Redesigning Bills: The Effect of Format on Responses to Electricity Use Information

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Abstract

Electricity bills could be a low-cost strategy for improving feedback about consumers' home electricity use and helping households reduce carbon dioxide emissions. However, quantitative feedback may be difficult to understand, especially for consumers with low numeracy or low energy literacy. Here, we build on the health communication literature, which has identified formats for communicating risks to low-numerate individuals. Participants saw one of three formats for presenting electricity use information including (a) tables, (b) bar graphs, and (c) icon graphs. In their assigned format, each participant saw three information types: (a) historical use, (b) comparison to neighbors, and (c) appliance breakdown. Three main findings emerged: First, the table format generated on average the best understanding across all three information types, across participants of all numeracy and energy literacy levels. Second, the benefit of alternative graphical formats varied depending on information type, in terms of effects on understanding and trust and liking. Neighbor comparison information was liked least and had the lowest intentions for behavior change, despite being no harder to understand than the appliance breakdown information. Third, individuals with lower numeracy and energy literacy understood all formats less. We discuss implications for designing utility bills that are understandable and motivate consumers.

Keywords: electricity use feedback, graphical communication, numeracy

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To curb the risks associated with climate change, the Intergovernmental Panel on Climate Change (IPCC, 2007) has posited that global carbon dioxide emissions from electricity generation must be reduced to 50-80% below 2007 levels by 2050. In 2009, the U.S. produced 18% of all carbon dioxide (CO_2) emissions worldwide (EIA, 2009a), with approximately 22% of that coming from U.S. residential energy consumption alone (EIA, 2009b). It has been estimated that residential energy consumption could be reduced by approximately 20% in 10 years (Dietz, Gardner, Gilligan, Stern, & Vandenbergh, 2009) through energy efficiency and conservation strategies (Pacala & Socolow, 2004).

Unfortunately, members of the general American public face several barriers to saving electricity, including a lack of information about which of their behaviors use the most electricity, and which strategies are most effective for achieving energy savings (Owens & Driffill, 2008; Gardner & Stern, 2008). For example, consumers often focus on turning off lights, which yields much lower energy savings than energy-efficiency improvements such as switching from incandescent light bulbs to compact florescent lights (Attari, DeKay, Davidson, & Bruine de Bruin, 2010).

Evidence suggests that feedback on electricity use is associated with reduced consumption (Darby, 2006; Fischer, 2008; Wilhite & Ling, 1995). Because most consumers pay at least some attention to their electricity bills, improving the information provided via the bill is one promising, low-cost strategy for enhancing consumers' understanding of their electricity use (Wilhite & Ling, 1995) and increasing their self-efficacy for saving electricity (Bandura, 1977). At present, however, most electricity bills are confusing and provide little detail or contextual information (Egan, 1999; Foster & Alschuler, 2011). For example, Southwell, Murphy, DeWaters, and LeBaron (2012) found that only 27% of 816 participants were able to correctly answer three simple questions about a hypothetical utility bill, which asked for calculations of: (1) the monetary cost of total energy usage given a different rate of $/kWh, (2) the monetary savings from using 300kWh less, and (3) the total kWh's used next month given the next meter reading.

Three types of information have been recommended as being potentially useful for helping consumers to understand their electricity use. First, presenting information about households' historical electricity use could help consumers to identify periods of high or low usage (Fischer, 2008). Second, adding an appliance-specific breakdown may provide insights about which appliance-specific behaviors use the most electricity (Fischer, 2008), although presenting too much information may lead to information overload (Peters, Dieckmann, Dixon, Hibbard, & Mertz, 2007; Zikmund-Fisher, Fagerlin, & Ubel, 2010). Third, showing consumers how their household's historical usage compares with similar households in the neighborhood or region may increase their motivation to save electricity, due to highlighting social norms for energy conservation and encouraging competition. One potential downside of providing neighbor-comparison information is that consumers who use less than their neighbors may actually increase their use so as to conform to the social norm (Allcott, 2011; Schultz, Nolan, Cialdini, Goldstein, & Griskevicius, 2007). However, follow-up research has found that adding a smiley face to neighbor-comparison information for low-use households encourages them to continue using less than most of their neighbors (Schultz et al., 2007).

Based on a meta-analysis of 21 original studies, Fischer (2008) suggests that feedback about electricity use, as provided through electronic and written media, tends to reduce energy consumption when it is frequent, presented in a clear and appealing way, and provides an appliance-specific breakdown. Such "improved billing" leads to reduction in overall energy consumption ranging on average between 5-12%. However, although graphs are commonly provided on electricity bills to communicate quantitative electricity use information, few have been empirically tested. Given the complexity of electricity use information, more research is needed to identify how to best communicate to consumers.

The role of numeracy and energy literacy in understanding electricity bills

To be effective, feedback provided through electricity bills should be understandable to *all* consumers. Therefore, it is important to recognize that consumers vary in their ability to understand numbers. The lack of numerical skills, also referred to as numeracy, may be a factor in people's inability to make simple computations based on the information provided with their electricity bill. Many Americans have low numeracy skills, which have been correlated to poor understanding of quantitative information about health risks (Fagerlin & Peters, 2011; Fagerlin, Ubel, Smith, & Zikmund-Fisher, 2007; Peters, Hart, & Fraenkel, 2011; Reyna, Nelson, Han, & Dieckmann, 2009; Schwartz, Woloshin, Black, & Welch, 1997). Americans also tend to have very low energy literacy, with a 2002 report by the National Environmental Education & Training Foundation stating that only 12% of Americans could pass a basic energy test (with a score over 70%) despite 75% rating themselves as having at least "a fair amount" of energy knowledge. As a result, it is important to consider how low numeracy and energy literacy may impede Americans' ability to correctly interpret and use numerical feedback about electricity use. Due to the relationship between income level and education attainment, issues of low numeracy and energy literacy are likely to disproportionately affect vulnerable low-income populations.

Effective formats for communicating quantitative information

Public health research on communicating quantitative information about health risks has suggested that graphical displays combined with text are a promising strategy for making numbers easier to understand, especially for low-numerate consumers (Stone, Yates, & Parker, 1997; Garcia-Retamero & Galesic, 2010). Simple graphs can capture attention and improve understanding of patterns, trends and proportions (Cleveland & McGill, 1984). However, graphs that aim to communicate more than one message may be too difficult to understand, thus introducing a trade-off between simplicity and comprehensiveness (Zikmund-Fisher et al., 2010; Rowe, Gibson, Bruine de Bruin, & Stone, 2013). Some individuals have trouble understanding graphs, especially when the message becomes more complex (Garcia-Retamero & Galesic, 2010). Unfortunately, graphs are often implemented without testing their effectiveness with the target audience (e.g. see Spiegelhalter, Pearson, & Short, 2011).

