances (Fischer 2008).[1]

Proposed Formats for Communicating Quantitative Electricity Use Information

Relatively few studies have examined the effectiveness of different formats for communicating quantitative electricity use information. Below, we present findings from health communication and graph comprehension research, while recognizing the need to test the best format for presenting different types of electricity use information.

The first presentation format of interest is the table format (See Figures 1A, 2A, 3A). Classic research on table and graph design has noted the importance of the 'cognitive fit' with the decision task at hand (Friel, Curcio, and Bright 2001; Shah and Hoeffner 2002; Vessey, 1991). Tables were found to be better than graphs for tasks that required understanding specific point values (Friel et al. 2001; Shah and Hoeffner 2002; Vessey, 1991). Even in the domain of health, tables are recommended for tasks that require understanding numbers 'verbatim' such as the specific percent of a patient population who will get sick (Hawley et al. 2008). In the domain of electricity use, tables may thus be helpful for communicating how much electricity a household used in a specific month, and whether their use is more or less than in the past or compared to their neighbor's. Indeed, qualitative interviews with consumers have indicated that they like tables for receiving electricity use information (Karjalainen 2011).

By contrast, tables are less useful than graphs for tasks that require understanding more complex 'integrative' patterns and interpretations (Friel et al. 2001; Shah and Hoeffner 2002; Vessey 1991). Tables are not recommended in the health domain, where the goal of communications is to inform complex comparisons between the risks and benefits of treatments (Brewer et al. 2012; Hawley et al. 2008). Hence, electricity consumers may find tables less useful when trying to get a deeper understanding of their electricity use patterns.

The second presentation format of interest is the bar graph format (see Figures 1B, 2B, 3B), which has been found to facilitate comparisons between groups (Lipkus and Hollands, 1999). Especially when showing multiple data points, bar graph formats are easier to interpret than tables (Brewer et al. 2012). Histograms, one type of bar graph format that presents bars to indicate the frequency of specific outcomes, are useful for communicating distributions of outcomes (Ibrekk and Morgan, 1987; Lipkus and Hollands, 1999). Bar graph formats facilitate simple point comparisons, and divided bar graphs can be beneficial when both absolute and relative values need to be communicated (Shah and Hoeffner 2002). However, as compared to other types of graphical formats, histograms may reduce the likelihood that recipients will recognize the specific point value of the overall mean, which is often confused with the mode of the distribution (Ibrekk and Morgan 1987; Rowe et al. 2013).

More recent research in the domain of health has highlighted the effectiveness of icon graph formats over other types of graphical formats. The icon graph format includes any graphical display that presents data points as discrete icons (see Figures 1C, 2C, 3C). In health communications, icon graph formats are typically used to indicate the specific percentage of people who are at risk (vs. not at risk) for a particular disease. This type of icon graph format is also referred to as an icon array, because it displays icons to represent the number of people who are at risk, using different colors for those who experienced and those who avoided the negative health outcome (Garcia-Retamero and Cokely 2013; Garcia-Retamero, Okan, and Cokely 2012). Icon graph formats can also be used to show distributions of outcomes as experienced in a population, thus replacing the bars in a histogram with stacks of icons (Egan 1999). Communications that compare consumers' electricity use to that of their neighbors are better understood with an icon graph format (similar to Figure 2C) than with a simple range chart (Egan, 1999; Iyer, Kempton, and Payne, 2006). Initial designs and tests of icon graph formats in the electricity use domain have focused only on presenting neighbor comparisons (see Egan 1999).

Of course, as noted above, formats that are best understood are not necessarily ones that people like to receive, or inspire behavior change (Ancker et al., 2006; Feldman-Stewart et al. 2000; Hawley et al. 2008). Tables may not be effective for improving understanding of complex information, but they tend to be liked because they seem more trustworthy and scientific than graphical formats (Johnson and Slovic 1995; Hawley et al. 2008). Icon graph formats may improve understanding and be perceived as useful, but undermine behavior change (Stone et al. 2003). Relatively little is known about how these formats affect understanding, preferences, and intentions to change behavior in the context of electricity use.

Individual Differences in Energy Literacy

According to theories of graph comprehension, consumers' responses will depend on their ability to understand the presented information (Shah and Freedman 2009). In the context of health communications, researchers have highlighted the importance of health literacy and numeracy, which refers to the ability to understand quantitative and qualitative information about health risks (Ancker and Kauffman 2007; Sorensen et al. 2012). Patients who have less of these skills are worse at self-managing their health conditions, perhaps in part due to misunderstanding instructions (Cavanaugh et al. 2008; Estrada et al. 2004).

In the context of electricity bills, individuals' responses will likely depend on their energy literacy, which refers to the ability to understand qualitative and quantitative information about electricity use (DeWaters and Powers 2011). According to a report by the National Environmental Education and Training Foundation (2002), only one in eight Americans can answer simple energy literacy questions, for example about how most of U.S. electricity is generated. Improving energy literacy may promote energy-saving behavior (Zografakis, Menegaki, and Tsagarakis 2008). However, little is known about how energy literacy influences consumers' responses to the energy information provided with electricity bills.

Research Questions

Before implementing expensive field trials, we aimed to identify the most promising interventions through a more cost-effective hypothetical survey-based experiment (Fischhoff et al. 2011). Our research questions focused on the effects of content, format, and individual differences on consumers' responses to electricity bill designs. As noted above, we followed health communication and bill design studies that defined responses in terms of understanding of the materials, preferences for materials, and behavioral intentions (Ancker et al. 2006; Egan 1999; Lipkus 2007). We presented participants with three types of information that have been recommended for helping consumers to understand their electricity use (Allcott 2011; Fischer 2008; Schultz et al. 2007): households' historical use, comparison to neighbors' use, and households historical use with appliance-specific breakdown and (see Figures 1-3). Based on the health communication and graph comprehension literature, we presented these types of information in the format of tables, bar graphs, or icon graphs, and recognized the importance of examining how these outcomes may vary with individual differences in domain knowledge or energy literacy (Shah and Hoeffner 2011).

