How Customers Interpret and Use Comparative Graphics of Their Energy Use

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Comparative energy information is one method energy policymakers have employed to motivate consumers to reduce their energy use. The US appliance labeling program, for example, has used graphical displays to illustrate the differences in energy consumption among home appliances. Little is known, however, about how consumers interpret various graphical displays and/or how they use the information. Additionally, subtleties in the accuracy with which these graphical displays convey the underlying data have yet to be addressed in the research literature.

This paper presents research on interpretation of graphical displays developed and tested by University of Delaware's Center for Energy and Environmental Policy under a cooperative agreement with the United States Environmental Protection Agency. The objective of the research is to provide utilities with tools that improve customers' ability to: (1) evaluate their energy use relative to others and (2) to measure the effects of their own efficiency efforts. Drawing upon the results of semi-structured interviews and a mail survey, we discuss the relative strengths and weaknesses associated with alternative display options. We have identified a number of problems with existing methods of presenting energy information in the areas of: (1) customer interpretations of the graphical displays and (2) their accuracy and reliability. We conclude with some suggestions as to how further research could address and overcome these problems.

INTRODUCTION

Gas and electric bills are the primary channel of communication between energy providers and their customers. Building on the previously documented problems customers often have in reading their bills and in making energy-efficiency decisions based on them (Kempton & Montgomery 1982; Kempton & Layne 1994), we are researching how bills can be improved by adding comparative energy consumption information. This research is one component of the Innovative Billing Project at the University of Delaware. We are investigating improved bill designs, their applicability across a range of energy distributions, and the reactions of customers to them. Development of alternative billing systems are of interest to utilities for potential energy-efficiency benefits, as well as for competitive reasons. It seems increasingly likely that the utility industry will face some level of deregulation, industry restructuring, and increased competition. With this transition, currently captive energy consumers will have greater freedom to choose among a wider range of energy service providers. In this new environment, customer needs and wants will take on greater importance (Kempton 1995). A focus group of bill payers in Seattle, Washington requested comparative information on their utility bills without prior solicitation. They expressed an interest in understanding how their consumption compared with neighbors based on square footage and household size (Brattesani 1995). To move forward into this new era, utilities will need to gain a greater understanding of information requirements and analytical processes of their customers.

Energy Star Billing is a voluntary program, sponsored by the United States Environmental Protection Agency (US EPA), to stimulate efficiency improvements in households. Energy Star Billing is based on the concept of comparison, and involves promoting the use of utility bill-based energy use feedback systems. The University of Delaware's Center for Energy and Environment (CEEP), through a cooperative agreement with the US EPA, is investigating different billing options, and this paper focuses on one component of CEEP's research—the development and testing of a set of innovative billing options displaying comparative residential energy consumption graphically.

HOW CUSTOMERS INTERPRET AND USE COMPARATIVE GRAPHICS OF THEIR ENERGY CONSUMPTION

There has been prior discussion in the energy-efficiency and demand-side management (DSM) program literature on the value customers place on accurate and easy to understand energy information (Kempton 1995). Research has also

shown that such energy information can motivate consumers to reduce their energy use. Some well-designed pilot energy information programs (billing and continuous metering) have achieved savings of up to 13 percent and/or costs of conserved energy as low as 1 cent per kWh. However, in a few cases, little or no measured savings have resulted from energy information services (Dobson & Griffin 1992; Harrigan, Kempton, & Ramakrishna 1995; McClelland & Cook 1979; Wilhite & Ling 1992). In part, the wide variation in savings from information programs is due to the limited understanding that most utilities, and many energy analysts, have of the type of information that customers want and the way in which they use and interpret various graphical displays of consumption data.

Within the limits of traditional meter reading and billing systems, the innovative billing programs encourage the development and adoption of bills that compare each residential consumer's energy consumption with others in their neighborhood, their utility, or similar comparison groups. Traditionally, utilities have not provided information that would allow customers to relate their energy use to that of other customers. One of the primary objectives of the US EPA Energy Star Billing program is to create ratings analogous to the automobile miles-per-gallon (MPG) rating which are easy for customers to use and understand.

