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CBEEDAC, sponsored in part by Natural Resources Canada via the National Energy Use Database Initiative, is housed at the University of Alberta.

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enerInfo Building is published three times per year by the Canadian Building Energy End-Use Data and Analysis Centre (CBEEDAC) at the University of Alberta.

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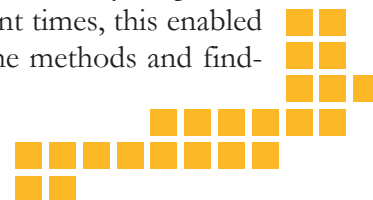
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Estimated Meter Readings

The advent of smart meters for measuring the consumption of electricity and natural gas may make the need for regular manual meter reading disappear, or at least fall drastically, in the not too distant future. Indeed, the possibility of continuous real-time metering that will enable households to respond to variations in utility prices as they occur might mean that in the future there will be absolutely no surprise to homeowners when they receive their utility bills. However, this version of the future has not yet arrived – at least not in any widespread sense – and currently, many homeowners may be surprised by reported consumption and the associated cost that appears on their utility bill. Often, this response may be intensified if there is an indication on the bill that household consumption for the billing period was estimated rather than being based on the difference between actual successive meter readings.

No doubt this surprise – especially if estimated consumption, and hence cost, appears to be high – often results in comments about gouging by the utility company, particularly if past consumption patterns do not appear to justify the estimated consumption used for billing purposes. Although any over- or under-estimation of consumption on the bill will be corrected next period when the meter is actually read, few consumers are likely to be keen to lend money to a utility provider, even if only for a short time. Thus, the extent of any over- or under-estimation when there is no actual meter reading taken can have non-trivial implications.

To investigate the methods used to estimate electricity consumption when no meter reading is taken, and the likely extent of any over- or under-estimation, CBEEDAC researchers David Ryan and Denise Young approached a local utility company – EPCOR – who graciously made available electricity consumption data by site over a three-year period. Since the meters at different sites are read at different times, this enabled these issues to be analyzed. A brief summary of the methods and findings are provided in the following article.



Electricity Bills and Meter Reading Cycles

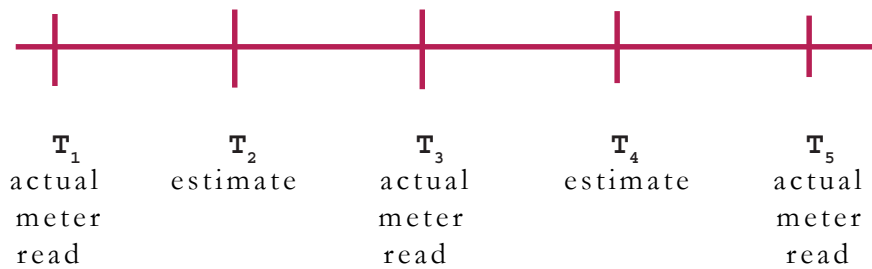
David L. Ryan and Denise Young

In many jurisdictions, households and small businesses receive bills for their electricity use each month, but their electricity meters are only read every other month. As a result, about half of all electricity bills that many customers receive are based on an estimate of their electricity use. Alternative methods that can be used for the preparation of electricity bills in the absence of a meter reading are evaluated based on a random sample

of historical data on meter readings over the course of three and one half years for approximately 30,000 customers in a large western Canadian city.

The basic problem faced by the electricity provider (who reduces its costs by reading meters at a less frequent interval than is used for billing) is illustrated in Figure 1.

Figure 1: A Schematic of Metering at a Particular Site

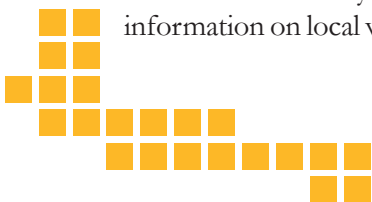


In this simple schematic, two metering cycles (T_1 to T_3 , T_3 to T_5) and four billing cycles (T_1 to T_2 , T_2 to T_3 , T_3 to T_4 , T_4 to T_5) are depicted. Actual consumption is known for the full metering cycles, but not for the individual billing cycles. In order to invoice for the T_3 to T_4 billing cycle, for example, the electricity provider must construct an estimate of energy consumption over that period. When the meter is read at T_5 an invoice for total electricity consumption over the metering cycle less the amount estimated for the T_3 to T_4 period is sent. As a result, total consumption billed for the full metering cycle will reflect actual consumption over that period, while the two individual invoices received over this period may or may not accurately reflect consumption for the relevant billing period.

How does an electricity provider estimate electricity use when preparing an invoice for a particular site (customer) in a month where the meter hasn't been read? The information that can be used includes total electricity consumption by all customers over the period (otherwise known as net system load, NSL), historical information on electricity use at the sites to be billed, and information on local weather conditions.

Given that the provider knows the NSL, it is able *on average* to provide estimated invoices to its customers that ensure that the sum of estimated electricity consumption over customers whose meters have not been read is equal to the actual electricity consumption over all of these sites. There are, however, many ways to be accurate *on average*. With any method of estimating consumption that is accurate *on average*, some customers will be over-billed and some will be under-billed for the month, with the inaccuracies in estimated electricity consumption being rectified at the time of the next meter reading.

Inaccuracies result in a temporary loan from individual customers to the provider for those invoices that are over-estimated and a temporary loan in the reverse direction for the case of under-estimated invoices. If it turns out that a subset of customers frequently receives estimated invoices that are too high, that group of customers may become dissatisfied. In jurisdictions where customers have options with respect to which provider to select, this dissatisfaction may be of concern to the electricity provider.