Methods

Sample

We recruited a diverse sample of 201 participants through community organizations in the greater Pittsburgh metropolitan area. A total of 80.1% of our participants had not finished a 4-year college degree, with 44.4% having only completed high school or less. Their mean age was 45.9 (SD=14.93) and ranged from 18 to 88, with 70.3% female, 77.3% non-white, and 65% earning less than $30,000 per year.

Procedure

Survey sessions were administered at the organizations through which participants were recruited. Participants arrived in groups, but worked individually and at their own pace. Following previous work (Egan 1999), participants received hypothetical information about the electricity use of the Smith family household in one of three formats.

Information. Each participant received three pieces of information about the Smiths' electricity use in order of complexity, which would be the presentation order preferred by electricity bill designers and educators in the real world because it allows participants to learn from the simpler formats before tackling the more complex formats (van Merriënboer, Kirschner, and Kester 2003). In order, the information received by each participant covered the Smith family's historical electricity use (Figure 1), electricity use as compared to neighbors (Figure 2), and historical electricity use broken down by appliances (Figure 3), which, as noted above, show promise for being well-received by consumers (Allcott 2011; Fischer 2008; Schultz et al. 2007). For each type of information, formats were designed to follow recommendations from the literature while ensuring enough similarity between conditions to allow for fair comparisons (Cleveland and McGill 1984; Lipkus 2007). All information was designed for a month in which electricity use was relatively high, both compared to the household's own use and compared to that of their neighbors, as those are the conditions under which behavior change is needed (Egan 1999; Schultz et al. 2007). All materials were pilot-tested with participants from a wide range of backgrounds, informing the readability of the instructions and the size of the presented materials.

Format. Our 201 participants were randomly assigned to receive information about the Smiths' electricity use in one of three communication formats, with 67 participants receiving each format. The following communication formats were developed to present comparable information, as in the health communication literature (Brewer et al. 2012; Hawley et al., 2008): (a) tables, (b) bar graphs or (c) icon graphs.

Dependent Variables. We used three outcome measures to evaluate each type of information and format, following recommendations in the health communication literature suggesting that effective information formats should improve understanding, preferences, and behavioral intentions (Ancker et al. 2006; Lipkus 2007). Each of these measures was repeated for the historical use information, the neighbor comparison information, and the historical appliance breakdown information. The full set of questions is available in the Supplemental Materials (Dependent Measures Section). For example, we measured participants' (1) understanding of the presented information as seen in the number of correct responses across seven true/false questions measuring both 'verbatim' understanding (for example "The highest electricity use was 1800kWh") and more 'complex' use of information (for example "The Smith's home used the most electricity in the summer months (Jun, July, Aug)"), (2) preferences for the materials reflected in mean ratings across ten Likert-scale items (for example, "How useful would it be if this information came with your electricity bill?") (1=Not at all; 7=Very much) for each type of content (α=.89 for historical use, α=.94 for neighbor comparison, and α=.92 for appliance breakdown), and (3) intentions to save electricity rated on one Likert-scale item ("How much does this information make you want to lower your electricity usage?") (1=Not at all; 7=A lot), while noting that findings based on single-item measures tend to replicate findings based on multi-item measures while reducing respondent burden (Bergkvist and Rossiter 2007; Wanous, Reichers, and Hudy 1997).

Individual Differences in Background Knowledge. Next, participants completed eight items about home energy use adapted from a high-school level energy literacy test, which is the background knowledge relevant to understanding the information presented on electricity bills (DeWaters and Powers, 2011; see Supplemental Materials – Individual Differences in Energy Literacy). Participants also completed questions about their demographic background.

Our study was part of a 1.5 hour session, for which participants received $45. We also offered participants the opportunity to enroll in a competition to win a $50 gift certificate, which was announced at the start of the study. Specifically, these gift cards were awarded to the four individuals with the most correct answers to our true/false questions measuring understanding of the presented electricity-use information. Such performance-based monetary payments have been shown to encourage more thoughtful responses (Hertwig & Ortman, 2001).

Results

Below, we discuss our analyses, which examine the effectiveness of the table, bar graph, and icon graph formats in terms of improving understanding, preferences, and intentions to save electricity, and how it varied across different types of information (i.e., historical use, comparison to neighbors' use, or historical appliance-specific use), as well as for individuals varying in background knowledge.

Individual Differences in Background Knowledge

Participants varied in their energy literacy (MDN=.39; M=.44; SD=.21), with a one-sample Kolomogorov-Smirnov test showing that the distribution of scores was significantly different from a Normal distribution (K-S=.005, $p<.05$; skew=.19, SE=.17; kurtosis=-.22, SE=.34). In the analyses below, we therefore divided participants into two groups, reflecting whether their energy literacy scores were above or below the median. Analyses with the full-range measure of Energy Literacy yielded the same conclusions (α=.05). For each dependent variable (understanding, liking, and behavioral intentions), we thus examined effects of the information provided (historical use, neighbor comparisons, and historical use with appliance breakdown), format (table vs. bar graph vs. icon graph) and energy literacy (high vs. low).

Effects on Understanding of Electricity Use Information

For each type of electricity use information (historical use, neighbor comparison, and historical use with appliance-breakdown), we conducted a separate Analysis of Variance (ANOVA) to examine the effect of format (table vs. bar graph vs. icon graph) and energy literacy (high vs. low) on understanding. Table 1 summarizes the mean and standard deviation of understanding scores by electricity use information and format.

[Table 1 near here]

There was a main effect for format for each type of the electricity use information, including historical use, $F(2,186)=5.83$, $\eta_p^2=.06$, $p=.004$, the neighbor comparison, $F(2,186)=32.48$, $\eta_p^2=.26$, $p<.001$, and the historical use with appliance breakdown, $F(2,186)=6.54$, $\eta_p^2=.07$, $p=.002$. As shown in Table 1, the table format was easiest to understand for each type of electricity use information. When receiving information about historical use and appliance breakdowns, participants showed better understanding when being presented with the table format rather than with either of the graphical formats. For the neighbor comparison information, participants understood the table and the histogram with icons similarly well, both of which led to better understanding than the histogram with bars.