Development and testing of graphical displays

Providing comparative information about energy consumption is one mechanism policymakers have used to encourage conservation. The Federal Trade Commission's (FTC) appliance energy labeling program, for example, has used graphical displays to illustrate energy consumption cost differences among home appliances. However, consumers often do not understand or use the cost information shown on these labels. Carswell et al. (1989) cite a study carried out by the California Energy Commission (CEC) that concludes that FTC energy labels on appliances have confused consumers. One California utility conducted focus group interviews about consumer understanding of the labels and discovered that about half of the participants largely misunderstood the information on the labels. The FTC has recently made changes to the energy labels but little is known about whether the changes have improved comprehension.

A number of subtleties in the design and interpretation of these graphical displays and others like them have yet to be illuminated in the research literature and our research addresses some of these issues. The purpose of the graphical displays on utility bills is to provide a relative energy consumption per house indicator, usually including control factors such as house size, weather, and appliance/fuel mix . We began our work in developing display options with several criteria in mind. A good display option would be readable and understandable by customers. It would provide accurate information leading to valid customer inferences. A good display option would put the customer in a position to make more informed energy-efficiency improvements, which in turn should act as a motivation to save energy. Additionally, the displays would be indifferent to technology—an empirical measure of household energy use not reliant upon computer models with building component/equipment data requirements. A final criterion was that the set of displays be flexible, allowing a utility to incorporate some variation of the suggested options.

CEEP is working to develop a set of possible graphical displays that could be used by utilities. In the first phase of this effort, five displays were created, each containing unique information or concepts. Three of these five are discussed in this paper (see Figures 1 through 3). Figure 1 shows the recipient's total bill (in dollars) as a point along a range of customer bills within a single comparison group (in this case houses in the same square footage group). Both a monthly and an annual (past 12 months) comparison are incorporated to allow for different evaluations of the individual to the group. Additionally, a table of historic monthly cost and kWh consumption is included to facilitate self-comparison. Figure 2 would be used by utilities providing their customers with both electricity and gas. Individual bars for each fuel are included, as well as a combined fuel comparison based on the prices of gas and electricity. Data is aggregated on a bi-monthly basis instead of monthly or annually. This display also shows the recipient in comparison with two groups (the neighborhood and the entire customer base) by overlaying two bars in one graph.

Figure 1. *Sample Energy Star Billing Bar Graph —Single Comparison Group Display*

