Residential Baseload Energy Use:
Concept and Potential for AMI Customers

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Abstract

Household electrical baseload is a concept launched by the BRANZ group, while working on the 10 year HEEP end-use load research study in New Zealand. "The baseload[1] of a house is the typical lowest power consumption when everything that is usually switched off is off, and was on average (112±4) W. This baseload represents the upper limit for the standby power consumption." (Camilleri, M., et al 2006, 9-61). The BRANZ group investigated how much of the "lowest 10-minute period load" is composed of standby load, and how much is driven by other identifiable causes.

This paper endeavours to take this new concept, "baseload", integrate it with available 15-minute utility load research data, in an attempt to provide tools for the utilization of the new utility advanced metering infrastructure (AMI[2]) hourly usage data for all residential households. Customers need to see how their dwelling uses energy at various times of the day, and they need to see how well they are doing compared a baseline, such as their neighbours, before investing more effort or money in energy savings. Many utility uses for hourly AMI data have been identified, but to use this data for residential customer information and energy savings guidance is of great importance to BC Hydro.

Background

Household electrical baseload is a concept launched by the BRANZ group, while working on the 10 year HEEP[3] end use load research study in New Zealand. The HEEP study is the most extensive residential metered end use energy study published, and its costs were much lower than its major predecessors, Hood River[4] in the 80s, and ELCAP[5] in the 80s and 90s. Given that the HEEP researchers did a complete audit of all the sampled households' appliances

[1] For at least twenty years economists have been referring to the "baseload" as the constant term in the conditional demand model, which was used to predict specific appliance end-use consumption values. The BRANZ group is using the word baseload in a very different context, and the values will have no relationship with each other.

[2] Advanced Metering Infrastructure (AMI) systems now generally focus on electric utility hourly consumption data, collected at special revenue meters, and returned to the utility via radio, power line carrier, etc. It can also be referred to as Smart Meter Infrastructure (SMI).

[3] "HEEP is a nationwide study of energy use and temperatures in New Zealand houses. Monitoring began in 1999 and was completed for 398 houses in mid-2005, with each house monitored for about one year. The study used a random selection of all New Zealand houses and is statistically representative." (Camilleri, M., et al, 2006, 9-63)

[4] BPA's Hood River Conservation Project was a leading research initiative in both the residential electricity conservation field, and in the monitoring area. The load research side resulted in 320 homes having end use metering, in the mid-80s. (Flanagan, 1992)

[5] End-Use Load and Consumer Assessment Program (ELCAP) began in 1983 and still ran into the 90s under the name of Regional End-Use Metering Project (REMP). The BPA program acquired various samples from different projects, and ended up with 327 or less sites in each of the 6 years covered by the 1992 report.

measuring connectivity and standby losses for the small appliances, as well as monitoring the hourly loads of the large appliances, they could look at several aspects of residential energy use and the load research process in new ways. They invested a lot of effort in trying to show how much of the "lowest 10-minute period load" is composed of standby losses, and how much is driven by other identifiable causes. As an exploratory paper in this new subject area, the readers will find that this paper attempts to comprehensively cover a wide array of potential interests.

Organization of this Paper

This paper describes the objectives for this line of research, and then provides definitions of baseload and standby loads. After a description of the methodology, directional information is provided on the variations in baseloads, followed by a review of how they vary by dwelling type. The bridge from load research data to customer AMI data is crossed, and it is followed by one example of how utility AMI reporting systems might help the customer discover potential energy savings.

Objectives

Over the next three years huge investments will be made in North America with the roll-out of AMI projects across the continent[6]. Utilities must continue to work to optimise this huge investment in infrastructure. This report is one step in the process of taking the new concept of "baseload", integrating it with available 15-minute utility load research data, in an attempt to provide tools to improve the utilization of the new utility AMI hourly usage data for all residential households. The current objective of this study is to provide guidance for residential web viewing tools, so that the residential customers can see if their measured overnight loads are as low as they might be, and what the causes of unexpected high overnight loads could be (faulty refrigerators and freezers, space heat left on, lights left on, constant-on appliances[7], high standby losses, etc.). Customers need to see a baseline which shows how their dwelling might use energy so they can tell how well they are doing, compared to this baseline, before investing more effort or money in energy savings. Many utility uses for hourly AMI data have been identified, but to use this data for residential customer information and energy savings guidance is of great importance to BC Hydro. Links shown in this paper, between the concept of baseload, and household appliance standby loads through ratios, are purely speculative, and need further, extensive research.

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[6] Useful updates on the progress of AMI projects are at: news@metering.com, http://maps.google.com/maps/ms?ie=UTF8&hl=en&msa=0&msid=115519311058367534348.0000011362ac6d7d21187, and IssueAlert@UTILIPOINT.COM, and a wide array of other industry information providers.