A similar pattern was found when conducting analyses separately for the verbatim and complex items, although they were less likely to reach significance due to having lower statistical power (see Supplemental Materials – Expanded Table 1).

There was also a main effect for energy literacy for all three pieces of electricity use information. For the historical use information, $F(1,186)=21.2$, $\eta_p^2=.10$, $p<.001$, participants with high energy literacy (M=5.85; SD=.95) had higher understanding than those with low energy literacy (M=5.05; SD=1.40). This same relationship held for the neighbor comparison information, $F(1,186)=6.18$, $\eta_p^2=.03$, $p=.014$ (M=4.94; SD=1.72 vs. M=4.34; SD=1.60) and the historical appliance breakdown information, $F(1,186)=9.03$, $\eta_p^2=.05$, $p=.003$ (M=4.93; SD=1.29 vs. M=4.33; SD=1.44).

Effects on Preferences for Electricity Use Information

A Repeated-Measures ANOVA examined the effect of between-subjects variables format (table vs. bar graph vs. icon graph) and respondents' energy literacy (high vs. low) as well as within-subjects variable of information type (historical use vs. neighbor comparison vs. historical appliance breakdown) on preferences for the materials. There was no significant main effect for format or energy literacy on preferences ($p>.05$). However, there was a significant main effect of type of information, $F(2, 378)=95.59$, $\eta_p^2=.34$, $p<.001$, with Sidak's post-hoc tests showing that, overall, the historical use information was preferred the most (M=5.75, SD=1.12), followed by the historical appliance breakdown information (M=5.26, SD=1.33), and lastly the neighbor comparison information (M=4.39, SD=1.62), with all being significantly different from each other ($\alpha=.05$).

In addition, there was a significant interaction between type of electricity use information and format, $F(4, 378)=5.27$, $\eta_p^2=.05$, $p<.001$. A multivariate ANOVA showed that the neighbor comparison information yielded a main effect of format, $F(2, 190)=3.68$, $\eta_p^2=.04$, $p=.027$, with Sidak's post-hoc tests ($\alpha=.05$) showing that the table was preferred more than the histogram with bars, and the histogram with icons showing no difference between either the table or histogram with bars (Table 2).

In addition, there was an interaction between the type of electricity use information and energy literacy, $F(2, 378)=5.01$, $\eta_p^2=.03$, $p=.007$. Simple t-tests showed that participants with lower energy literacy preferred the historical use information significantly less than did participants with higher energy literacy (M=5.56, SD=1.37 vs. M=5.88, SD=.89), $t(196)=-1.98$, $p=.049$, with no significant differences for the other types of information ($\alpha=.05$). There were no additional interactions ($\alpha=.05$).

[Table 2 near here]

Effects on Intentions to Save Electricity

A Repeated-Measures ANOVA examined the effect of format (table vs. bar graph vs. icon graph), type of electricity use information (historical use vs. neighbor comparison vs. historical appliance breakdown), and respondents' energy literacy (high vs. low), on their behavioral intentions. The only main effect was for content $F(2, 366)=21.74$, $\eta_p^2=.11$, $p<.001$. According to Sidak post-hoc tests ($\alpha=.05$), intentions to save electricity in response to the historical use information (M=5.71; SD=1.76) and historical appliance breakdown information (M=5.42; SD=1.73) were significantly higher than those for the neighbor comparison information (M=4.83; SD=2.09) – but not significantly different from each other.

Discussion

To reduce climate-change risks, it is important to help consumers to lower their residential electricity use and associated carbon emissions (IPCC 2014). Better communications about electricity use could be added to electricity bills, to provide a relatively inexpensive strategy towards achieving this goal. We therefore sought to inform the design of electricity bills by building on theories and methods of health communication and graph comprehension. These literatures have posited that the effectiveness of communication materials depends on the type of information, the presentation format, as well as recipients' background knowledge (Lipkus 2007; Peters, Hart, and Fraenkel 2011; Shah, Freedman, and Vekiri 2005; Shah et al. 2009). Thus, we created table, bar graph, and icon graph formats to provide information about a household's historical electricity use, comparisons to neighbors' use, and historical appliance-specific use. We tested their effects on recipients' understanding, preferences for the presented information, and intentions to save electricity, while taking into account individual differences in background knowledge (i.e., energy literacy). Below we present our findings on these three outcome measures, and their theoretical implications, followed by a discussion of limitations and practical implications.

Improving Understanding of Electricity Use Information

Our first main finding is that the tables we designed to communicate electricity use information were the easiest format for participants to understand. Independent of the specific type of electricity use information that was provided, the table format performed as well or better than the icon graph format and consistently better than the bar graph format. A qualitative study also found that tables presenting household electricity use information were well-understood and preferred by consumers (Karjalainen 2011). These findings are in line with theories suggesting that the table format provides the best ‘cognitive fit’ when tasks require understanding simple point reading of a specific number, while graphical formats are better for use with more complex tasks that require information integration and interpretation (Friel et al. 2001; Shah and Hoeffner 2002; Vessey 1991). Indeed, as noted, electricity bills may mostly be used for point reading of household electricity use, and simple comparisons to previous use or that of neighbors.

Of course, other real-world contexts may require more complex interpretations of information, which can be better communicated with graphs. For example, health communications often involve the evaluation of health options’ risks and benefits, following complex health regimes, and weighing short-term against long-term benefits (Garcia-Retamero and Cokely 2011; Peters et al. 2007). Indeed, icon graph formats have shown promise for communicating risk comparisons in the health domain (Garcia-Retamero and Cokely 2013; Garcia-Retamero, Okan, and Cokely 2012).