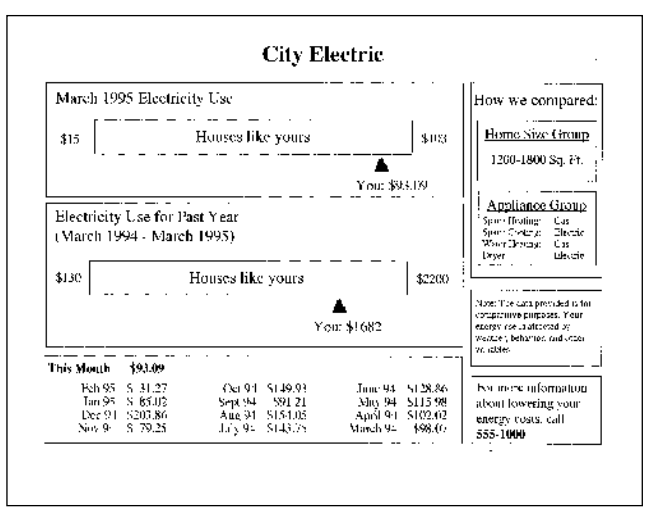


Figure 2. *Sample Energy Star Billing Bar Graph—Combined Fuels Display*

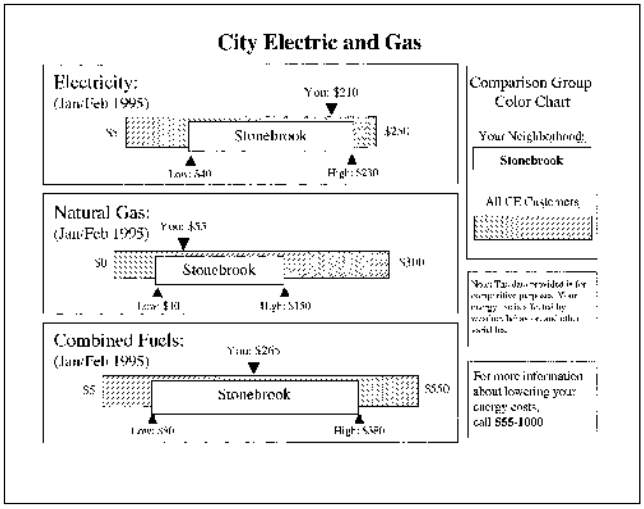


Figure 3. *Sample Energy Star Billing Graph—Bell Curve Display*

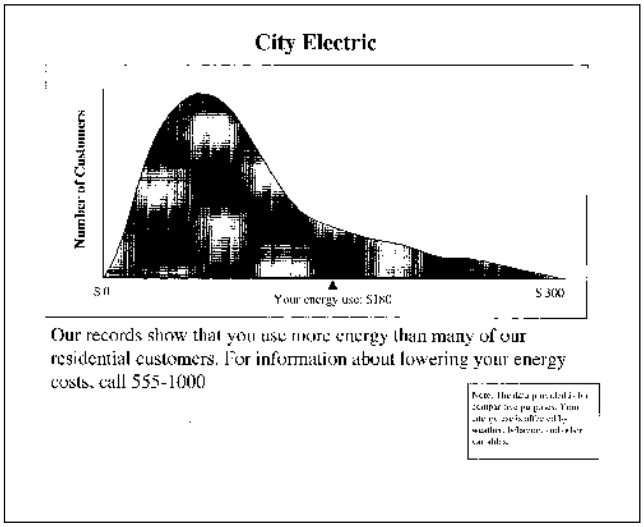


Figure 3 is based on a bell curve. This display shows the recipient as a point on a distribution curve of the comparison group. The data could be provided on a monthly or annual basis depending on the utility's preference.

After developing several possible graphical displays, our next step was to evaluate them in trial readings with eight customers. The results of this effort are discussed in more detail in the section entitled ''Findings from Semi-Structured Interviews.'' In the second phase, we distributed a mail survey that reflected a variety of improvements deemed necessary as a result of the semi-structured interviews. This effort was aimed at gaining a more precise understanding of how customers interpret and use comparative graphics of their energy use. The results of this work are presented in the section entitled ''Findings from Mail Survey.'' Additionally, some of the technical problems involved in selecting a graphical display is discussed in the section entitled ''Graphical Information Displays: Problems of Accuracy and Reliability.'' As of May 1996, CEEP had entered the final phase of the initial innovative billing option research. As part of this final phase (1) a large-scale survey of 300 to 400 randomly selected utility customers in Delaware; and (2) semi-structured interviews with customers of utilities already participating in the program will be conducted.

Findings from semi-structured interviews

The researchers tested the first set of sample billing displays in semi-structured interviews with eight utility customers. The interviewees were selected through a process of referral. Although this is a small sample, the findings were useful as an initial evaluation of the graphic display options. Seven interviews were conducted with a single resident of the household, the bill payer. In one interview, two residents of the household participated. In reference to the latter interview, in cases where responses were divergent, the data was recorded separately. Otherwise, the interview was treated as a single unit in the recording of data.