[7] Constant-on appliances are ones which are left on by user choice, such as computers, HD set-top boxes, the Personal Video Recorders (PVRs), and some lighting. They may or may not have a subsidiary standby value, and some, like PVR, may not have noticeable consumption changes when turned "off".

What Is Baseload?

According to BRANZ, "The baseload[8] of a house is the typical lowest power consumption when everything that is usually switched off is off." (Camilleri, M, et al) p. 9-61. It is made up of the standby power of appliances, off-cycle power consumption of refrigeration appliances, continuous loads like heated towel rails, and other appliances that are always on (including faulty refrigeration appliances).

The estimation of baseload is closely related to the estimation of standby load, as the standby load is a significant subset of the baseload, but is not affected by customer behaviour. "Estimation is more complex, because there are a large number of appliances switching on and off during the course of a day, so that the total power may only be rarely at baseload level and there is not usually a clear and distinct mode of low power. It may perhaps occur in the middle of the night, when everyone is asleep and all possible appliances are switched to off or standby." (Camilleri, M., et al, 2006, 9-65).

What Are Standby Loads?

Standby loads (occasionally referred to as standby losses, or phantom loads)[9] are the amount of energy used by specific appliances when the household thinks everything is "off". The instant on features have been shown to consume significant amounts of energy, and small loads such as clocks and cell phone chargers also contribute load to this category. While a microwave can consume a lot of electricity for short periods of time while cooking, over the whole year it might actually use more energy while "off" (The Economist, 2006). The new HD TV set-top boxes, especially the PVR (personal video recorder) versions, might be called the largest standby load appliance we have[10], although they might not fit some definitions of standby due to their constant activity in the communications functions, and their background recording functions.

While HEEP was aimed at better understanding hourly usage patterns, and how homes were heated, it also included a complete standby load audit, for each home. This enabled the researchers to compare the standby load to the measured 10-minute interval energy use, with the lowest period use being named as the baseload. In their case they found that the measured standby loads were about ½ of the baseload, with the rest being divided almost equally between electric towel warmers, and faulty refrigerators. In BC we do not ask about electric towel

[8] For BRANZ and load researchers, baseload is a 10 or 15-minute interval measure. For utilities using AMI and dealing with customers, AMI-Baseload will be a one-hour value. All customer comparisons will be on the one-hour values.

[9] "Standby power is drawn by an appliance when it is not in operation but is connected to the mains. This can range from zero (e.g. a non-electronic clothes dryer) to 20 W or more (e.g. a television). These power levels may seem trivial (1 W continuous power is approximately 9 kWh per year), but since most households have many such appliances, the actual energy consumption is usually a significant fraction of the total energy consumption of a household. Standby mode is defined in the NZ standard (AS/NZ62301:2005, 2) as: *The lowest power consumption mode which cannot be switched off (influenced) by the user and may persist for an indefinite time when an appliance is connected to the main electricity supply and used in accordance with the manufacturer's instructions.*

The **standby power** is defined as the average power measured in **standby mode**." (Camilleri et al, 2006, 9-61)

[10] Over a 258 hour period one PVR (contains a DVD recording devise and communicates with the cable system regularly to update program changes, a.k.a. Tivo) used 10.85 kWh, which is equivalent to 42 W, and 368 kWh/year. It is difficult to define standby with a constantly on, interactive device.

warmers in our end use surveys, but they are available in Wal-Mart, and their saturation rates may increase to the point where they are a significant load. Faulty refrigeration is also of great interest to BC Hydro, due to our intense focus on residential energy conservation.

Methodology

This simple research project started out with two Excel summaries of BC Hydro's residential load research sample's 15-minute baseload data; one which showed the distribution of the time for the monthly lowest consumption readings of approximately 300 households, for a recent 12 month period. The second spreadsheet contained the monthly 15-minute lowest consumption readings for each household, for each month. Initially we eliminated all zero readings, and .001 kWh and .002 kWh 15-minute readings. Further review suggests that these small readings are legitimate. A later step added hourly data for comparison, and to support the assessment of transferability of findings to AMI[11] systems. Then annual minimum interval baseload values were requested. Finally a year of raw 15-minute interval data for the author's house was utilized, to reduce privacy issues, and to attempt to use interval data where the causal factors might be understood.

When Is Household Electricity Consumption the Lowest?

One would expect to find the lowest electricity consumption period for a household, within any given month, to be in the 3:00am to 5:00am period. For most households, that period would contain the lowest average consumption hour, but not necessarily the lowest individual hour, or in the case of the first part of this study, the lowest 15-minute period.