Yet, even in the health domain, tables are sometimes better than graphs for communicating straightforward numbers, such as the specific percent of a patient population who will get sick (Hawley et al. 2008). Tables have also been found to be useful for the presentation of financial statements that require the point reading of a specific number, while graphs are better for processing more complex patterns in financial data (Davis 1989).

Although the table format was most effective across the types of information we presented, the histogram with icons showed promise for communicating neighbor comparisons. In our study, the histogram with icons showed the location of a specific household in the distribution of electricity use across neighbors (Figure 2C). Hence, it was similar to a bar graph (Figure 2B), but replaced the bars with icons of houses. Recent research in health communication has indicated that the types of icons that are used in the graph can make a difference, with anthropomorphic icons such as restroom icons, head outlines, and photo leading to better risk recall than other icons such as blocks or ovals (Hawley et al. 2013). However, the effectiveness of the specific icons may depend on the context under consideration, and the background knowledge of the recipients (Hawley et al. 2013, Stone et al. 1997). Although people have indicated that they like the presentation of house icons (Egan 1999), icon types have not yet been studied in the context of electricity use information.

Improving Preferences and Intentions to Save Electricity

Our second main finding is that preferences for the presented information and intentions to save electricity were the strongest for the historical use information. Historical use information is requested in qualitative interviews with consumers (Karjalainen 2011). Even when electricity bills provide no historical use information, consumers may attempt to understand trends in their use by comparing their current electricity bill with preceding ones (Hayes and Cone 1981). Because individuals have a choice of whether or not to pay attention to the presented information, it is important to design electricity bills that they are willing to look at (Egan 1999). Presenting information that consumers prefer and perceive as useful is an important goal for companies who seek to promote customer satisfaction (Keller-Cohen 1987).

Possibly, historical use information evoked such positive responses due to its familiarity and associated ease of processing, especially among individuals with higher background knowledge (Shah and Freedman 2009). We deliberately presented historical use information first, thus choosing a presentation order that would realistically be implemented on electricity bills. Indeed, educators recommend allowing participants to learn from the simple version of a task before asking them to tackle more complex versions (van Merriënboer et al. 2003). Yet, we also recognize that it is important for future research to test how many tasks can be presented before causing fatigue (Galesic and Bosnjak 2009; Krosnick 1999), or how well individual complex tasks can be understood when simpler tasks are not presented first.

Although historical use information can provide insights about a household's overall usage pattern, it has been criticized for making it difficult to interpret irregularities due to extreme weather or long absences (Egan 1999; Karjalainen 2011). We are not aware of studies that have tested whether consumers recognize such effects on their historical use information. Another remaining empirical question is how to present more complex historical use information that is corrected for local weather, so that recipients understand and trust it. Moreover, research is needed to examine the long-term effects of bill-based historical use information on electricity use behavior. When electricity use is already low, historical use information should have little to no effect on motivations to save electricity, and may even cause use to go up. Adding smiley face when use is low as compared to neighbors avoids increases in use (Schultz et al. 2007). Possibly, adding a smiley face to the electricity bill when historical use is low could also reduce adverse effects on low users, but that strategy has not yet been tested.

Interestingly, neighbor comparison information was not received as positively as historical use information. In studies of communications about water use, consumers have also been found to pay the most attention to historical use information, as compared to neighbor comparisons and other types of information (Erickson, Podlaseck, Sahu, Dai, Chao, and Naphade 2012). Yet, providing neighbor comparisons has shown promise in previous work on electricity use, in terms of yielding positive responses (Egan 1999; Schultz et al. 2007). However, those studies did not directly compare neighbor comparisons with historical use information, leaving it unclear which type of information consumers prefer.

Our study did compare recipients' responses to different types of electricity use information. In a within-subjects design, participants saw historical use information and neighbor comparison information, as well as appliance-specific information. In qualitative interviews, people had shown similar preferences (Karjalainen 2011). When making direct comparisons, it is easier for people to identify the presentation they find most appealing and comprehensible (Brewer et al. 2011). However, the ultimate test of the effectiveness of electricity bill information should involve measures of actual household electricity use, with the best information leading to the largest reductions.

Recognizing Individual Differences in Background Knowledge

Although initial studies had examined consumers' responses to electricity bills (Egan 1999; Karjalainen 2011), none had examined the role of individual differences in recipients' ability to understand the presented knowledge. Yet, individual differences in domain knowledge are found to be important to table and graph comprehension (Shah and Freedman 2009). Our third main finding is that individuals with low energy literacy understood all information less, independent of the presented content or format. Thus, individuals with low energy literacy may need to be provided with written descriptions of how to interpret the presented information, and apply it to decisions about their own electricity use (Shah and Hoeffner 2002).

In addition, low energy literacy participants found the historical use information less useful than those with high energy literacy. Possibly, they found the historical use information too technical. The health communication literature does indeed suggest that individuals with low health numeracy prefer to focus on the qualitative rather than the quantitative aspects of communications (Peters et al. 2007; Peters et al. 2011; Reyna et al. 2009; Ancker et al. 2006). Individuals with low numeracy may not want to think hard about complex numerical information (Bruine de Bruin, McNair, Taylor, Summers, and Strough, 2015).

Our work included no performance measures of numeracy or graph literacy, both of which are important for understanding graphs (Garcia-Retamero and Galesic 2010). Such general skills promote graph comprehension beyond specific domain knowledge (Shah and Freedman 2009). These specific skills may interact, such that individuals with low numeracy and high graph literacy may benefit from having visual displays added to standard numerical health risk information (Garcia-Retamero and Galesic 2010). Future research should examine whether such effects are also seen in domains where simple ‘verbatim’ numbers are the main focus of communication.

Taken together, these findings suggest that the type of information that is provided could be tailored to the needs and wants of the individual. With the advance of online billing, it may be possible to allow individuals to choose the type of information they find most useful, in the format they prefer. Studies of in-home displays have indeed suggested that people are interested in designing the information they receive about their electricity use, though they may not always be good at selecting the information that they understand best (Krishnamurti, Davis, Wong-Parodi, & Canfield, 2013).