In order to determine which methods of estimating consumption in the absence of a meter reading work best, five basic methods were evaluated based on a series of criteria designed to compare the abilities of the methods to provide accurate invoices to individual customers.

Estimation Methods

Historical information regarding electricity consumption at the site in question is factored in for all five of the estimation methods considered. Two methods use consumption information from the previous metering cycle, while the other three methods use consumption information from the same general period in the previous year. Three of the methods outlined below (Methods A, B, and C) have been used by one or more electric utilities. Method E, the most computationally burdensome method considered here has been proposed but is not currently used in any jurisdiction.

Method A

Method A bases the estimate of electricity consumed over the current billing cycle on the proportion of NSL attributable to this particular site during that previous metering cycle (the site's usage factor). For the billing cycle T_3 to T_4 depicted in Figure 1, the site's usage factor would simply be calculated as ratio of the amount consumed at the site during T_1 to T_3 to the NSL for that same period. This usage factor is then multiplied by the actual NSL over the T_3 to T_4 period to obtain estimated consumption for the current billing period.

Method B

Method B uses the known levels of consumption per day or average daily use (ADU) at the same site in the previous period. ADU is simply calculated as the ratio of total consumption for the site over the previous metering cycle (T_1 to T_3 , for example) to the number of days in the cycle. The ADU value is then multiplied by the number of days in the current billing cycle (T_3 to T_4 , for example).

Method C

This method is a direct generalization of Method B. The difference is that the ADU calculation is based on average daily consumption from the same time period for the previous year. This may better capture seasonal components in consumption.

Method D

This method, in the spirit of Method C, is an adaptation of Method A where the 'usage factor' ap-

plied to current aggregate consumption is calculated as the share of total consumption attributable to a site from the same time period in the previous year rather than in the previous period.

Method E

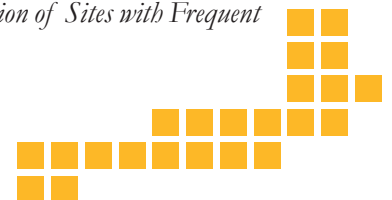
This method is a multi-step variation of Methods C and D that has been suggested. The estimate of electricity consumption is obtained by determining the percentage of that site's annual consumption that occurred in (approximately) the same period in the previous year, and then applying that percentage to that site's projected annual consumption for the current year.

Estimates based on each of the various methods were constructed using historical urban metering cycle data running from January 2001 to mid-2004 for approximately 30,000 residential, small commercial, and medium commercial sites as well as aggregate NSL data. For each site, we have meter readings that correspond to points such as T_1 , T_3 and T_5 in Figure 1. In order to 'mimic' the estimation problem of the electricity provider, we consider periods such as T_1 to T_5 to be our pseudo-metering cycle and periods such as T_1 to T_3 and T_3 to T_5 to be our pseudo-billing cycles. In this way, the estimates of consumption for periods such as T_1 to T_3 can be compared to actual consumption over the period for evaluation purposes.

Evaluation Criteria

Four measures of accuracy are considered. Two are standard statistical approaches: (i) *Average Estimation Error (AEE)* which is obtained by averaging the difference between estimates and actual values across all data points; (ii) *Root Mean Square Percentage Error (RMSPE)* which considers the size of the error relative to the value that was being forecast and, since it takes the square root, positive and negative errors cannot offset each other. Unlike AEE, RMSPE can only be zero if every forecast for every site and every meter cycle is perfect.

The final two 'customer satisfaction' measures assess the extent and frequency of the over-estimates that are made when applying particular estimation methods. They are based on the idea that customers are likely to be less concerned with underestimates than with overestimates, since the former simply requires them to pay more next period and less in the current period. The two criteria are: (i) the *Proportion of Large Consumption Overestimates*; and (ii) the *Proportion of Sites with Frequent Large Overestimates*.





Results

The evaluation results for the residential customers in the data set are summarized in Table 1 for the statistical criteria and in Tables 2 and 3 for the ‘customer satisfaction’ criteria. The results indicate that Method A performs well according to all criteria with the lowest AEE, RMSPE, proportion of large overestimates and

(in most cases) proportion of sites with frequent overestimates. The results for small and medium commercial customers were less clear, with no one method performing well according to all criteria. Further details are available in the complete report which is available from CBEEDAC.

Table 1: Statistical Criteria Results - Residential

Criterion	Method A	Method B	Method C	Method D	Method E
AEE	0.866	-10.345	-2.830	33.136	79.530
RMSPE	5.738	6.104	7.619	7.772	9.842

Table 2: Proportion of Overestimates - Residential

Extent of Overestimate	Method A	Method B	Method C	Method D	Method E
Overestimates	0.5054	0.4762	0.4833	0.5695	0.5156
More than 5% over	0.3667	0.3764	0.3675	0.4466	0.3882
More than 10% over	0.2569	0.2917	0.2809	0.3412	0.2896
More than 25% over	0.1005	0.1287	0.1486	0.1731	0.1358

Table 3: Percentage of Sites with Frequent Overestimates - Residential

Frequency of Occurrence	Percentage of Sites where Estimates exceed Actuals by at Least 10%				
	Method A	Method B	Method C	Method D	Method E
More than 75% of the time	0.06	0.04	2.98	4.85	0.20
More than 67% of the time	0.31	0.40	6.71	9.99	0.94
More than 60% of the time	0.79	0.92	11.06	15.75	1.89
More than 50% of the time	4.72	6.01	19.93	26.43	8.37

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