The communication literature provides strategies for effectively designing understandable graphs. As noted, most of that research has been conducted in the context of health communications, with graphs displaying health risks. Specifically, three strategies have been recommended for designing more understandable graphs: 1) minimizing the computations needed to understand the main message, 2) matching the format to the task, and 3) using a familiar format for the audience.

First, minimizing the computations needed to understand the main message is important for improving recipients' understanding of graphical displays. Waters, Weinstein, Colditz, and Emmons (2006) found that graphs improved accuracy only when showing the crucial comparison without requiring additional computations. For example, a grouped bar graph, where each component of a whole is presented as a separate bar, can be difficult to use because it requires recipients to add up the separate bars before making a comparison between options. A stacked bar graph is easier to use because it removes the need to do this computation.

Second, the best format may depend on the specific task at hand. The most effective format is typically the one that focuses on the main message, while also allowing individuals to look up specific values (Reyna et al., 2009). Tables make it easy to find specific values (Felman-Stewart, Kocovski, McConnell, Brundage, & Mackillop, 2000). Graphs are typically better than tables for communicating a single main message, but only if the presented information remains relatively simple (Ancker, Senathirajah, Kukafka, & Starren, 2006; Cleveland & McGill, 1984). Histograms, which also use bars, are useful for communicating information about the distribution of outcomes, especially when relevant features such as the overall mean are clearly marked (Ibrekk & Morgan, 1987). Nevertheless presenting histograms to teach recipients about the distribution of outcomes may reduce the likelihood that recipients will learn the overall mean (Rowe et al., 2013).

Icon graphs or pictographs, where the data are represented by discrete icons (see Figure 1C for example, in which each icon represents 100kWh of usage), can be useful for both identifying specific values and making comparisons. In the medical context, an icon graph is often used to indicate the percentage of people who are at risk (vs. not at risk) for a particular disease or treatment. If multiple icon graphs for different medical treatments are presented side by side, people can compare the effects of the different medical treatments on people's risks (Galesic, Garcia-Retamero, & Gigerenzer, 2009; Hawley et al., 2008; Okan, Garcia-Retamero, Cokely, & Maldonado, 2012). In the context of a hypothetical medical treatment, Hawley et al. (2008) found that the icon graph improved accuracy for various tasks across individuals with different numeracy levels, as compared to tables and several types of graphs including bar graphs and pie charts. The tasks ranged from looking up a specific value to comparing treatment options. However, the best format for electricity use information may differ from health communication due to the different types of information involved.

A third strategy for making graphs understandable is to use formats that are familiar to the specific audience. Even high-numerate individuals are more familiar with certain formats and consequently, and are best able to interpret information in that form. Coll, Coll, & Thakur (1994) found that graduate engineering and business students performed best on mixed tasks (involving making comparisons and looking up values) when using tables. However, engineering students outperformed business students when using graphs, likely because business students are much more familiar with using tables than graphs. Hence, particularly for complex information, graphical formats may create a greater cognitive burden unless the user is highly accustomed to graphical interpretation.

Of course, formats that are best understood are not necessarily liked the most. People prefer bar graphs even in cases where icon graphs may enhance performance (Feldman-Stewart et al., 2000). Supporting this notion, a review by Ancker et al. (2006) identified that graphical features that recipients like are not necessarily the ones that enhance their understanding. It is possible that people process new graphs differently than familiar graphs, which causes a difference in comprehension. In addition, Hawley et al. (2008) found that tables were perceived as more trustworthy and scientific, compared to five graphical formats. Although high numeracy individuals rated all the graphs as easier to understand than did low numeracy individuals, both groups rated the icon graph favorably. In one of the few studies focusing on graphical display of energy information, Egan (1999) showed that normative feedback that compares consumers' electricity use to that of their neighbors is better understood with a distribution graph of houses (i.e. an icon graph) than with a range chart that removed distributional information (Iyer, Kempton, & Payne, 2006). In addition, although people tended to correctly interpret a bell-curve graph, they strongly disliked it (Egan, 1999). In general, particularly for complex electricity use information, consumers are not good at predicting what information they will understand best (Anderson & White, 2009). Given that enhancing understanding, trust and liking, as well as behavioral intentions all improve decision-making, effective communication must maximize scores on all of these factors to encourage energy conservation behavior.

Research Questions

Overall, the literature on graphical displays, which mostly focuses on communicating health risks, suggests that effective graphs should promote (a) understanding, (b) trust and liking, and (c) behavioral intentions (Ancker et al., 2006; Lipkus, 2007). Ideally, these outcomes will be experienced across recipients with varying competency levels. This paper aims to apply methods from the health communication literature to the design of electricity bills, by randomly assigning participants to receiving electricity bills that use either (a) tables, (b) icon graphs, or (c) bar graphs, to communicate information about three types of information that have been recommended as potentially useful for helping consumers to understand their electricity use (Allcott, 2011; Fischer, 2008; Schultz et al., 2007): (1) households' historical use, (2) comparison to neighbors' use, and (3) historical use with appliance-specific breakdown as shown in Figure 1-3. Specifically, this study explores the following questions:

1. Which format for presenting electricity use information (table vs. icon graph vs. bar graph) best facilitates recipients' understanding, trust and liking, as well as behavioral intentions in terms of reducing electricity use?
2. Does the best format depend on the type of information that is being conveyed about electricity use (i.e., historical use, comparison to neighbors' use, or historical appliance-specific use)?
3. Do individuals with low numeracy and low energy literacy respond differently to information formats, in terms of understanding, trust and liking, as well as behavioral intentions than do those with high numeracy and high energy literacy?

Methods

Sample

We recruited 201 participants through community organizations in the greater Pittsburgh metropolitan area. We aimed for a diverse community sample, because our goal was to examine the role of numeracy and energy literacy in understanding quantitative information about electricity use. A total of 80.1% had not finished a 4-year college degree, with 44.4% of the total 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, 77.2% non-white, and 65% earning less than $30,000 per year.

Procedure

Survey sessions were administered at the organizations through which participants were recruited. Following previous work (Egan, 1999), participants received hypothetical information about the electricity use of the Smith family household. In order, the materials received by each participant covered the Smith family's (a) historical electricity use, (b) recent electricity use as compared to their neighbors, and (c) historical electricity use broken down by appliances, because these types of information have been recommended as potentially useful for understanding residential electricity use (Allcott, 2011; Fischer, 2008; Schultz et al., 2007). Participants were randomly assigned to receive those three types of information in one of three communication formats, which were adapted from the health communication literature (Garcia-Retamero & Galesic, 2010; Hawley et al., 2008; Stone et al., 1997): (a) tables, (b) bar graphs or (c) icon graphs. Figure 1 shows the household's historical electricity use in kWh per month, over the period between January 2011 and February 2012 in (a) a table, (b) a bar graph and (c) an icon graph that was similar to the bar graph, but replaced each bar with light bulb icons to represent every 100kWh. Figure 2 shows the households' electricity use in the previous month as it compared to the distribution of their neighbors' electricity use in the previous month, in (a) a table, (b) a bar graph or histogram, and (c) an icon graph in which each bar was replaced with house icons to represent each home, following Egan (1999). Figure 3 shows the household's appliance-specific breakdown information from January 2011 to February 2012, including (1) central A/C, (2) space heating, (3) lighting, (4) kitchen appliances, and (5) other appliances including "TVs, computers, a washing machine, and a dryer", in the format of (a) a table, (b) a stacked bar graph and (c) an icon graph in which a separate icon is used to represent 100kWh's of use for each appliance group. For each type of information, formats were designed to follow recommendations from the literature and to contain the same level of detail. All materials were pretested with participants from different backgrounds to ensure ease of use.