Limitations

Like any study, ours had limitations. We summarize the main limitations here, even though some have already been noted above. First, we presented participants with hypothetical electricity bills and had no direct measure of electricity use, leaving it unclear which type of information or format would have actually led to the most electricity savings. Because field trials tend to be expensive, we conducted a cost-effective survey-based experiment to identify the most promising bill designs (Fischhoff et al. 2011). Yet, to be more confident about our findings, it is important to invest in randomized controlled field trials in which the responses of actual consumers are followed over time after random assignment to different electricity bills. Second, the presented information pertained to only one month in which electricity use was relatively high, both compared to the household's own use and compared to that of their neighbors. As noted, information may be less effective and even counter-productive when use is relatively low. However, presenting low users with positive feedback in the form of a smiley face may encourage continued savings (Schultz et al. 2007). Third, our understanding questions focused on point reading and simple point comparisons, which are the types of tasks consumers face when being presented with electricity bills. Our findings may not generalize to contexts that require more complex information integration and interpretation, which may be more easily executed when the data are presented in graphical formats (Friel, Curcio, and Bright 2001; Shah and Hoeffner 2002; Vessey 1991).

Practical Implications

Despite its limitations, our study suggests the possibility that information presented on electricity bills may be better understood and preferred, as well as increase intentions to save electricity, if they start presenting information about households' historical use in table format (rather than information about neighbor comparisons or appliance breakdowns, or graphical formats). If additional information is provided, people prefer an appliance-specific breakdown, which is also better understood in table format. It is likely that other billing or account statements could also benefit from the presentation of tables with historical use information. For example, our findings may also be useful for providing information about consumers' use of water, gas, telecommunications, and banking, especially if these tasks involve point reading. To date, few studies have examined bill design in such contexts (for exceptions see Egan 1999; Karjalainen 2011; Keller-Cohen 1989; Wilhite and Ling 1995).

Perhaps as a result, bills often provide no useful information for evaluating the need to reduce electricity use (Fischer 2008). Even if tables and graphs are presented in real-world contexts, they can be hard to understand (Beattie and Jones 1997; Woller-Carter, Okan, and Cokely 2013). Because experts' may not have good intuitions about how to present information to non-experts, developing effective communications requires input from interviews and survey-based experiments with the intended audience (Bruine de Bruin and Bostrom 2013; Fischhoff et al. 2011). Our study provided the first step towards understanding the effect of content, format and individual differences on consumers' responses to bill-based electricity use information.

Before widespread implementation of new bill designs, it is critical to empirically test the usefulness of the presented information. Re-designed electricity bills may be augmented with other strategies to promote long-term behavior change. Longitudinal field trials are lacking in the domain of energy behavior, but promising strategies may include goal setting, competitive games, incentive schemes, and real-time visual information through in-home displays (Abrahamse et al. 2005; Fischer 2008). Similar strategies have been suggested for promoting reductions in residential water use (Erickson et al. 2012). Each of these strategies may benefit from being presented with electricity use information that promotes understanding, preferences, and behavior change. Hence, our findings contribute to a potential portfolio of strategies for reducing residential electricity use and curbing climate change.

Footnote

[1] To provide households with feedback about their appliance-specific electricity use, homes may need to be instrumented with appliance-level meters. Lower-cost options include estimating appliance use based on consumer-provided information (e.g., Residential Energy Consumption Survey, www.eia.gov/consumption/residential), which may not be as accurate.

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Table 1: Proportion of correct responses to the seven understanding questions.

Electricity use information	Table formats	Bar graph formats	Icon graph formats
Historical use	.84[bi] (.16)	.73 (.20)	.77 (.17)
Neighbor comparisons	.75[b] (.19)	.49 (.22)	.75[b] (.21)
Appliance breakdown	.73[bi] (.19)	.64 (.20)	.61 (.18)

Note: Symbol indicates significantly higher understanding scores than the bar graph ([b]) or icon graph ([i]), at α=.05.

Table 2: Mean (SD) ratings of preferences for information.

Electricity use information	Table format	Bar graph format	Icon graph format
Historical use	5.67 (1.12)	5.72 (1.14)	5.85 (1.11)
Neighbor comparisons	4.80[b] (1.51)	4.09 (1.55)	4.26 (1.72)
Appliance breakdown	5.41 (1.21)	5.41 (1.14)	4.97 (1.57)

Note: Symbol indicates significantly higher understanding than the bar graph ([b]) or icon graph ([i]), at α =.05.

Figure 1. Historical use information as presented to participants in (a) a table format, (b) a bar graph format, and (c) an icon graph format.

(A)

Imagine that this table shows the Smith's electricity use. This table shows their historical usage over the past year.

