Commercial and Industrial Customer Perceptions of Electric End-Use Consumption: A Comparison With Audit-Based Estimates

Andrew Parece and Thomas Michelman, XENERGY, Inc.
Dinesh Bhagani, Northeast Utilities

Understanding how commercial and industrial customers perceive their energy needs, a critical determinant of how they use technologies and end uses, is invaluable to promoting energy efficiency. Perceptions can be more important than actual end-use consumption in understanding decisions for investments in energy-efficient equipment and targeting customers for new products and services. This paper compares two estimates of electric end-use consumption for the same commercial and industrial customers:

- Estimates provided by building managers, based on perceptions of what the major electric end uses are and their percentage contribution to total usage.
- Estimates based on an on-site audit that provides a disaggregation of the energy bill utilizing data on operating schedules, equipment inventories, and weather.

As part of a large data collection effort for Northeast Utilities (NU), an electric utility serving parts of Connecticut, Massachusetts and New Hampshire, these estimates were developed for a random sample of commercial and industrial customers. In total, 456 customers were surveyed over the telephone, and a subsample of 119 received on-site energy audits. The telephone surveys elicited customers perceptions of their major electric end uses. The on-site audits supported a statistical and engineering based disaggregation of their total electricity consumption.

These two estimates of electric end-use consumption can result in dramatically different perspectives on which end uses are significant. For instance, some customers indicated that space cooling usage was double the estimate developed through the energy audit. The data can be used to identify customers whose perceptions of end-use energy usage are inconsistent with audit-based estimates.

INTRODUCTION

Background

As part of a recent evaluation of its Energy Savers Lighting Rebate (ESLR) Program, NU provided a comprehensive audit of customers' facilities, including an end-use disaggregation. To identify the naturally occurring savings for the program, a group of nonparticipants was sampled and received an audit as well. This nonparticipant group (i.e. customers who had no prior program participation) is the focus of this paper. The nonparticipants who received an on-site audit were sub-sampled from a larger group of customers who completed a telephone survey, and for whom information on end-use perceptions was collected. Thus, there are two samples for which data exist on end uses and perceptions of end uses, as depicted in Figure 1.

Scope

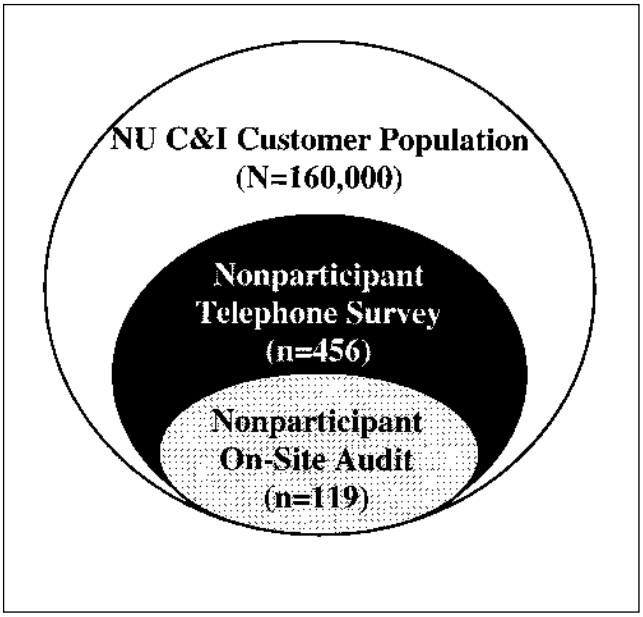
This paper describes a study of the end uses that customers perceive to be significant, as reflected in their ratings (in percentage terms) of contribution to total energy usage. In addition, several comparative analyses of these perceptions relative to estimates developed through an audit-based end-use disaggregation are provided. In contrast to a recent EPRI-sponsored study of residential customers' end-use perceptions (Cambridge Systematics, 1995), this study does not address how the audit information may have affected usage or perceptions over time.

METHODOLOGY

Sample selection

A sample of 456 customers was selected from NU's commercial and industrial population. These customers were selected

Figure 1. *Overview of Study Samples*



on the basis of not having participated in previous NU commercial and industrial programs. To ensure that these customers had not previously participated in NU programs, account numbers were cross-referenced to prior years' participation tracking systems. As a further check, the first customer contact, a telephone survey, identified customers who reported that they had in fact participated in NU programs. Thus the sampled customers are representative of customers who have not participated in NU's DSM programs.

From the 456 customers interviewed via telephone, a subsample of 119 were randomly selected to have an on-site audit. The primary purpose of the audit was to establish what conservation actions had been taken for comparison with program participants. These 119 customers also received a report that provided estimates of end-use contribution to total usage.