The time that the household uses the least amount of energy, very roughly approximating the standby losses, can be at any time the household is essentially empty or inactive. Some houses may be empty in the evenings in the summer, and show very low consumption periods, while in the winter their monthly low points might be in the early morning. Ventilation fans in the summer and plug-in space heaters in the winter will shift the times and levels significantly.

If we look at hourly data, we see essentially the same picture, with less rough edges. In the 8 hours between midnight and 8:00am, as seen below, we find that 49.4% of the "lowest times" occur. Before assembling this data, the author would have expected all of the low periods to fall into those "nightime" periods.

[11] AMI systems are also now referred to as Smart Meter Infrastructure (SMI) systems.

Figure 1. Time of the Baseload Interval

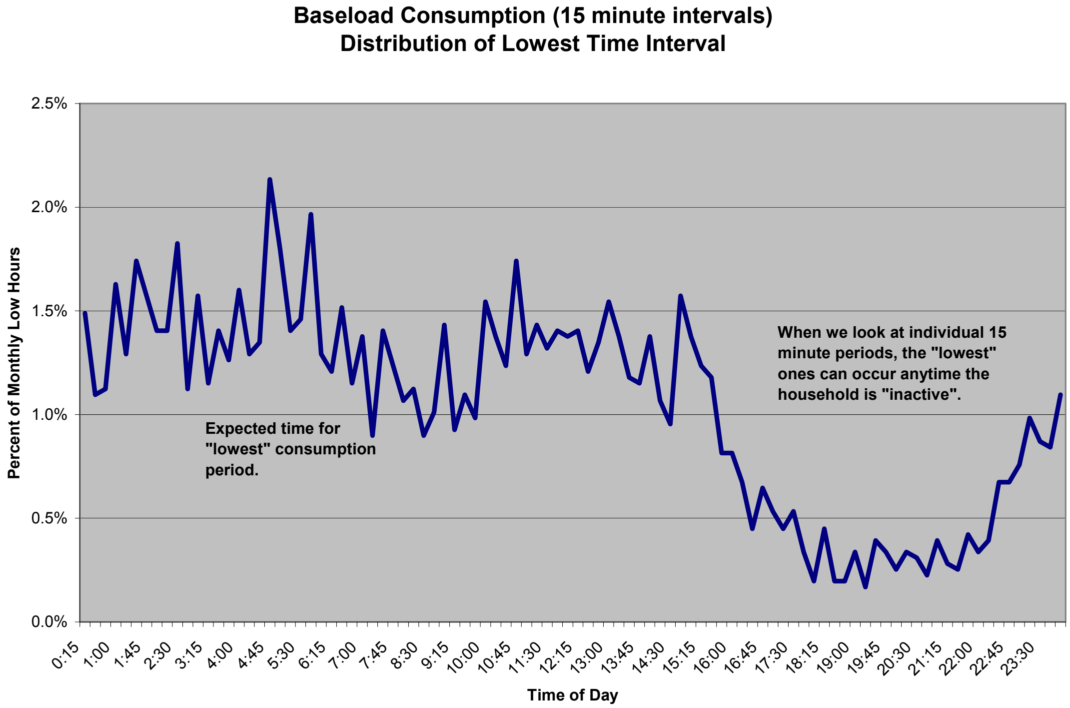
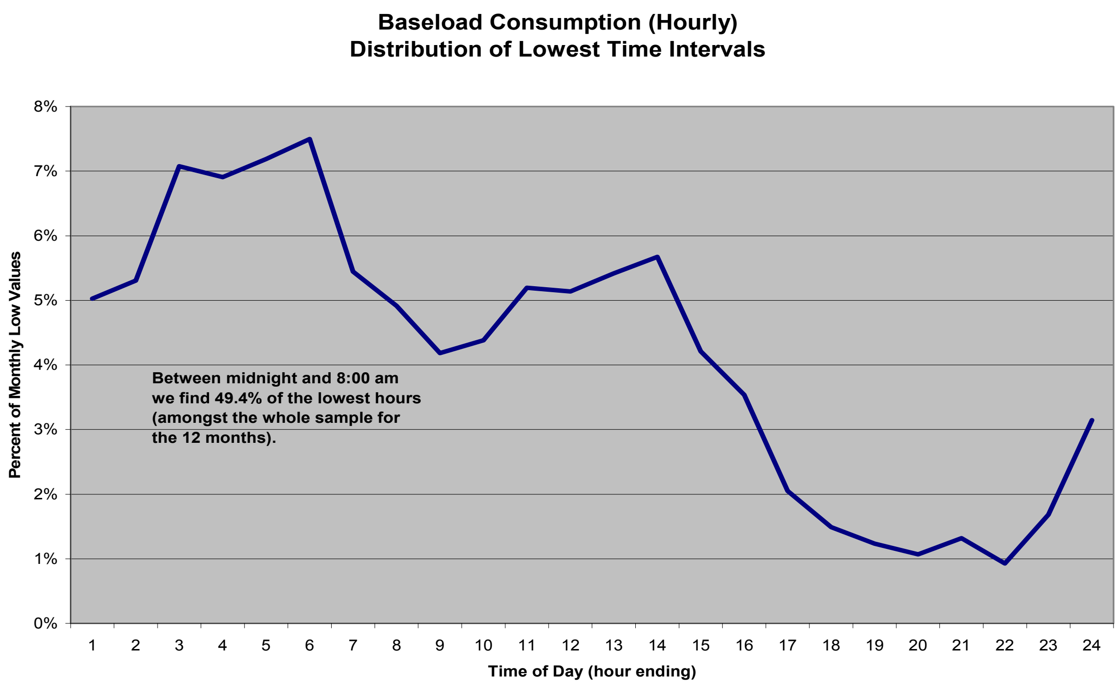