Measures

We used three outcome measures to evaluate each format and type of information, following recommendations in the health communication literature suggesting that effective information formats should improve understanding, trust and liking, as well as behavioral intentions (Ancker et al., 2006; Lipkus, 2007). We measured participants' (1) *understanding* of the presented information with seven true/false questions assessing their understanding of the content, designed to cover a range of tasks (listed in the appendix), (2) *trust and liking* of the materials as rated on nine Likert-scale items (for example "How much do you like the way this information was presented?") (1=Not at all; 7=Very much), and (3) *behavioral intentions* as rated on two Likert-scale items (for example "How much does this information make you want to lower your electricity usage?") (1=Not at all; 7=A lot) (full measures listed in the Appendix). Each of these measures was repeated for the historical use information, the neighbor comparison information, and the appliance breakdown information.

Next, participants completed 8 items about home energy use adapted from a high-school level energy literacy test that was checked for accuracy by a panel of experts (DeWaters & Powers, 2011) (see Appendix). They also rated their own numeracy skills on an 8-item Subjective Numeracy Scale (Fagerlin et al., 2007; Zikmund-Fisher, Smith, Ubel, & Fagerlin, 2007). We chose the Subjective Numeracy Scale instead of an objective performance measure of numeracy because participants experience it as much less aversive than the performance items, are more willing to answer it, and are less likely to refuse participation in subsequent studies after completing it (Fagerlin et al., 2007; Zikmund-Fisher, Smith, Ubel, & Fagerlin, 2007). After answering demographic questions and completing the survey, participants received $45. To encourage thoughtful responses, we also offered participants the opportunity to enroll in a competition to win a $50 gift certificate, awarded to the four individuals with the most correct answers to our true/false questions measuring understanding of the presented electricity-use information.

Results

Below, we discuss our analyses, which tested (a) the effectiveness of the table, bar graph, and icon graph in terms of improving understanding, trust and liking, as well as intentions for behavior change (Ancker et al., 2006; Lipkus, 2007), (b) variations of format effectiveness by information type (i.e., historical use, comparison to neighbors' use, or historical appliance-specific use), and (c) the role of numeracy and energy literacy.

Numeracy and energy literacy

Participants varied in their ability to use numbers, as reported on the 8-item Subjective Numeracy Scale (e.g., How good are you at calculating a 15% tip?) which was developed and validated against an objective numeracy scale by Zikmund-Fisher et al. (2007) (*MDN*=4.13; *M*=4.06; *SD*=1.01). A one-sample Kolomogorov-Smirnov test showed that the distribution of numeracy scores was not significantly different from a Normal distribution (K-S=.64, $p<.05$; skew=-.35, *SE*=.17; kurtosis=-.11, *SE*=.34). We divided participants into two groups reflecting whether their numeracy scores were above or below the median to be consistent with previous research (Fagerlin et al., 2007; Peters et al., 2006) and the energy literacy measure described below.

Participants also varied in their energy literacy, as assessed on 8 items about home energy use adapted from the high-school level energy literacy test created by DeWaters &

Powers (2011) (*MDN*=.39; *M*=.44; *SD*=.21). A one-sample Kolomogorov-Smirnov test showed that the distribution of energy literacy scores was significantly different from a Normal distribution (K-S=.005, p<.05; skew=.19, *SE*=.17; kurtosis=-.22, *SE*=.34). Energy literacy was correlated to numeracy, *r*(197)=.19, p=.008. In the analyses below, we divided participants into two groups, reflecting whether their energy literacy scores were above or below the median.

Understanding of the information

A Repeated-Measures Analysis of Variance (ANOVA) examined the effect of format (table vs. icon graph vs. bar graph), and information type (historical use vs. neighbor comparison vs. appliance breakdown), as well as respondents' numeracy (low vs. high) and energy literacy (low vs. high), on their understanding. Information type was a within-subject variable. Table 1 summarizes the mean and standard deviation of understanding scores by information type and format.

Our first main effect was for format $F(2,179)=18.93$, $\eta_p^2=.18$, $p<.001$, with Sidak post-hoc analyses ($\alpha=.05$) showing that the table format yielded the best understanding followed by the icon-graph format, which was easier than the bar-graph (histogram) format. Second, there was a main effect of information type $F(2, 358)=33.48$, $\eta_p^2=.16$, $p<.001$. Following findings from health communication research that have suggested that "less is more" when presenting quantitative information (Peters et al., 2007; Zikmund-Fisher et al., 2010), Sidak post-hoc analyses ($\alpha=.05$) showed that information about historical electricity use was easier to understand by itself than when the neighbor comparisons or appliance-specific feedback were added, with no significant difference between the latter two ($\alpha=.05$). Third, despite attempts to make all formats understandable to all participants, high-numerate participants (*M*=.73; *SD*=.17) scored better on all formats than did low-numerate participants (*M*=.68; *SD*=.14), $F(1, 179)=5.94$, $\eta_p^2=.03$, $p=.016$. Fourth, there was a main effect of energy literacy, $F(1, 179)=18.10$, $\eta_p^2=.09$, $p<.001$, such that participants with high energy literacy (*M*=.76; *SD*=.13) performed better than those with low energy literacy (*M*=.66; *SD*=.17).

Although the table was the easiest to understand across all information types, the effectiveness of the graphical formats did vary by information type. As seen in Table 1, there was a significant interaction effect of format and information type on understanding $F(4,358)=13.22$, $\eta_p^2=.13$, $p<.001$. We examined this interaction via a multivariate ANOVA for each of the three information types. First, there was a significant format effect for historical use information, $F(2,179)=5.17$, $\eta_p^2=.06$, $p=.007$, with Table 1 showing that the table format yielded significantly better understanding than the bar graph, with the icon graph showing no difference from the other two formats. There was also a significant format effect for the neighbor comparison information $F(2,179)=30.47$, $\eta_p^2=.25$, $p<.001$, with recipients of the table and the icon graph having the best understanding, and the histogram (bar graph) being significantly less effective. Finally, a significant format effect for the appliance-specific information $F(2,179)=6.75$, $\eta_p^2=.07$, $p=.001$, showed that table recipients performed better than both types of graph recipients. There were no additional significant interactions (p>.05).