Customer ratings of end uses

The telephone survey was used to elicit information regarding customer perceptions of the end uses contributing to total annual energy usage. Customers were asked a series of questions that resulted in both ranking and rating (in percentage terms) of end-use energy contribution. The survey consisted of the following sequence for each customer (repeated for the top five end uses that the customer could identify):

We are interested in the five end-use categories that in your judgment use the ***most*** *electricity at your facility.*

Which of the following end uses would you say uses the ***most*** *electricity at your facility?*

Cooling
Space Heating
Water Heating
Interior Lighting
Exterior Lighting
Cooking
Refrigeration
Ventilation
Process Heating Equipment
Process Motors
Office Equipment
Miscellaneous Equipment
other (SPECIFY) _____
Don't know

And of total electricity usage at your facility, what percent is attributable to this end use?

Percent of total electricity _____
Don't know

As noted above, both questions were repeated for up to five end uses, where the respondent could provide such information (or, in effect, where one hundred percent of the usage was covered in fewer than five end uses.) In all, there were 456 respondents to the survey. The data resulting from the survey were, for each of the top five end uses, an estimate of the rank and the rating, stated in terms of estimated percentage of total usage. The estimates based on customer perceptions are referred to as the ''survey estimates'' below.

Audit-based end-use disaggregation

For the sample of 119 customers who were randomly selected (from the 456 completed telephone surveys), an on-site audit was performed. XENERGY's XenCAP™ data collection and software system was used to collect detailed data on building construction, square footage, vintage, equipment characteristics and operating/occupancy patterns. These data are used together with the customers' actual monthly bills and weather data to provide an estimates of annual end-use energy. The XenCAP system involves numerous quality control procedures to ensure that the estimates are as reliable as possible. In all, over 100,000 facilities with a total floorspace of over 2.5 billion square feet have been audited using this methodology. Furthermore, this methodology has been scrutinized by scientists and regulators, and end-use metering studies have confirmed the reliability of the end-use estimation methodology (Ackerman and Perkins, 1992). These factors notwithstanding, when comparing the survey estimates described above with audit based estimates, we are careful to recognize that in fact both

Table 1. *Summary of Telephone Survey Responses*

	Frequency of Ranking					Times Ranked	Not Ranked*	Mean Ranking**	Mean Estimate % Total Usage
	1st	2nd	3rd	4th	5th				
Lighting	138	118	57	11	1	325	35	1.83	40.0
Misc.	87	59	56	21	13	236	124	2.21	26.0
Cooling	54	81	43	16	4	198	162	2.17	12.0
Space Heating	30	31	29	13	4	107	253	2.35	7.2
Outdoor Lighting	13	23	25	19	8	88	272	2.84	4.4
Refrigeration	15	11	9	9	4	48	312	2.50	4.3
Process	14	3	1	0	0	18	342	1.28	3.6
Cooking	5	4	4	4	2	19	341	2.68	1.2
Ventilation	3	7	8	8	4	30	330	3.10	1.0
Hot Water	1	6	9	10	8	34	326	3.53	0.6
TOTAL	360	343	241	111	48				100.5

*''Not Ranked'' among the top five end uses.
**Mean Rank is calculated as the arithmetic mean of the ranks for each end use; the number of rank values used in the calculation is given in the column ''Times Ranked.''

are estimates. That is, we cannot characterize differences between the end-use estimates provided by customers and those developed through an audit-based disaggregation as ''errors'' without a more definitive end-use measurement (such as those based on end-use metering). However, these differences are illustrative of the ways that customers perceive of their end uses relative to an estimation method that is more systematic, and that accounts for the most significant factors affecting usage.

RESULTS

A variety of analyses have been developed to present the findings from the study. In summary, the following key statistics were developed, and are presented in the following sections:

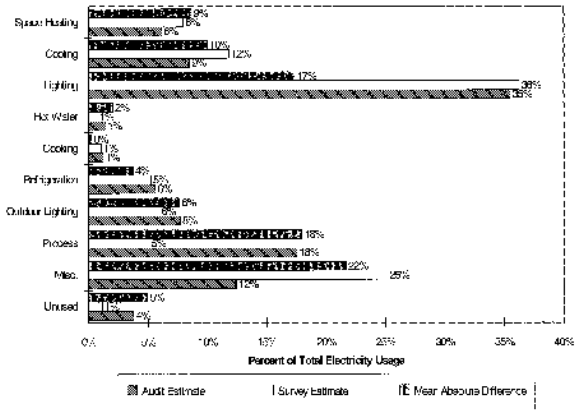
- Telephone survey end-use rankings and ratings
- Number of customers identifying significant end uses consistently with audit estimates
- Comparison of average survey/audit end-use percentages and absolute differences
- The deviation in customer estimates of percent contribution for the top audit end use
- Frequency distribution of percent of total usage attributable to three top end uses, and number of these three mentioned by customers
- Examples comparing individual customers' survey and audit end-use estimates

These summaries are provided below, along with comments on the findings and implications.