Figure 2. Hour of the Baseload Interval

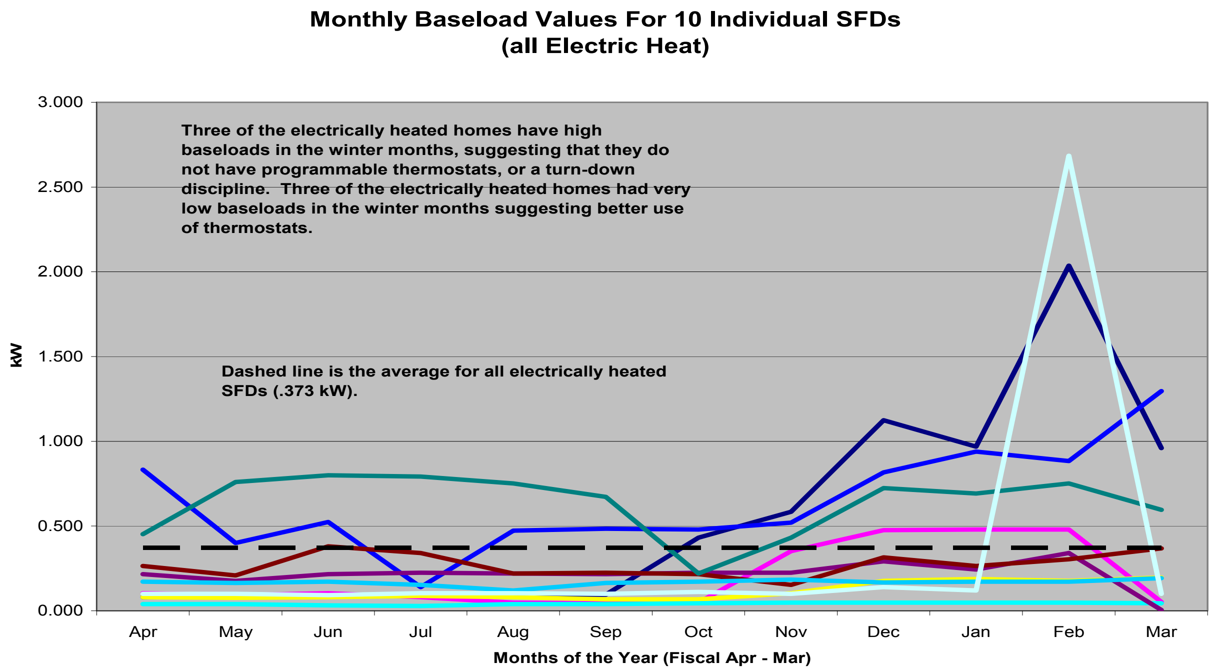


How Variable Is Baseload Between Dwellings of the Same Type?

When looking at single family dwellings, we can see that some have very high values for their minimum 15 minute load[12] in the month. This generally indicates 24-hour loads for space heat, or other process loads.

Twenty-four homes, about 17% of the single family dwelling part of our sample, have one or more minimum monthly 15-minute loads that exceed 2kW. One home uses a heater in the garage to serve as a dehumidifier (dehumidifiers would freeze up in this climate) in the winter, to remove moisture to reduce rusting risk with older vehicles. Aquariums and pool pumps running all the time are other reasons for high baseloads being found. And as mentioned above, seasonal non-thermostatically controlled "HVAC" loads are significant. By looking at monthly baseloads, seasonal behaviours and evolving equipment problems will become evident.

Figure 3. Examples of Monthly Baseloads – Electric Heat



The sample of ten electrically heated homes in the graph above provides some insight into the characteristics of the baseload values that researchers need to understand. Electrically heated homes with good thermostat control, or personal discipline, may have the same low baseloads in the winter that non-electrically heated homes tend to have. Electrically heated homes with baseboards or portable heaters that have little or no thermostatic control will have higher baseloads in winter.