Trust and liking of the information

The responses for trust and liking had high internal consistency, with a Cronbach's alpha of .88 for historical use, .93 for neighbor comparison, and .91 for appliance breakdown information. A summary measure for trust and liking was created for each information type.

A Repeated-Measures ANOVA examined the effect of format (table vs. icon graph vs. bar graph), information type (historical use vs. neighbor comparison vs. appliance breakdown), respondents' numeracy (low vs. high), and respondents' energy literacy (low vs. high), on their trust and liking of the materials. Information type was the only within subjects variable. Table 2 shows the mean and standard deviation of trust and liking ratings by information type and format. There was a main effect of information type, $F(2,366)=97.78$, $\eta_p^2=.35$, $p<.001$, with Sidak's post-hoc tests ($\alpha=.05$) showing that the historical use context had the highest trust and liking ratings, followed by the appliance breakdown context, and lastly the neighbor comparison context. There was no main effect for format, numeracy, or energy literacy on trust and liking ($p>.05$).

In addition, there was a significant interaction between format and information type, $F(4,366)=5.57$, $\eta_p^2=.06$, $p<.0001$. A multivariate ANOVA showed that the neighbor comparisons yielded a main effect of format, $F(2,183)=3.48$, $\eta_p^2=.04$, $p=.033$, with Sidak's post-hoc tests showing that the table yielded higher ratings for trust and liking, than the histogram with the icon graph showing no difference from the table or histogram.

In addition, there was an interaction between information type and energy literacy ($F(2,366)=3.95$, $\eta_p^2=.02$, $p=.02$). For the historical use and appliance breakdown contexts, participants with lower energy literacy rated lower trust and liking for the materials. For the neighbor comparison context, participants with lower energy literacy ($M=4.51$; $SD=1.57$) rated higher trust and liking for the materials than those with higher energy literacy ($M=4.26$; $SD=1.60$). There were no additional interactions ($p>.05$).

Behavioral intentions

The responses for behavioral intentions had high internal consistency, with a Cronbach's alpha of .82 for historical use, .86 for neighbor comparison, and .83 for appliance breakdown information.

A Repeated-Measures ANOVA examined the effect of format (table vs. icon graph vs. bar graph), information type (historical use vs. neighbor comparison vs. appliance breakdown), respondents' numeracy (low vs. high), and respondents' energy literacy (low vs. high), on their behavioral intentions. The only main effect was for information type $F(2,354)=32.55$, $\eta_p^2=.16$, $p<.001$. According to a Sidak post-hoc test ($\alpha=.05$), behavioral intention ratings in the historical use ($M=5.70$; $SD=1.60$) and appliance breakdown ($M=5.49$; $SD=1.61$) contexts were significantly higher than those for the neighbor comparison information ($M=4.74$; $SD=1.97$) – but not significantly different from each other.

Discussion

To reduce climate-change risks, it is important to help consumers to reduce their residential electricity use and associated carbon emissions. Better feedback through electricity bills may help to achieve this goal. This paper applies methods from the health communication literature to design electricity bills. We examined the effectiveness of tables, bar graphs (histograms), and icon graphs for communicating different types of electricity use information including historical electricity use, comparison to neighbors' use and appliance-specific feedback. We evaluated the effectiveness of each format in terms of understanding, trust and liking, as well as behavioral intentions. We reported on three main findings.

First, we found that, with the designs we used to communicate electricity use information, tables were the easiest to understand overall, with the effectiveness of the graphs depending on the information type. Indeed, as noted in the health communication literature, graphical displays are good for communicating simple messages but are known to produce cognitive overload when their message becomes too complex (Coll et al., 1994; Okan et al., 2012). Coll et al. (1994) found that for complex information, tables enhance recipients' ability to both look up values and identify relationships, which is what is typically required to understand how much electricity a household is using. In a qualitative study, Karjalainen (2011) found that tables of electricity use information were "instantly understood by everyone" and "clearly the preferred presentation method". We found no main effect of format for trust and liking or behavioral intentions.

Second, we examined whether format effects varied with information type, including historical use, comparison to neighbors' use, and appliance-specific use. The benefit of specific graphical formats varied depending on information type. For the historical use information, the table was significantly better than the bar graph, but not the icon graph, for understanding. For the neighbor comparison information, the icon graph and table performed much better than the histogram for promoting understanding – possibly because the icon format matches participants' mental process of counting houses and many people struggle to interpret histograms (Ibrekk & Morgan, 1987). For trust and liking, the table was preferred over the histogram. By contrast, for the appliance breakdown information, the icon graph was less useful for promoting understanding than the stacked bar graph. In this case, it seems that the variety of icons representing different types of energy use (such as lighting, cooking, heating, and cooling) made the icon graph too complex, and aggregating the appliance information in a stacked bar graph reduced the overall complexity of the format. While tables are more useful for improving understanding of complex information, the better graphical format varies depending on the context and complexity of the information.

It should also be noted that, independent of display format, historical use information was the easiest to understand, yielded the highest trust and liking, and led to highest behavioral intentions (tied with appliance-specific feedback), possibly because it was the least complex. The historical use information was the first piece of information participants saw in this study, while their responses to the later pieces of information may have been affected by fatigue (Galesic & Bosnjak, 2009; Krosnick, 1999). It is also important to note that the second piece of information people saw, the neighbor comparison, was liked least and had the lowest intentions for behavior change, despite being no harder to understand than the appliance breakdown information. Using a table helped to make the neighbor comparison be perceived as more trustworthy and likeable. This finding confirms other literature that has found that the neighbor comparison context has a weaker effect on behavioral intentions than historical information (Costa & Kahn, 2010; Fischer, 2008; Karjalainen, 2011; Roberts, Humphries, & Hyldon, 2004). As a result, utility companies may find mixed results when including neighbor comparison information in electricity bills.

Third, we examined whether format effects varied with individuals' competency levels, including numeracy and energy literacy. We found that individuals with low numeracy and low energy literacy understood all of the formats less, despite our efforts to make materials easy to understand. There were no interactions with numeracy and only one interaction with energy literacy for trust and liking. This implies that tailoring electricity use communications to specific groups may not be necessary because these groups did not differ significantly in terms of what formats were understood the best or preferred. However, participants with low energy literacy rated higher trust and liking for the neighbor comparison information compared to those with high energy literacy. The literature suggests that low-numerate individuals have a tendency to focus more on non-numerate information than on numerical information, when processing health communications (Peters et al., 2007; Peters et al., 2011; Reyna et al., 2009; Ancker et al., 2006). Similarly, low energy literacy individuals may prefer to focus on elements of non-energy information such as neighbor comparisons when processing their electricity bills.