Respondents were generally receptive to the idea of their utility providing comparative data on home energy use. However, Figure 3 was not well received by the majority of the interviewees. Although five and a half out of eight respondents interpreted the bell curve correctly, most did not react favorably to this type of graphic display. Displays containing the bar graph were preferred by all interviewees. This finding is consistent with results from a FTC study testing appliance energy labels (FTC 1991). Six interviewees commented negatively on the bell curve in Figure 3. Three of these interviewees stated flatly that they would throw it away because they did not like this way of illustrating comparative data. Another important finding that emerged from the initial semi-structured interviews was that the bar graph was not automatically and immediately understood by all, or even a majority, of the interviewees. In fact, in four of the eight interviews, the interviewer noted that time and/or explanation was required for the bar graph to be correctly interpreted. In all four of these cases, the problem seemed to be that the respondents did not recognize that the length of the bar represented a range of utility bill costs for a given time period. For example, in one case, the interviewee assumed that the low-end represented a daily cost and the high-end an average cost. The result was that the interviewee put her consumption (represented by the triangle labeled ''You'') as below average. Given her interpretation, there would have been no point along the bar graph at which this interviewee would have placed her consumption as above average. The interviewer had to explain the bar graph in

order for the respondent to correctly interpret the information. Another interesting finding was that seven of eight interviewees responded positively to the energy consumption statement included at the bottom of Figure 3. In sum, none of the displays were perfect. Comprehension of both the bar graph and the bell curve was problematic for a significant portion (at least 50 percent) of the interviewees. Further revision, along with additional testing, was deemed essential.

Findings from mail survey

Originally we intended to move from the semi-structured interviews immediately into a large-scale mail survey. However, the results of the interviews suggest that what we were trying to accomplish as more complicated than initially anticipated, and that some of our underlying research assumptions were incorrect. For example, we assumed that customers would readily understand bar graph displays. Consequently, we decided to make several changes to the graphs, and to conduct a pilot mail survey. Sixty individuals were selected for the survey by drawing a random sample from the 1995 Delaware telephone directory (which also covers Salisbury, Maryland and the surrounding area). A dollar bill was attached to each of the surveys to encourage prompt return. Because the latest version of the telephone book available was 1995, 18 of 60 surveys did not reach their destinations on the first try (30 percent). Six of these 18 surveys were able to be resent to addresses confirmed either by the recipient or the post office. Thus, our actual sample was reduced from 60 to 48 (a 20 percent reduction). Twenty-nine out of 48 surveys (60 percent) were returned. Twenty-three of these were returned without a follow-up. Only three of 48 (6 percent) were refused.

Our main purpose in this small sample survey was to gather additional data about how customers understand and interpret the graphical displays and the information they convey. The eight interviews did not clarify whether or not those who had difficulty interpreting the bar were truly unable to see that the bar represented a range; or, if they simply were thrown off track by endpoints that were too low/high to be reasonable, and a level of consumption that was not consistent with their own bill.

As an initial step in refining the billing displays, they were compared with those required by the Department of Energy for appliance labeling. The appliance labels clearly identify the low and high ends by labeling them ‘‘uses least energy’’ and ‘‘uses most energy.’’ Similar labels saying ‘‘lowest bill’’ and ‘‘highest bill,’’ were added to the bar graph displays to improve comprehension. In an effort to avoid the problem of respondents trying to place their own energy consumption on the graph, ‘‘You’’ was changed to an impersonal example of ‘‘The Smith’s.’’

We also concluded that it was necessary to distill and test the basic concepts contained in the innovative billing displays, thereby limiting the number of variables that changed from one display to the next. Figure 4 is one of four graphs sent out as part of the mail survey, and was intended as a test of customers’ comprehension of the basic bar graph concept with the addition of endpoint labels. Preliminary interview results also pointed to potentially serious problems with the bell curve in Figure 3. It appears that some respondents did not understand it and that the majority did not like it. We therefore set about devising a more user-friendly way of communicating the distributional information that is contained in the bell curve format. Figure 5, another of the four graphical display options included in the survey, is our attempt at accomplishing this end-goal. Figure 5 uses small pictures of houses to display the same information as that presented in the bell curve in Figure 3.