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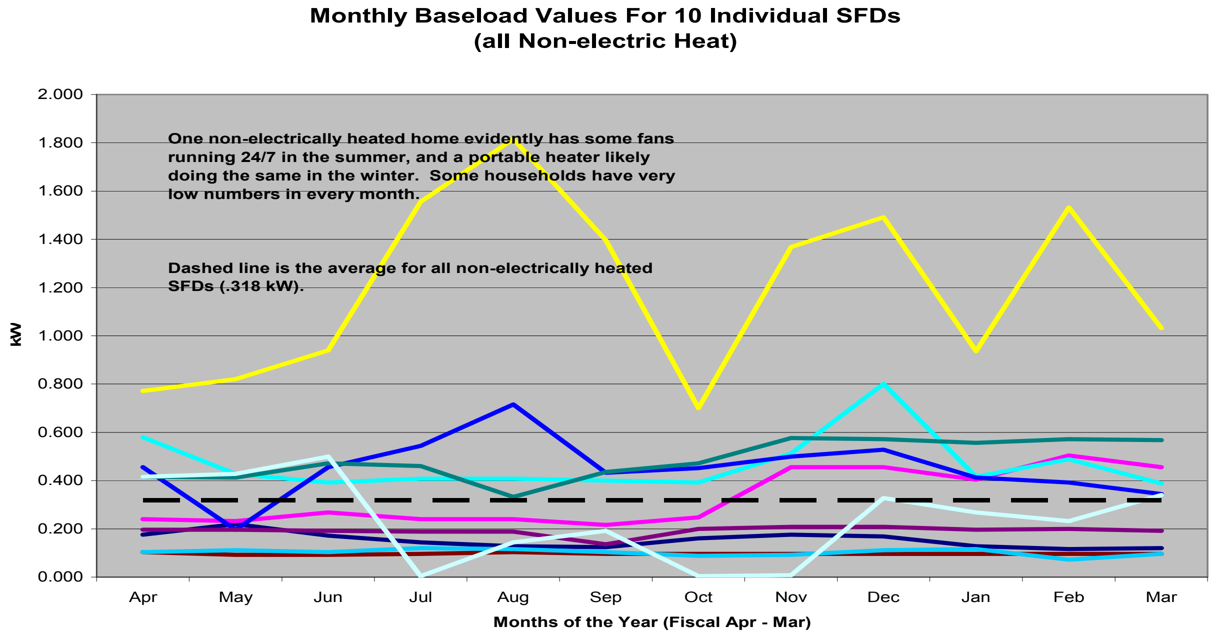
[12] In this report two types of hourly figures are used. When one uses 15-minute energy values from load research, one has to multiply the energy value by four to get the hourly energy equivalent, or more important, the kW value. When one uses real hourly data, such as one would get from an AMI system, the granularity is lost, and you find baseload values that are essentially doubled, about 113% higher. These differences will be primarily due to more cycling appliances being on within every hour, such as refrigerators.

Figure 4. Examples of Monthly Baseloads – Non-Electric Heat



In the graph above one non-electrically heated home looks as if it uses small fans around the clock in the summer, and a non-thermostatically controlled (or set to full power) heater in winter.

Dwelling Type and Average Monthly 15-Minute Baseload – The Demand View

Infrastructure may be significant when we compare the various dwelling types. The SFDs appear to have average baseloads which are 2 or 3 times those found in row houses and apartments. This could be affected by the distribution of non-thermostatically controlled "HVAC" equipment, and the probability of larger numbers of refrigeration products, somewhat reducing the chance of finding a 15-minute interval where they are all off. As annual baseload means that summer months likely set the values, heating type does not seem to be an influence.

Table 1 – Annual Minimum Baseload by Dwelling Type - kW

Dwelling Type	"N" Electric Heating	Ave 12-month Baseload kW	"N" Non-Electric Heating	Ave 12-month Baseload kW	Difference Elec - non
SFD	72	0.113	98	0.162	0.053
Row	39	0.065	37	0.065	0.000
Apt	43	0.060	45	0.056	0.004
Mobile	2	0.052	13	0.057	-0.007
Seasonal	4	0.061	1	0.028	0.033
Farm	1	0.152	1	0.004	0.148
Total - Heating Type	161	0.086	195	0.112	0.030
Total - Sample	356	0.100			

Small "Ns" should not receive much consideration.