Three main limitations should be noted. First, the presented bills were an artificial representation of the Smiths' household. Presenting participants with their own electricity use information may have increased their involvement with the materials with positive effects on their understanding, trust and liking, and behavioral intentions. Second, our study used a diverse sample from the Pittsburgh metropolitan area, potentially limiting generalizability to other populations. To make more confident claims about how to design electricity bills, we would need to repeat this study with a randomly selected sample of consumers from a wider population with their own electricity use information. Third, we limited our study to paper bills, though electricity companies are increasingly using the internet to provide feedback about residential electricity use. That information mode may benefit high-numerate consumers in search of more detailed information, but it may prove challenging for low-numerate consumers.

Nevertheless, our findings provide specific recommendations for designing better electricity bills. Specifically, we show that understanding as well as trust and liking can be improved by using tables and focusing on historical use information. Although appliance-specific feedback was difficult to understand, adding it may increase people's trust, liking, and behavioral intentions. We discourage using histograms or icon graphs with five separate icons. Given that neighbor comparison information had low ratings for trust and liking as well as behavioral intentions, even when displayed in the more understandable table or icon graph formats, we encourage using caution when including this information in electricity bills. However, most importantly, our work affirms that it is critical to empirically test electricity use information displays with consumers before widespread implementation to ensure comprehension. This is increasingly important as the use of smart meters and alternative pricing schemes (such as time-of-use pricing) enhance consumers' access to information as well as the need for all consumers to understand electricity use feedback. Designs that appear simple and easy to use to experts may not be as easy for consumers to use.

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Table 1

Mean Understanding Scores by Information Type and Format.

Information Type	Table		Icon Graph		Bar Graph		Total	
	M	SD	M	SD	M	SD	M	SD
Historical Use	0.85[b]	0.16	0.78	0.17	0.74	0.19	0.79	0.18
Neighbor Comparison	0.76[b]	0.19	0.75[b]	0.21	0.50	0.23	0.67	0.24
Appliance Breakdown	0.74[i]	0.19	0.62	0.19	0.64	0.20	0.66	0.20
Total	0.78[bi]	0.13	0.71[b]	0.17	0.63	0.14		

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

Table 2

Mean Trust and Liking Ratings by Information Type and Format.

	Table		Icon Graph		Bar Graph		Total	
Information Type	M	SD	M	SD	M	SD	M	SD
Historical Use	5.65	1.17	5.85	1.14	5.77	1.14	5.76	1.15
Neighbor Comparison	4.77[b]	1.45	4.25	1.68	4.10	1.58	4.37	1.59
Appliance Breakdown	5.44	1.21	4.95	1.54	5.43	1.16	5.27	1.33
Total	5.29	1.05	5.02	1.20	5.02	1.14		

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

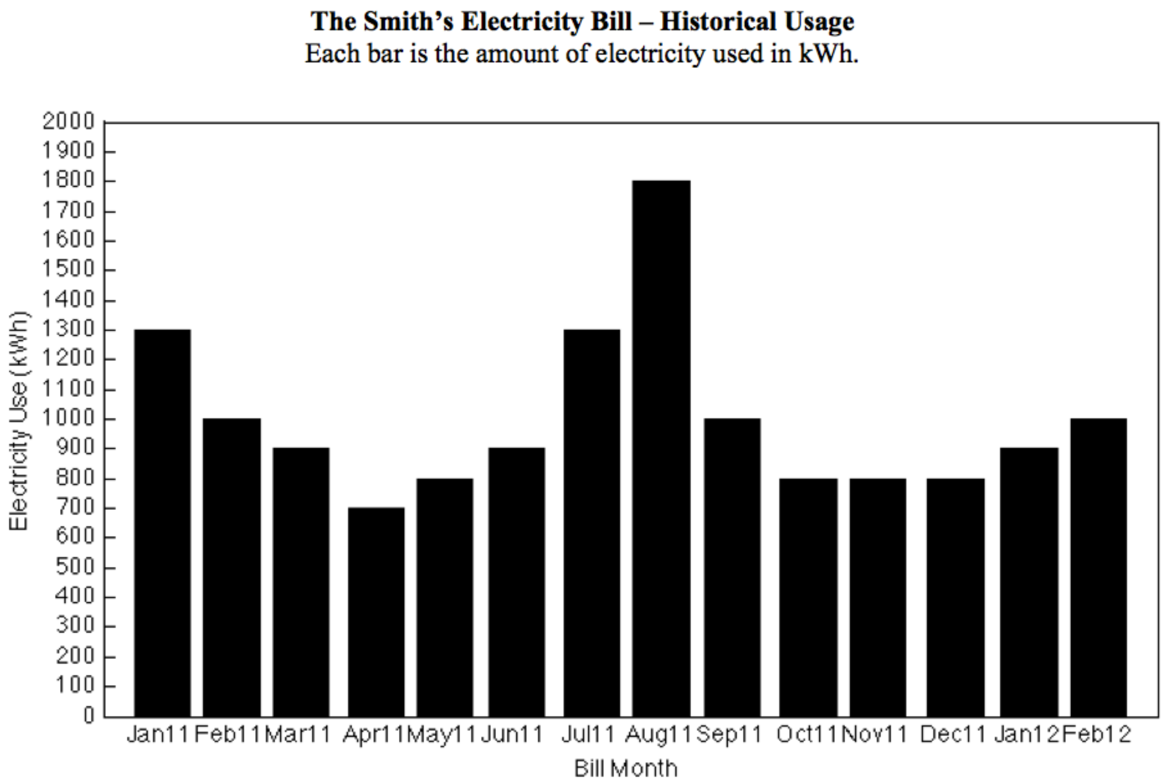
Figure 1. Historical use information presented in (a) a table, (b) a bar graph, and (c) an icon graph.

(A)

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

(B)

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



(C)