The Smith's Electricity Bill – Historical Usage

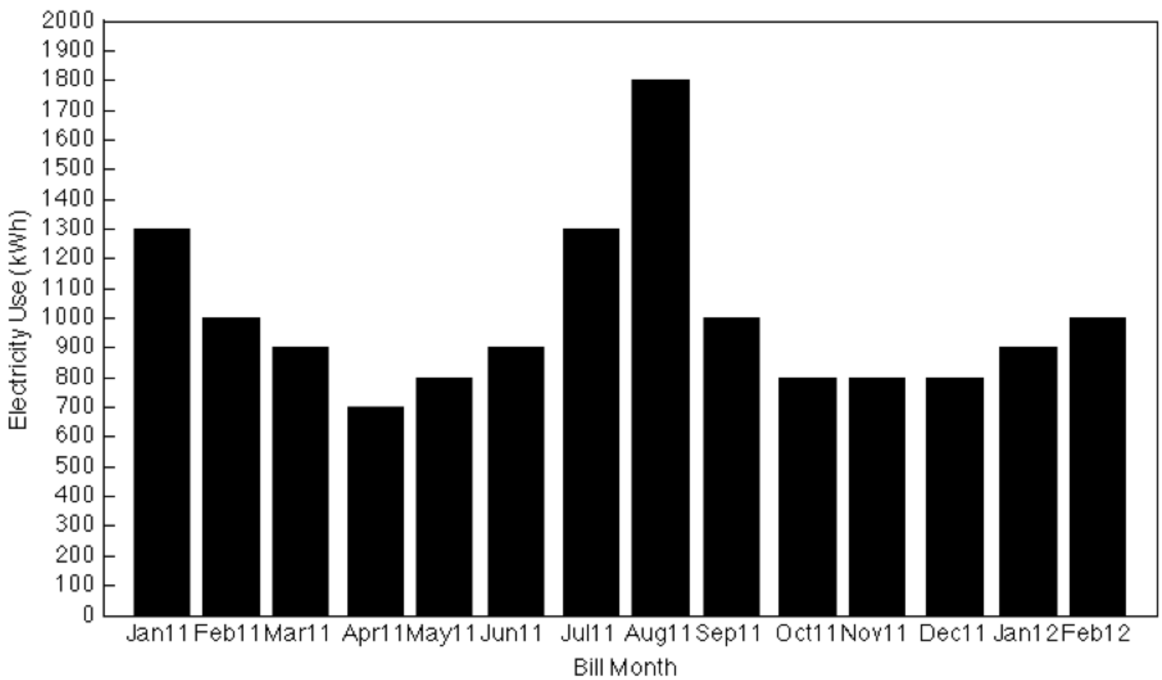
Bill Month	Electricity Use (kWh)
Jan 11	1300
Feb 11	1000
Mar 11	900
Apr 11	700
May 11	800
Jun 11	900
Jul 11	1300
Aug 11	1800
Sep 11	1000
Oct 11	800
Nov 11	800
Dec 11	800
Jan 12	900
Feb 12	1000

(B)

Imagine that this graph shows the Smith's electricity use. This graph shows their historical usage over the past year.

The Smith's Electricity Bill – Historical Usage

Each bar is the amount of electricity used in kWh.



(C)

Imagine that this graph shows the Smith's electricity use. This graph shows their historical usage over the past year.

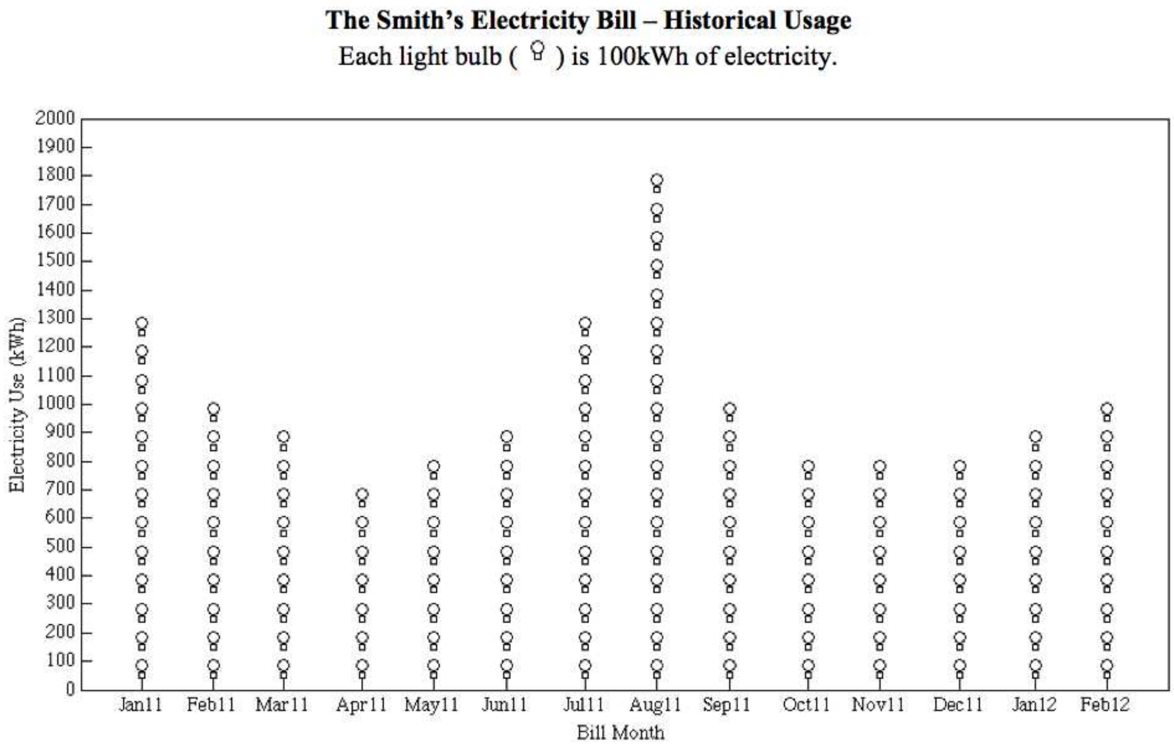


Figure 2. Neighbor comparison information as presented to participants in (a) a table format, (b) a bar graph format (histogram with bars), and (c) an icon graph format (histogram with icons).

(A)

Imagine that this table shows the Smith's electricity use compared to their neighbors. This shows how much electricity the Smiths used in total last month compared to 20 of their neighbors.

Their 20 neighbors live in nearby homes that are similar to the Smiths.