Table 2. *Consistency of Survey Responses of Top End Uses With Audit Results*

(A) Number of End Uses Identified in Survey	(B) Total	(C) % of Total	Number Consistent With All Top Audit End Uses (Any Order) (D) Total	(E) % of Col. B	Number Consistent With All Top Audit End Uses (Exact Order) (F) Total	(G) % of Col. B
1	4	4.4	2	50.0	2	50.0
2	26	28.6	6	23.1	3	11.5
3	32	35.2	7	21.8	3	9.3
4	17	18.7	1	5.8	0	0.0
5	12	13.2	1	8.3	0	0.0
All	91	100.0	17	18.7	8	8.8

Figure 2. *Mean Percentages for Audit/Survey Estimates and Absolute Differences (n = 47)*



Telephone survey end-use rankings and ratings

A total of 456 telephone surveys were completed. Of these 456 customers, many provided inconsistent responses or were unable to venture a guess about the rankings of end uses. Of these 456 customers, 437 remained after eliminating those with data problems. Of these 437 customers, 360 customers attempted to rank at least one end use, i.e. the highest end use contributing to total electricity usage. That is, 18% were unable to provide a guess as to the highest electric end use. Table 1 summarizes the telephone survey responses for the 360 customers who attempted to rank at least one end use. The table shows that for these 360 customers, lighting, miscellaneous, cooling and heating are the end uses ranked most often in the top five. In terms of the average rankings of end uses, process is ranked the highest when present. That is, for the eighteen customers who ranked process usage as one of the top five end uses, the average ranking was 1.28. Among the end uses ranked most often, the order of average ranking was lighting (1.83), cooling (2.17), miscellaneous (2.21) and space heating (2.35). The last column in the table lists the average percent contribution to total usage estimated by customers for each end use. Customers' ratings of end-use contribution are lighting (40.0%), miscellaneous (26.0%), cooling (12.0%) and heating (7.2%).

Consistency of survey end-use rankings with audit rankings

Of the 119 customers who received on-site audits and end-use disaggregation reports, a total of 112 were merged with the survey data after screening the survey data for data problems. Of these 112 customers, a total of 91 attempted to rank at least one end use. A comparison of the audit and survey rankings for these customers is provided in Table 2. The data show that a small number of customers can rank their top end uses in any order. For example, for customers who ranked one end use, it was consistent with the audit estimate only 50% of the time. For customers who ranked two end uses, these two were consistent with the top two end uses estimated from the audit (in any order) 23% of the time. Similarly, for customers who ranked three end uses,

these three were consistent with the top three end uses estimated from the audit (in any order) 22% of the time. When looking for matches in the same order, these percentages are 50%, 11% and 9% respectively. These data demonstrate that the top end uses (if the audit data are accurate) are not well understood by C&I customers.

Comparison of average survey/audit end-use percentages and absolute differences

Further analyses were performed on the customer ratings of end-use contribution to total usage. Of the 91 customers whose end-use rankings are summarized in Table 2, 47 customers were able to account for 100 percent of their electricity usage. Figure 2 presents a comparison of the percentages given by customers (the survey estimate), and those developed in the audit-based bill disaggregation (the audit estimates), for these 47 customers. The survey estimates are remarkably consistent with the audit estimates *on average*. However, these averages could be consistent, and yet all individual customers quite inconsistent, if some customers overestimate the contribution of a given end use to total consumption (relative to the audit estimate), and others underestimate its contribution. A measure of consistency that avoids the effect of averaging of errors is to compute the average ''absolute'' difference. This statistic is provided in Figure 2, and shows that despite the fact that customer estimates of percent contribution are consistent with audit estimates on average, an individual customer estimate is likely to differ substantially from the audit estimate for most end uses.

Deviation in customer estimates of percent contribution for the top end use (from audit)

For the top end use estimated in the audit, Table 3 provides a comparison with the percentages estimated by customers in the survey. The difference between the audit estimate for the highest end use and the survey estimate for this end use was computed. Customers were grouped into categories based on the size of the difference. Seventeen percent of customers estimated within ±10% of the audit estimate for the top end use. The percentages of customers with differences of ±10–20%, ±20–30%, and >30% were 21%, 17% and 45% respectively. That is, over 60% of customers cannot estimate the contribution of the top end use within ±20%. The findings indicate that even for the highest end use, customers cannot estimate its contribution to total usage accurately.