Variations in Baseload Values by Measurement Time Interval

Nigel Isaacs of BRANZ emphasised the need for 10-minute interval data, and has had some concerns about the use of 15-minute or longer data. With 10-minute data their methodology "was able to remove all cycling appliances." (Camilleri, 2008) For regular AMI customers who have the chance to look at their interval data, the one hour increment is likely the only option. In BC Hydro's utility load research sample[13], one has the opportunity to look at both 15-minute data and hourly data. If one could estimate the percentage of standby losses compared to 15-minute baseload, then these values could compared to the hourly data by using the ratios found in the following tables. It is important to differentiate load research baseload values from AMI-Baseload values.

The top section on the next page shows the 15-minute interval, annual minimum baseload values, averaged for each dwelling and heating segment. The signs are in the right direction, as for those dwelling types with a reasonable sample size, electrically heated dwellings generally have a slightly higher baseload than non-electrically heated dwellings, and the single family dwellings have higher baseloads than the smaller row houses and apartments. This "size" difference could be attributed to income, or size, but likely both have a lot to do with the amount of baseload. The second section uses what would be available from an AMI system, the hourly interval, annual minimum AMI-Baseload values, averaged for each dwelling type, for the same sample and time period as the 15-minute data. These numbers are about twice those for the 15-minute intervals, probably due to the cycling of multiple food cooling appliances, as well as other diversity issues.

One can calculate the percentage value of 15-minute interval data divided by the hourly data. Now it is clear that 15-minute data shows a baseload value of just under 50% of that seen through the hourly data.

Annual Minimum Hourly AMI-Baseload by Dwelling Type and Heating Type

By using a percentile distribution to deal with the varying sample sizes, one can show the relationship between the annual minimum hourly baseload value for electrically heated and non-electrically heated dwellings of the same type, as well the relationship between the different dwelling types.

[13] When BC Hydro's SMI project is rolled out, the residential load research sample will be ~5,000 households, and conceivably data can be collected in 1-minute, 5-minute, 10-minute or 15-minute intervals. If deemed of value, further research can be done in this area, at that time, with much greater accuracy expected.

Table 2 – 15-Minute Interval Data vs. "AMI-Baseload" Data

Variation In Baseload Values by Time Interval

15-Minute Interval Minimum Baseload Values

Dwelling Type	"N" Electric Heating	Ave 12-month Baseload kW	"N" Non-Electric Heating	Ave 12-month Baseload kW	Difference Elec - non
SFD	72	0.113	98	0.162	-0.049
Row	39	0.065	37	0.065	0.000
Apt	43	0.060	45	0.056	0.004
Mobile	2	0.052	13	0.057	N/A
Seasonal	4	0.061	1	0.028	N/A
Farm	1	0.152	1	0.004	N/A
Total - Heating Type	161	0.086	195	0.112	-0.027
Total - Sample	356	0.100			

Hourly Interval Minimum Baseload Values

Dwelling Type	"N" Electric Heating	Ave 12-month Baseload kW	"N" Non-Electric Heating	Ave 12-month Baseload kW	Difference Elec - non
SFD	72	0.299	98	0.295	0.004
Row	39	0.181	37	0.147	0.035
Apt	43	0.116	45	0.112	0.004
Mobile	2	0.088	13	0.145	N/A
Seasonal	4	0.088	1	0.033	N/A
Farm	1	0.263	1	0.097	N/A
Total - Heating Type	161	0.213	195	0.212	0.001
Total - Sample	356	0.213			