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

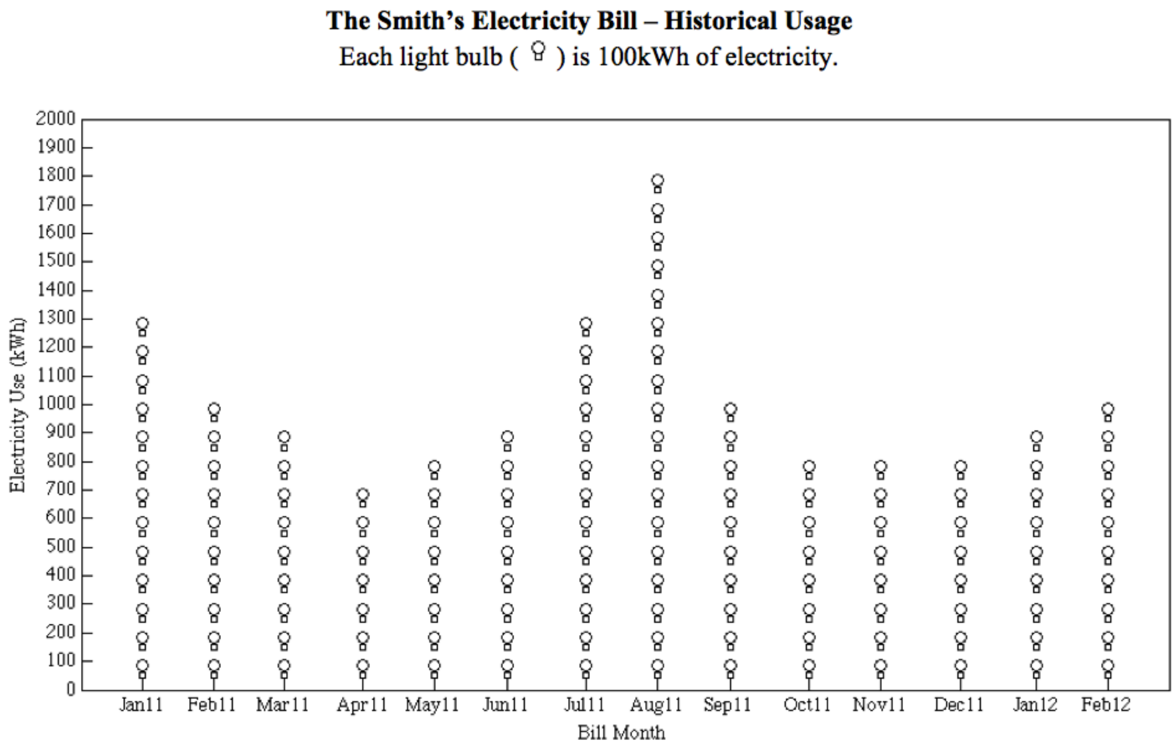


Figure 2. Neighbor comparison information presented in (a) a table, (b) a bar graph, and (c) an icon graph.

(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.

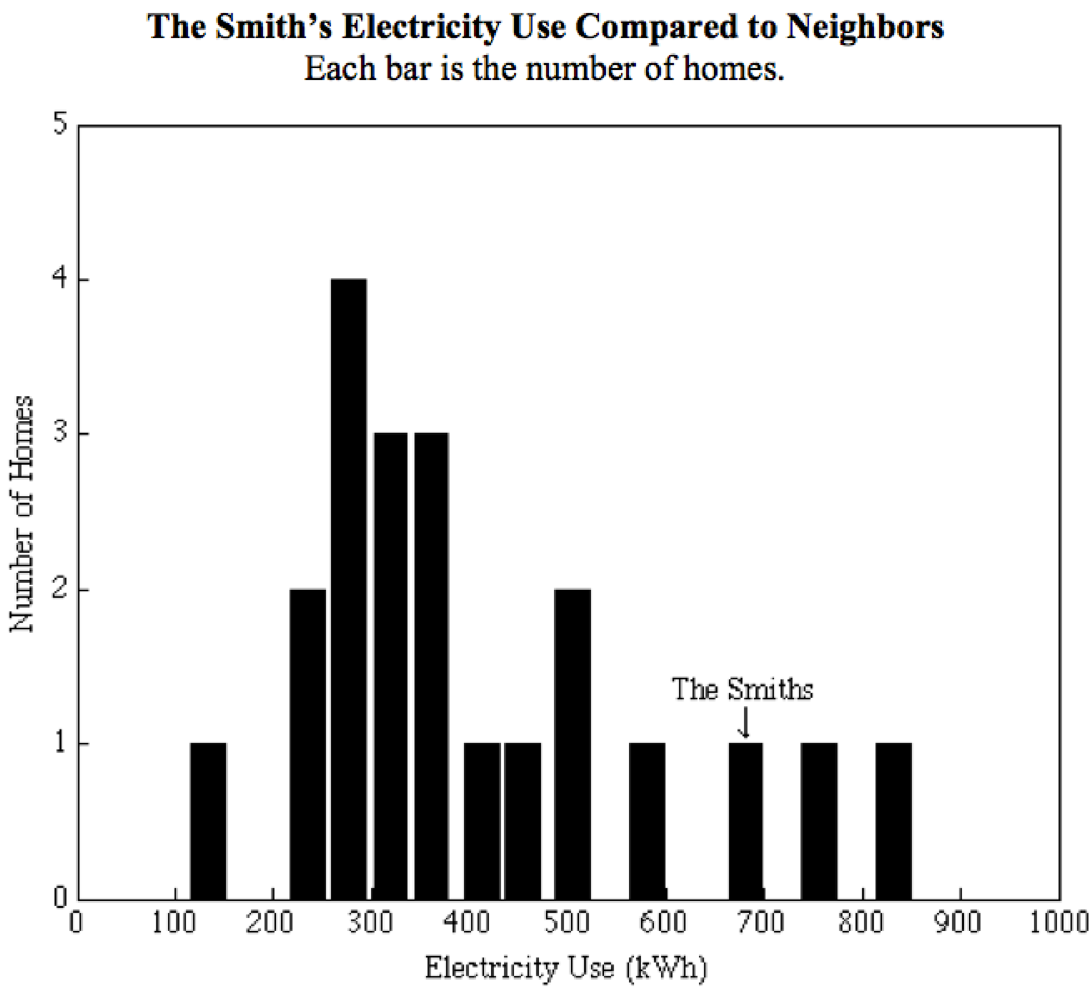
Their 20 neighbors live in nearby homes that are similar to the Smiths.

s	Electricity Use (kWh)

(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.

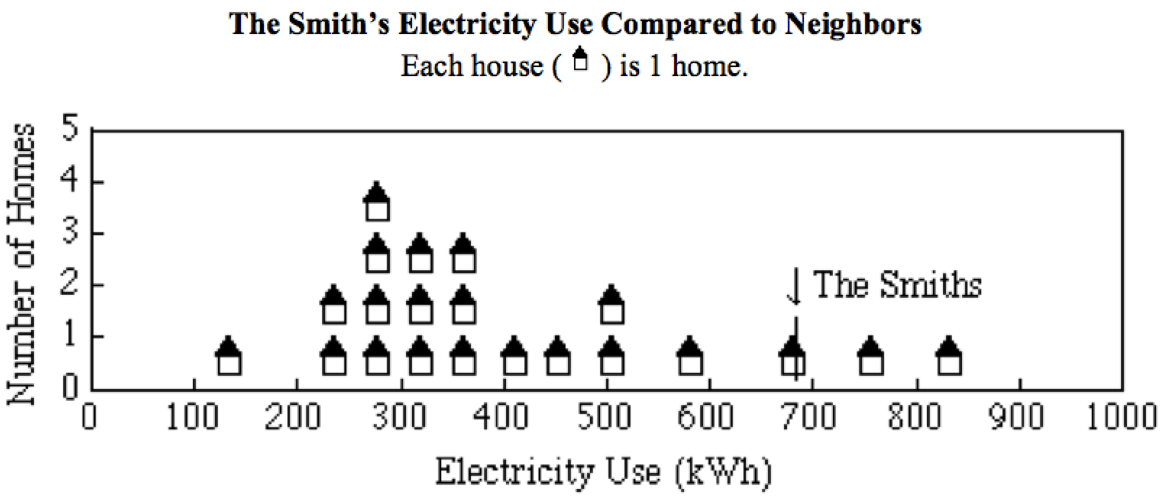


Figure 3. Appliance-specific information presented in (a) a table, (b) a bar graph, and (c) an icon graph.