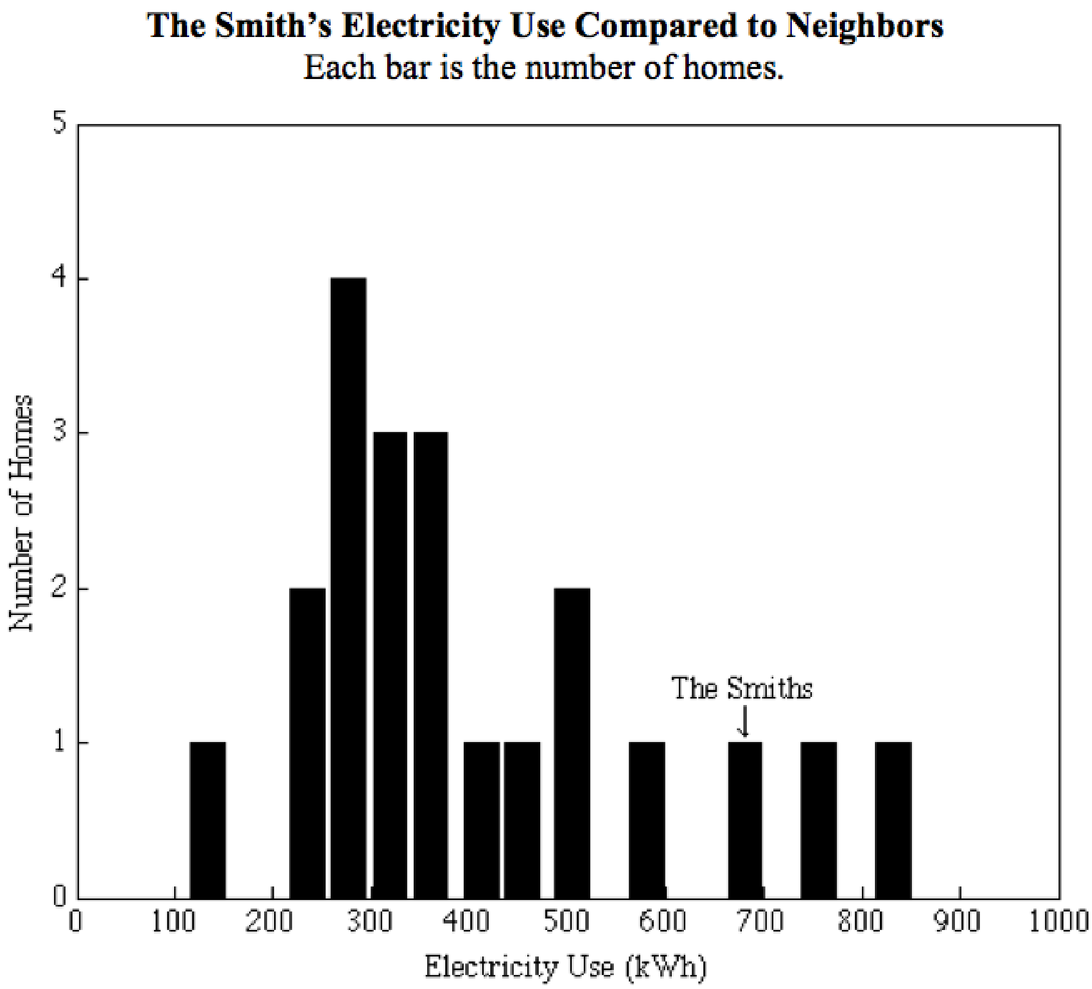
The Smith's Electricity Use Compared to Neighbors

Number of Homes	Electricity Use (kWh)	
1	137	
2	238	
4	279	
3	322	
3	364	
1	412	
1	450	
2	504	
1	581	
1	682	← The Smiths
1	758	
1	833	

(B)

Imagine that this graph shows the Smith's electricity use compared to their neighbors. This shows how much electricity the Smiths used in total last month compared to 20 of their neighbors.

Their 20 neighbors live in nearby homes that are similar to the Smiths.



(C)

Imagine that this graph shows the Smith's electricity use compared to their neighbors. This shows how much electricity the Smiths used in total last month compared to 20 of their neighbors.

Their 20 neighbors live in nearby homes that are similar to the Smiths.

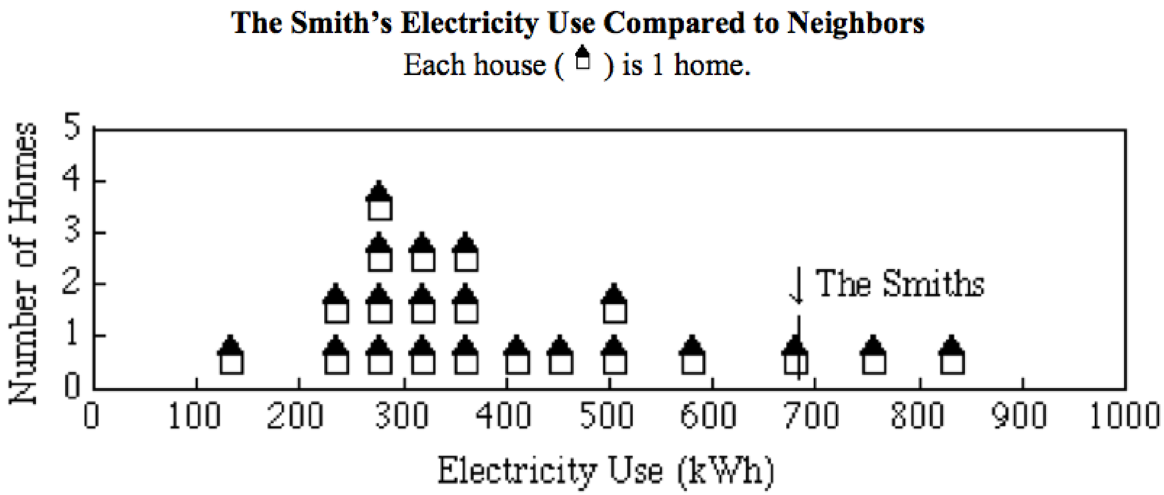


Figure 3. Historical appliance breakdown information as presented to participants in (a) a table format, (b) a bar graph format, and (c) an icon graph format.

(A)

Imagine that this table shows the Smith's electricity use by appliance. This table shows personalized estimates of how much electricity their appliances used over the last year.