Hourly Minus 15-Minute Interval Values

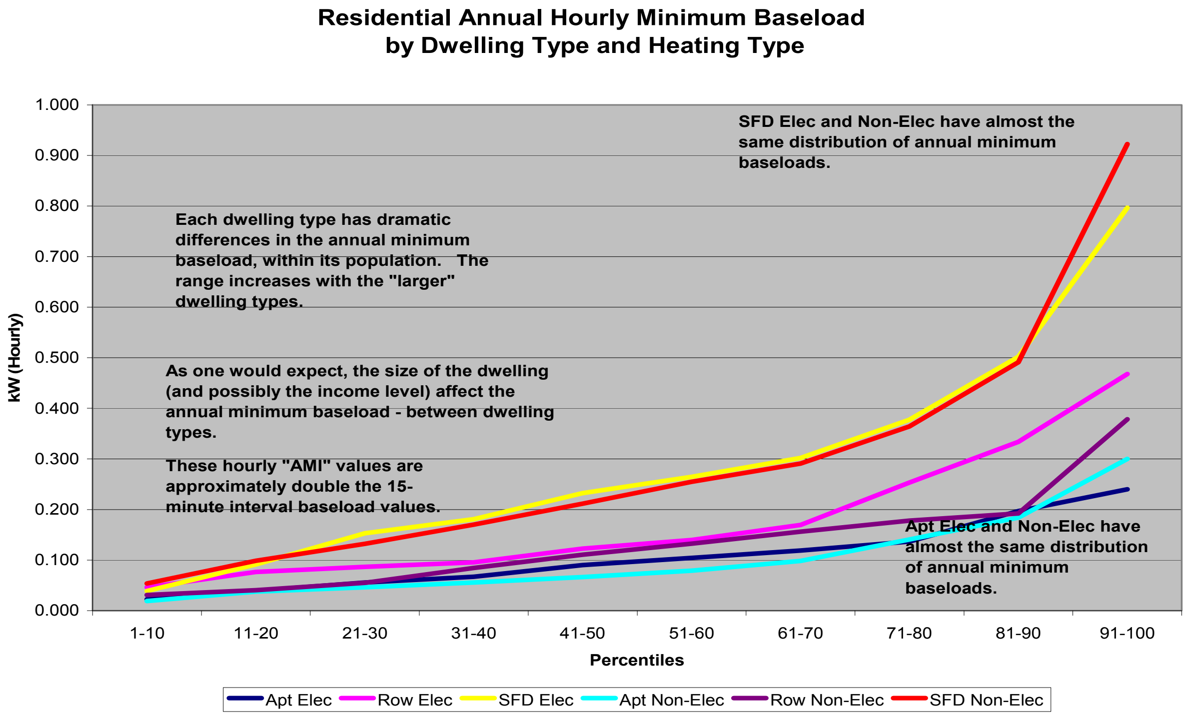
Dwelling Type	"N" Electric Heating	Ave 12-month Baseload kW	"N" Non-Electric Heating	Ave 12-month Baseload kW	Difference Elec - non
SFD	72	0.186	98	0.133	-0.053
Row	39	0.116	37	0.082	-0.035
Apt	43	0.056	45	0.056	0.001
Mobile	2	0.036	13	0.088	N/A
Seasonal	4	0.027	1	0.005	N/A
Farm	1	0.111	1	0.093	N/A
Total - Heating Type	161	0.128	195	0.100	-0.028
Total - Sample	356	0.113			

15-Minute Interval Values as a Percentage of Hourly

Dwelling Type	"N" Electric Heating	Ave 12-month Baseload kW	"N" Non-Electric Heating	Ave 12-month Baseload kW
SFD	72	38%	98	55%
Row	39	36%	37	44%
Apt	43	52%	45	50%
Mobile	2	N/A	13	N/A
Seasonal	4	N/A	1	N/A
Farm	1	N/A	1	N/A
Total - Heating Type	161	40%	195	53%
Total - Sample	356	47%		

Small "Ns" should not receive much consideration.

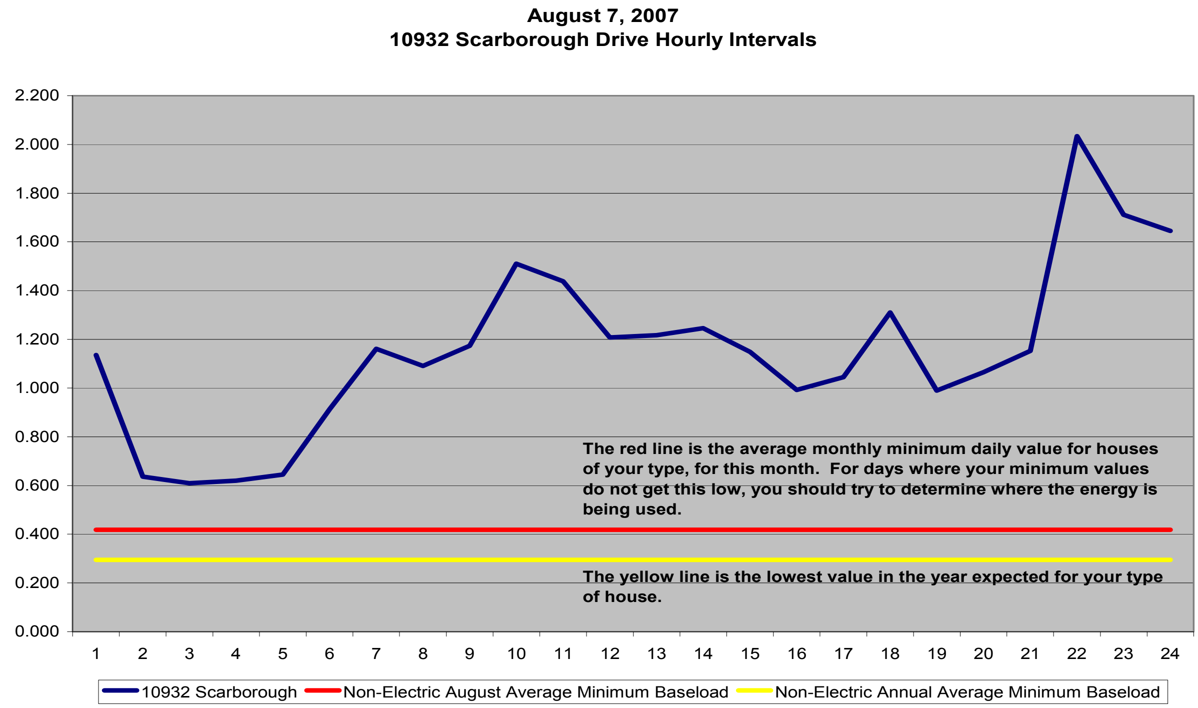
Figure 5. Distribution of Baseload Values