(A)

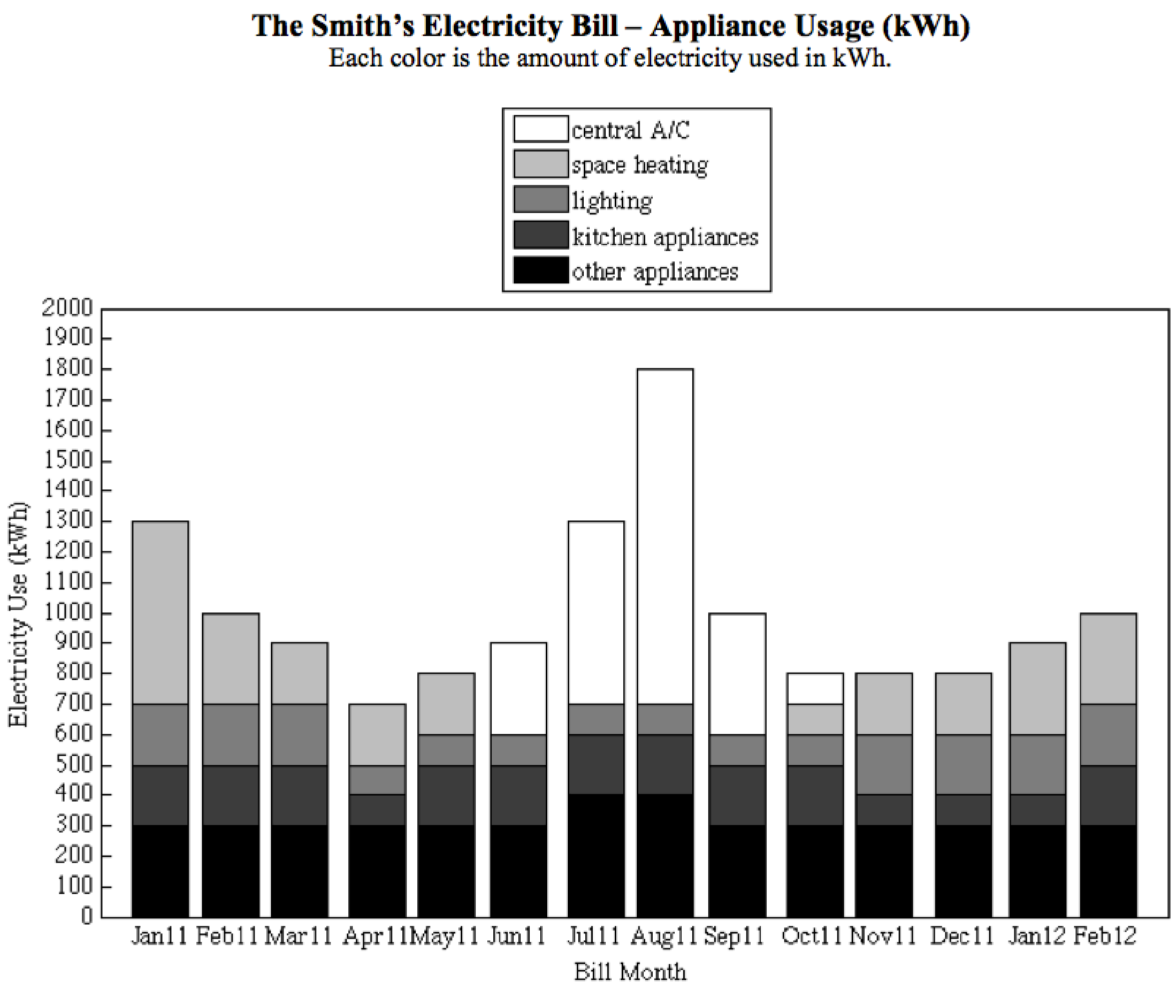
Imagine that this table shows the Smith's electricity use by appliance. This table shows personalized estimates of how much electricity their appliances used over the last year. The Smith's house has central A/C for cooling and mostly uses natural gas instead of electricity for heating. However, they 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.

c 11 0

(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.