The results of the survey indicate that the original problems with the innovative billing graphs have been reduced, and

Figure 4. *Revised Energy Star Billing Graph Ranked First in Mail Survey*

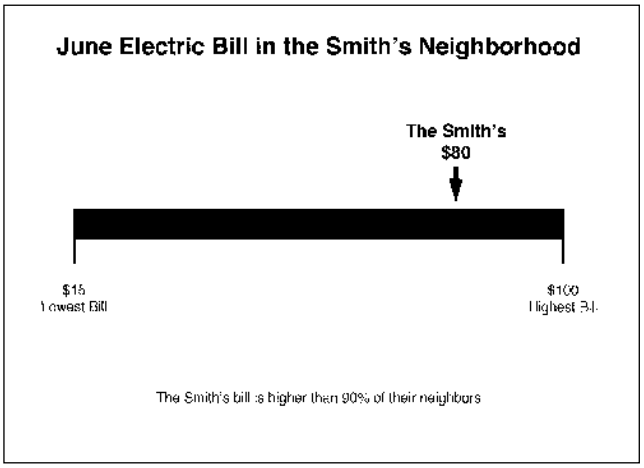
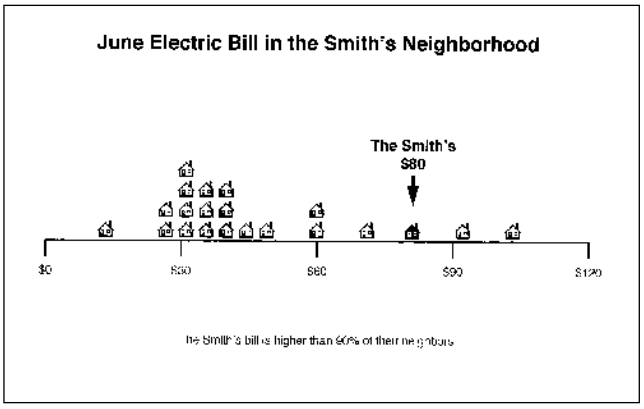


Figure 5. *Revised Energy Star Billing Graph Ranked Second in Mail Survey*



that comprehension of the graphs has been improved. The survey began with the presentation of one of the four graphs included in the survey. This initial graph was rotated so that all four graphs were placed first in a subset of 20 of the 60 surveys that were sent out. The first question asked the respondents to interpret how much electricity ''The Smiths'' were using compared to others in their neighborhood (See Figures 4 and 5). Twenty-four respondents answered correctly that ''The Smiths'' were most likely using more electricity. Three respondents answered incorrectly, and for two surveys the data could not be used as multiple options were selected. It is a possibility, however, that the level of comprehension in the mail survey is inflated by the relatively high level of education of the survey respondents. For the planned large-scale survey, steps will be taken to ensure that a more representative sample is drawn.

Twenty of the respondents said that they would take action based on this information if they lived in ''The Smith'' household. Two said that they would not take action and six said they did not know if they would. One of the responses had to be discarded, as multiple answers were checked. When asked specifically what action they would take, seventeen people said their first response would be to try to use less energy by turning off the lights, using the dryer less, or making other behavioral changes. An additional five respondents, indicated that they might also take this course. A total of 16 respondents said they would add insulation, install storm windows, or make other improvements to their house. Although only four people said that this would be their first response, 12 more indicated they might consider this option in addition to other alternatives. Eleven respondents said they would call the utility company—seven said this would be their first response, while an additional four selected this option as one of a range of other options they might undertake.