The Smith's house has central A/C for cooling and mostly uses natural gas instead of electricity for heating. However, they do have a few electric space heaters that are shown on this table. The kitchen appliances include a refrigerator, freezer, dishwasher, and microwave. The other category includes all electronics such as TVs, computers, a washing machine, and a dryer.

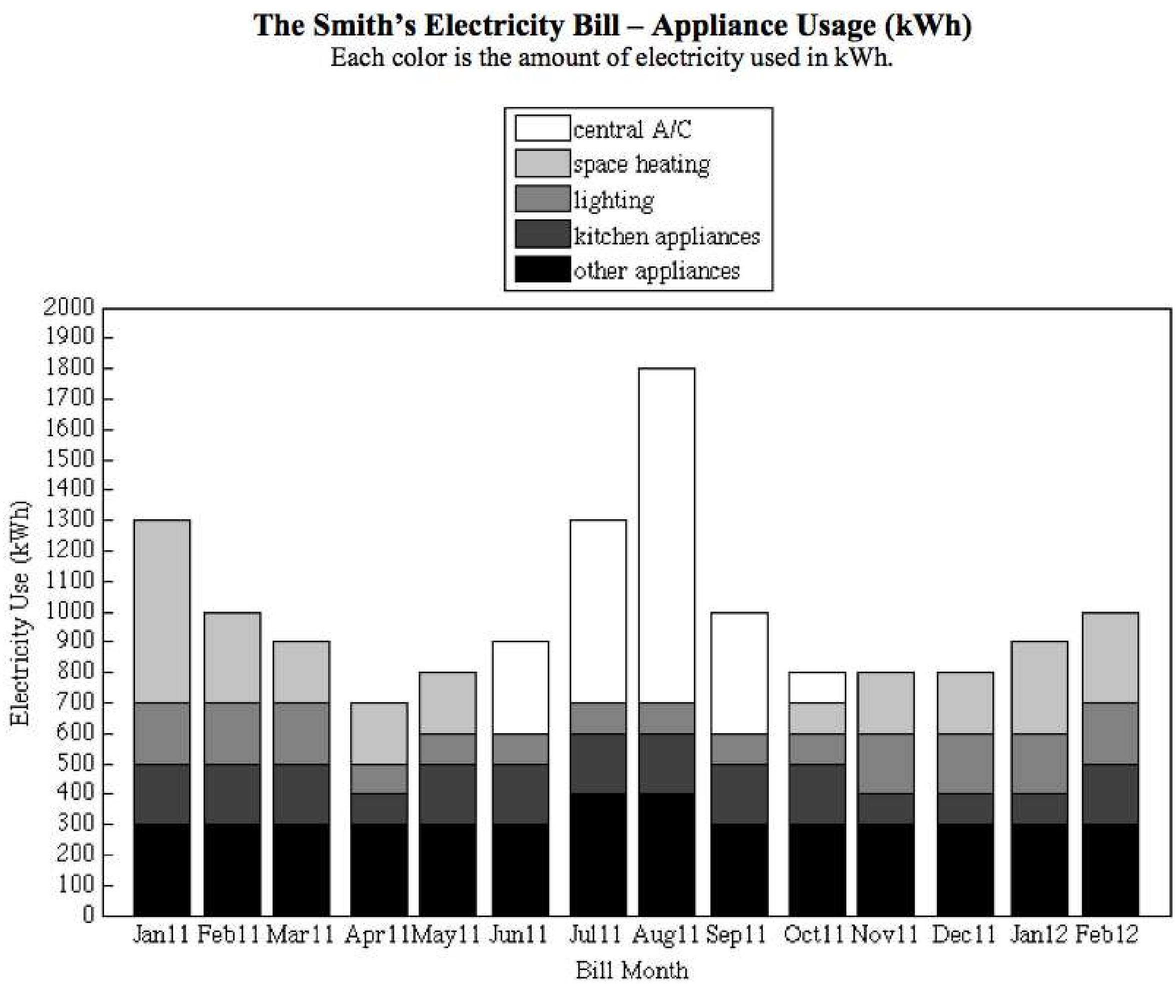
The Smith's Electricity Bill – Appliance Usage (kWh)

	Electricity Use (kWh)					Total
Bill Month	**Central A/C**	**Space Heating**	**Lighting**	**Kitchen Appliances**	**Other Appliances**	**(kWh)**
Jan 11	0	600	200	200	300	1300
Feb 11	0	300	200	200	300	1000
Mar 11	0	200	200	200	300	900
Apr 11	0	200	100	100	300	700
May 11	0	200	100	200	300	800
Jun 11	300	0	100	200	300	900
Jul 11	600	0	100	200	400	1300
Aug 11	1100	0	100	200	400	1800
Sep 11	400	0	100	200	300	1000
Oct 11	100	100	100	200	300	800
Nov 11	0	200	200	100	300	800
Dec 11	0	200	200	100	300	800
Jan 12	0	300	200	100	300	900
Feb 12	0	300	200	200	300	1000

(B)

Imagine that this graph shows the Smith's electricity use by appliance. This graph shows personalized estimates of how much electricity their appliances used over the last year.

The Smith's house has central A/C for cooling and mostly uses natural gas instead of electricity for heating. However, they do have a few electric space heaters that are shown on this graph. The kitchen appliances include a refrigerator, freezer, dishwasher, and microwave. The other category includes all electronics such as TVs, computers, a washing machine, and a dryer.



(C)

Imagine that this graph shows the Smith's electricity use by appliance. This graph shows personalized estimates of how much electricity their appliances used over the last year.

The Smith's house has central A/C for cooling and mostly uses natural gas instead of electricity for heating. However, they do have a few electric space heaters that are shown on this graph. The kitchen appliances include a refrigerator, freezer, dishwasher, and microwave. The other category includes all electronics such as TVs, computers, a washing machine, and a dryer.

The Smith's Electricity Bill – Appliance Usage (kWh)

Each picture is 100kWh of electricity.