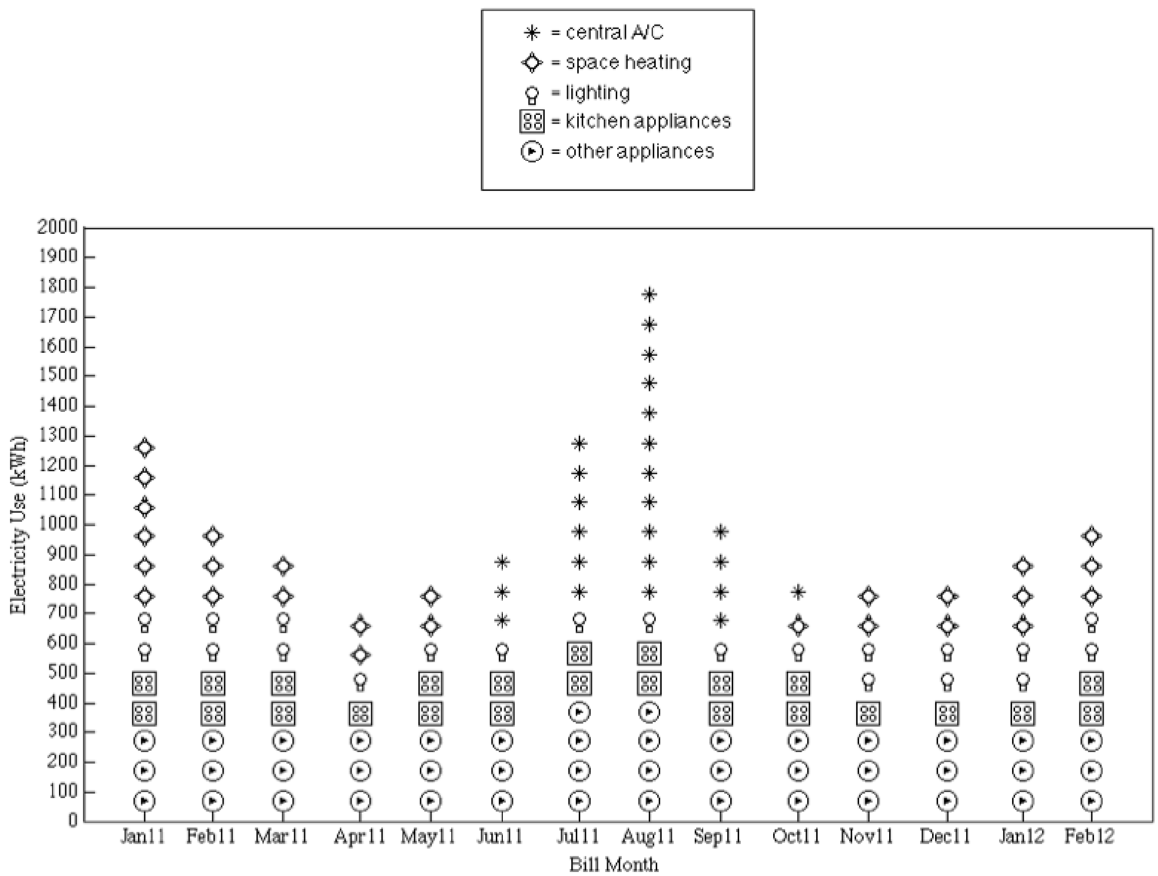


(C)

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.



Appendix

Knowledge Questions: Historical use information

1. True / False The highest electricity use was 1800kWh.
2. True / False The lowest electricity use was 700kWh.
3. True / False Just looking at the winter months (Dec, Jan, Feb), the Smiths tend to use the most on electricity in February.
4. True / False The Smith's home used more electricity in February 2011 than February 2012.
5. True / False The Smith's home used the most electricity in August.
6. True / False The Smith's home used the most electricity in the summer months (Jun, Jul, Aug).
7. True / False Every month, the Smith's electricity use was above 600kWh.

Knowledge Questions: Neighbor comparison information

1. True / False The Smith's neighbors vary in how much electricity they use.
2. True / False 18 homes used less electricity than the Smith's home.
3. True / False The Smith's home used more electricity than most of their neighbors.
4. True / False The Smith's home should use less electricity to be closer to the neighborhood average.
5. True / False Most homes used more than 300kWh of electricity.
6. True / False There is a difference of about 696kWh between the home that used the most and the least electricity.
7. True / False The maximum amount of electricity used by the Smith's neighbors was about 279kWh.

Knowledge Questions: Appliance breakdown information

1. True / False In January 2011, the Smiths used the most electricity for space heating.
2. True / False In May 2011, the Smiths used the most electricity for running their "other" appliances.
3. True / False The Smith's home used less electricity in January 2011 than in January 2012.
4. True / False The Smith's use 300-400kWh of electricity a month for "other" appliances.
5. True / False The difference in usage for lighting and kitchen appliances is never more than 100kWh.
6. True / False The main reason why the Smith's electricity use changes from month-to-month is because of lighting.
7. True / False Without heat or air-conditioning, the Smiths would probably use between 400-500kWh per month.

Survey Questions: Trust and liking

1. How confident do you feel about your answers to the 7 questions above?

1	2	3	4	5	6	7
Not at all						Very much

2. How clear is this information?

1	2	3	4	5	6	7
Not at all						Very much

3. How easy is this information to understand?

1	2	3	4	5	6	7
Not at all						Very much

4. How much do you like the way this information was presented?

1	2	3	4	5	6	7
Not at all						Very much

5. How easy is this information to use?

1	2	3	4	5	6	7
Not at all						Very much

6. How much would you like it if this information were included in your electricity bill?

1	2	3	4	5	6	7
Not at all						Very much

7. How useful would it be if this information came with your electricity bill?

1	2	3	4	5	6	7
Not at all						A lot

8. How professional does this information seem?

1	2	3	4	5	6	7
Not at all						Very much

9. How much would you trust this information if it came with your electricity bill?

1	2	3	4	5	6	7
Not at all						A lot

10. How much more detail would you like to see if this information came with your electricity bill?

1	2	3	4	5	6	7
None						A lot

Survey Questions: Behavioral intentions

11. How much does this information make you want to lower your electricity usage?

1	2	3	4	5	6	7
Not at all						A lot

12. How much would this information help you decide how to change your electricity use?

1	2	3	4	5	6	7
Not at all						A lot

Survey Questions: Energy literacy test adapted from DeWaters and Powers (2011)

1. The amount of ELECTRICAL ENERGY (ELECTRICITY) we use is measured in units called …
   - ☐ Kilowatt (kW)
   - ☐ Kilowatt-hours (kWh)
   - ☐ British Thermal Units (BTU)
   - ☐ Volts (V)
   - ☐ Horsepower (HP)

2. The amount of ENERGY consumed by an electrical appliance is equal to the power rating of the appliance (watts or kilowatts) …
   - ☐ Multiplied by the cost of electricity
   - ☐ Added to the cost of electricity
   - ☐ Multiplied by the time it's used
   - ☐ Divided by the time it's used
   - ☐ Added to the time it's used

3. When you turn on an incandescent light bulb, which of the following energy conversion takes place?
   - ☐ Electrical energy to radient energy (light)
   - ☐ Chemical energy to radient energy (light)
   - ☐ Electrical energy to radient energy (light) and thermal energy (heat)
   - ☐ Chemical energy to radient energy (light) and thermal energy (heat)
   - ☐ Electrical energy to radient energy (light) and mechanical energy

4. The best reason to buy an ENERGY STAR® appliance is …
   - ☐ ENERGY STAR appliances are usually bigger
   - ☐ ENERGY STAR appliances cost more
   - ☐ ENERGY STAR appliances use less energy
   - ☐ ENERGY STAR appliances are more modern looking
   - ☐ ENERGY STAR appliances cost less

5. Which uses the MOST ENERGY in the average American home in one year?
   - ☐ Refrigerating food and beverages
   - ☐ Washing and drying clothing
   - ☐ Heating and cooling rooms
   - ☐ Heating and cooling water
   - ☐ Lighting the home

6. Which of the following items uses the MOST ELECTRICITY in the average home in one year?
   - ☐ Lights
   - ☐ Refrigerator

- ☐ Telephone
- ☐ Television
- ☐ Computer

7. Which of the following sources provides most of the ELECTRICITY in the United States?
    - ☐ Nuclear power
    - ☐ Burning petroleum
    - ☐ Burning coal
    - ☐ Solar energy
    - ☐ Water (hydro) power

8. Some people think that if we run out of fossil fuels we can just switch over to electric cars. What is wrong with this idea?
    - ☐ Most electricity is currently produced from fossil fuels (coal, oil, natural gas)
    - ☐ Switching to electric cars will make unemployment rates go up
    - ☐ It has been proven that it is impossible to build electric cars in great quantities
    - ☐ You can't use electricity to operate a car
    - ☐ There is nothing wrong with this idea