A series of questions were asked to determine which of the graphical displays the survey recipients preferred and most often understood. However, no clear preference could be identified. When asked which of the graphical displays they would most like to receive on their own bill, eight people selected Figure 4 and seven people Figure 5. Another eight people selected the simplified version of Figure 3 that was included in the survey. One could easily conclude that all three options appear to be strong candidates. When asked to circle the one graph they found easiest to read and understand, ten people selected Figure 4, five people chose Figure 5, and eight people chose the simplified version of Figure 3. Once again, no clear winner emerges. From the question, however, it seems that Figure 4 and 5 were preferred. The responses to the question of which display the respondents would prefer if one had to be chosen show slightly different results, however. When combining these two questions, the responses indicate that overall Figure 4 is the most preferred as well as best understood of the four options the survey respondents were presented.

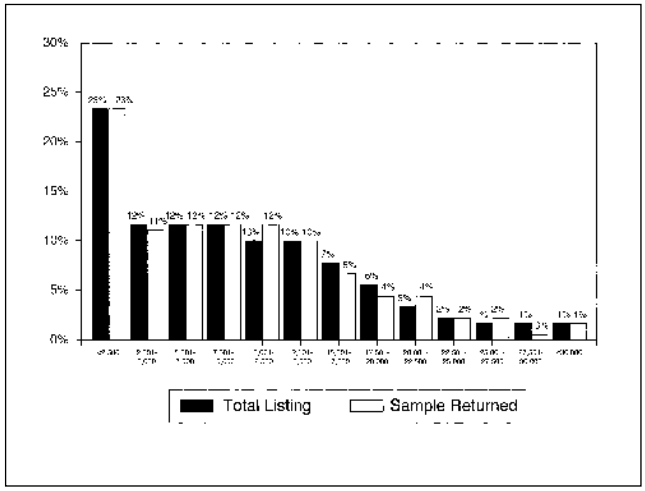
GRAPHICAL INFORMATION DISPLAYS: PROBLEMS OF ACCURACY VERSUS ACCESSIBILITY

The horizontal bar graph is a common display that has been assumed to be easily understood by consumers. As has already been discussed above, results from our semi-structured interviews suggested that this may not always be an accurate assumption. However, a study conducted by one of the authors using actual utility distributions suggests another equally difficult problem with using the bar graph to compare across residential utility customers.

Unlike the bell curve, a horizontal bar graph does not always accurately provide the reader information about the relative distribution of the underlying data. In our research with actual utility distributions, we found that this could have very misleading consequences. One particular problem is that small percentages at the end of the utility's overall distribution can often make the horizontal bar chart appear deceivingly long. Four actual distributions were taken from actual residential customer records including: Mecklenburg Electric, Shehnandoah Valley Electric, Delaware Electric, and Northern Virginia Electric (Wessex Group 1995). For all four distributions, a graphic was created to establish what these distributions would look like in both a bell curve and a horizontal bar graph format. The location of customers in the 20th and 80th percentile of the utility's kWh usage distribution was estimated and a rough approximation drawn on the graphics. In the most striking case, Mecklenburg Electric, a consumer who was in the 80th percentile of energy use appeared in the middle of the horizontal bar graph due to outliers lengthening the bar's ends (See Figures 6 through 8).

It is doubtful that a person in the 80th percentile receiving this graph would conclude that their energy use was relatively high. Of the four utilities selected, only Northern Virginia Electric's bar graph accurately communicated information about the distribution. The authors concluded that this was due to the similarity of that distribution to a standard bell-shaped curve. In sum, there are tradeoffs between customer comprehension of graphics and the accuracy with which the display presents underlying data. Although the bar graph is generally assumed to be understood by a larger share of readers than the bell curve, irregular distributions can result in highly inaccurate bar graph representations of the underlying data. Given that the distribution of utility bill costs/energy use in a utility's customer base is not always (or even usually) normally distributed, the bar graph may

Figure 6. *Mecklenburgh Electric's Residential Customer Distribution*



(Adapted from Report by the Wessex Group. 1995)

Figure 7. *Mecklenburgh Electric's Residential Customer Distribution in Bell Curve Form*