Table 3. *Differences in Percentage of Top End-Use, Audit vs. Survey Estimate (n = 47)*

Difference	Frequency	Percentage
± 0%–10% Difference	8	17%
±10%–20% Difference	10	21%
±20%–30% Difference	8	17%
±30+% Difference	21	45%

Frequency distribution of percent of total usage attributable to three top end uses

As a way of determining how much customers need to understand about their end-use consumption, an analysis of the percentage contribution of the top three end uses, as estimated by the audit, was performed. Table 4 shows a frequency distribution of the percent of total consumption accounted for by the top three end uses. The figure shows that the top three end uses typically comprise a substantial portion of the total usage.

Number of top three end uses mentioned by customers

Given the result presented in Table 4, another perspective on customers' understanding of their top end uses is the number of end uses (of these three) that were mentioned at all in their rankings (from a possible total of five end uses ranked). Table 5 shows a breakdown of the number of customers who mentioned zero, one, two and three of the top three end uses estimated in the audit. In contrast to the previous findings that indicate customers' inability to rank and rate their end uses consistently with the audit estimates,

Table 4. *Frequency Distribution on Percentage of Total Usage Comprising Top 3 Audit End Uses (n = 47)*

Percent of Total Usage	Frequency	Percentage
50%–60%	0	0%
60%–70%	5	11%
70%–80%	12	25%
80%–90%	18	38%
90%–100%	12	25%

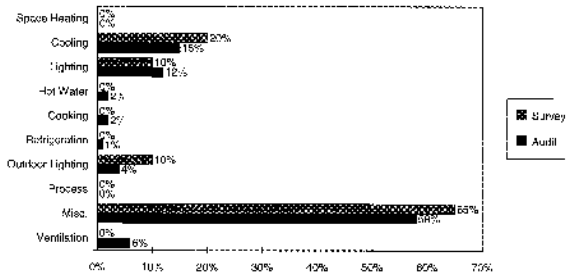
Table 5. *Number of Top 3 Audit End Uses Mentioned by Customers (n = 47)*

Number of Mentioned	Frequency	Percentage
Zero Mentioned	1	2%
One Mentioned	5	11%
Two Mentioned	30	64%
Three Mentioned	11	23%

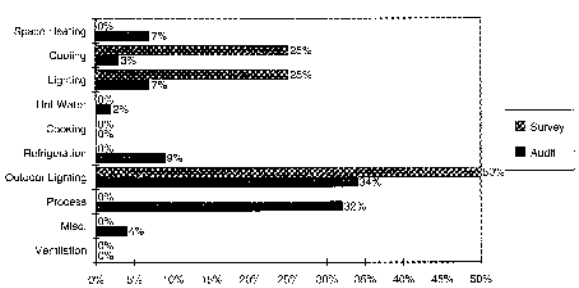
these data indicate that 87% of customers mentioned at least two of their top three end uses in the survey. This seems to suggest that customers have some idea about the top end uses contributing to total usage, yet may not be able to rank or rate them accurately.

Comparison of individual customers' survey and audit end-use estimates. Figure 3 compares the survey and audit estimates for two customers, one customer that provided relatively good estimates of their end uses as compared with the audit (Customer A), and another who did not (Customer B).

Figure 3. *Comparison of Individual Customers Survey vs. Audit Estimates*
Customer A



Customer B



CONCLUSIONS

The key finding of this study was that commercial and industrial customers' understanding of the end uses that contribute to their total electricity usage is relatively poor. These findings are based upon a comparison with estimates developed through an audit-based bill disaggregation. Several measures of consistency with the audit data indicate that customers have trouble ranking or rating the top end uses that contribute to total usage. One encouraging finding was that customers apparently have some idea about the top two or three end uses, as evidenced by their mentioning these end uses (without necessarily ranking or rating them consistently with the audit estimates).

The findings suggest that commercial and industrial customers' understanding of their electric end uses could be greatly improved. Other research on the disparity between actual and estimated energy usage, energy conservation opportunities and efficiency investments (Kempton 1982, 1995) demonstrates the importance of perceptions to customer behavior, energy utilization and investment choices. The evidence suggests that misperceptions can result in energy usage and investments that are not economically optimal. In this context, improving perceptions of energy usage can be a significant factor, perhaps as important as technical advances, in promoting more efficient utilization of energy resources.

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