The heating type seems to have essentially no effect on the annual minimum hourly baseload value within households of the same dwelling type. And this should be expected as the one single lowest hourly value may well be registered on a summer's evening, when no heating loads would be found. Earlier graphs have shown that the monthly values for some electrically heated single family dwellings have a distinct seasonal pattern. The dwelling type, however, looks to be quite significant.

AMI Customer Potential Benefits

Figure 6. Household Potential AMI Report

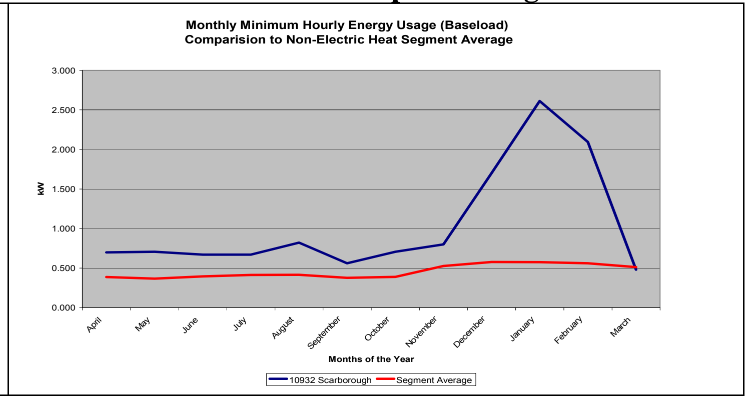


For BC Hydro, a major goal for the AMI project is to increase customer awareness of how much electricity they use, when they use it, and to support decisions to try to use electricity more efficiently. Our Conservation Rate Initiative (a residential pilot program for time of use pricing) has shown, in a winter peaking utility, some peak shifting, and winter energy savings of about 7% (Tiedemann, 2007, 2008). For future AMI work, we hope the customer would be able to see, on their daily consumption graphs, what their neighbours with similar homes had as their minimum hourly consumption, for the month, as in the example above.

The other value an AMI system can provide is to show the utility customer how their monthly minimum consumption value (hourly) changes by month, and how it compares to the average for their dwelling/heating segment.

Table 4 – Monthly AMI-Baseload – One House vs. Sample Average

Monthly Minimum Hourly Consumption Values		
	10932 Scarborough	Segment Average
April	0.698	0.386
May	0.705	0.366
June	0.669	0.396
July	0.669	0.413
August	0.822	0.416
September	0.560	0.376
October	0.705	0.389
November	0.800	0.525
December	1.702	0.577
January	2.611	0.575
February	2.095	0.561
March	0.480	0.513



Key Learnings

1. The hour of the lowest monthly load may be any hour of the day, but about 50% of the lowest monthly readings were in the early morning hours.
2. While the month of the lowest hourly figure can be any month, the month of the high figures is often a winter month – but anything is possible.
3. Some household monthly baseload variations appear to be related to constant-on heating or ventilation equipment.
4. Between dwelling types the variation in baseload is significant, and this variation is consistent with size/income assumptions for the dwelling type.
5. Within dwelling types the variation in annual hourly AMI-Baseload is very significant.
6. The relationship between 15-minute and hourly baseload values is reasonably consistent, and of a significant size. The load research 15-minute interval baseload value seems to be about 47% of the 1-hour AMI-Baseload values.
7. The concept of AMI-Baseload should be of value for the customer in AMI information systems, as it could be used by the customer to identify defective refrigeration appliances or unexpected energy use at "low use" times, when compared to their peers, or to their own billing history.
8. One process finding is that it is useful for a Load Research department, when assessing the validity of interval data, to start to look at the "bottom" of the hourly usage charts, rather than just looking at the peaks. The shift in paradigm provides a more complete perspective on what is happening in the home.
9. Subject to further research, one might surmise that the standby load is about 50% of the 15-minute minimum annual baseload value (with the rest being constant-on appliances, faulty refrigeration, and a few cycling appliances, etc.), and the 1-hour AMI-Baseload minimum annual value being about twice again the value of the 15-minute interval data due to more cycling appliances. Thus from an AMI perspective, standby load might be estimated to be ¼ the minimum annual AMI-Baseload.

End Notes

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