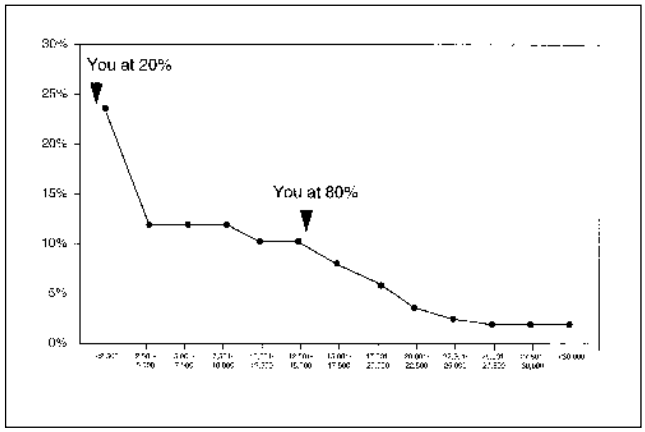
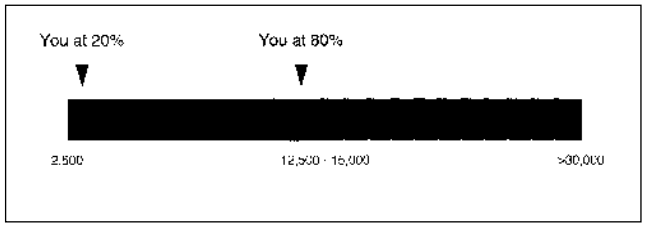


Figure 8. *Mecklenburgh Electric's Residential Customer Distribution in Bar Graph Form*



not be a valid instrument for displaying comparative energy information for the entire customer base. However, although it appears that the bar graph may not aid customers in making valid inferences about their energy use compared to others in the entire customer base, it is unclear if this would also be true for more narrowly defined comparison groups such as the neighborhood or houses of similar square footage. Further research is underway to explore this issue.

CONCLUSIONS

The findings from the initial phase of this research suggest that reading and understanding graphics displaying comparative energy consumption information may be more difficult for consumers than previously thought. By making relatively simple changes, however, such as adding end-point labels to the graphical displays, we found that consumer comprehension was improved considerably. Consistent with existing research evidence, findings from both the semi-structured interviews and the mail survey indicate that consumers prefer the bar graph to other displays, such as the bell curve.

However, several problems relating to the use of a horizontal bar graph to display comparative energy consumption data were identified. Our findings suggest that there are trade-offs between the accuracy and accessibility of the information. Although a horizontal bar graph may be the easiest for consumers to understand, it does not always provide accurate information about the relative distribution of the underlying data. Using actual utility distributions, we found that the failure to account for this factor could lead to consumers making incorrect inferences about their energy use. The trade-offs between accuracy and comprehension, as well as the relevance of this issue to comparison groups other than house size in square footage, must be explored further using real utility data of residential customer energy consumption distributions.

A key recommendation emerging from this research is that additional research is essential to improving comprehension of billing displays and the quality and customer value of the comparative energy consumption data. We acknowledge that the data collected to date does not allow us to make generalizable conclusions. However, we believe that our research supports the conclusion that respondents are generally receptive to the notion of utilities providing comparative energy consumption data in bills. This conclusion is based on qualitative factors, such as remarks made by interviewees and survey respondents. One interviewee noted that while consumers often were told to use less energy, they were very rarely given a clear idea of how successful their efforts actually were. Also the high return rate (60 percent) of the mail survey suggests that consumers are interested in this information despite the complexity of the survey.

Areas of ongoing research include further testing of innovative billing options through surveys and semi-structured interviews. The goal of ongoing research is to identify innovative billing displays that aim to minimize the trade-offs

between accuracy and comprehension by developing billing options that consumers like, find easy to understand and that accurately represent the relative distribution of the underlying data. Several problems were identified in our research. Findings from research addressing these issues are expected to contribute to improvements in the success rate of utility implementation of innovative billing systems in the future.

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