# ENERGY WISE HOME DIAGNOSTIC: IMPLEMENTATION OF A WEB-BASED ENERGY AUDIT FOR A NORTHERN CLIMATE UTILITY

E. Dumont, S. Sansregret, Hydro-Quebec
D. Trumble, Enernex

## Abstract

Hydro-Québec has recently implemented a Web-based energy audit tool to meet energy efficiency requirements of Régie de l'énergie (Quebec energy regulator). The primary focus of this software tool is to assist customers to better understand their energy consumption. This is accomplished by breaking down the customer's total energy costs to specific end uses and providing customized recommendations for saving energy and reducing costs. Recommendations are quantified and adapted to each customer situation, giving them a personalized energy analysis.
In order to account for northern climate realities, a specialized heating model has been designed. This model uses a dual approach with both engineering and statistical models to estimate heating consumption. The detailed specification of internal loads yields cross-effect heating estimates that are reflected in the savings calculations

A reconciliation process with billing history is included to vary end-use estimates within a reasonable range to minimize otherwise unexplained consumption. This implementation also includes a simulation tool, not constrained by actual consumption, to provide customers the ability to see the energy impact of "what if" appliance or behaviour changes.

The resulting tool entirely meets Hydro-Québec's needs and expectations. Customers are provided a reliable tool to better understand their consumption and receive customized recommendations to reduce their energy costs. The achievement of this project is evident by the successful completion of over 835 000 surveys since February 2004.

## Introduction

As energy cost continues to grow, utility customers are increasingly interested in ways to reduce their energy consumption. However, few customers have the means to easily identify cost effective solutions to reduce their energy costs. In fact, many customers have no idea where their energy dollars are spent, and for those who think they know, a majority are just misled popular misconceptions. This paper presents a tool that addresses the need for the customer to better understand their energy usage. Taking into account the objectives, we will see the constraints that brought a major electric utility, Hydro-Quebec, to implement a deeply customized tool for its customers. Models used by the software will be briefly presented, with a focus on the heating model which is most important in the context of a northern climate utility. Impressive results obtained by the diagnostic program will also be discussed, exemplifying its success.

# Objectives and constraints

### *Objectives*

Hydro-Quebec (HQ) is a government owned electric company that serves the vast majority of the Quebec territory. The distribution division has approximately 3 million residential customers. Since many electric utility customers do not have a clear understanding of how they utilize the electricity that they are billed for[1] Hydro-Quebec made the decision in 2002 to implement a new tool on its web site to help customers better understand their personal energy consumption.

At the same time, Quebec's regulator requested HQ to assist customer in finding ways to reduce their energy consumption. The "Energy Wise" home diagnostic has been designated as the lead tool for this task.

### *Constraints*

In order to be approved as an energy efficiency program for customers, the regulator requested that the diagnostic program be able to make "personalized" recommendations, recommendations that could be customized for each customer. It also had to be available to people without access to the internet, necessitating the availability of a paper survey. For HQ, it was important to have a reliable tool. Being a government own entity, HQ's actions are scrutinized and expectations regarding quality of service are high. In addition, with a heating dominant climate and an important share of electric heating, over 65 %, the cross-effect of energy savings were a concern. These cross-effects are caused by the increased heating demand due to the reduced usage within the home thermal envelope. For example, the energy savings from compact fluorescents are generally offset during heating season, by the increased heating demand, which constitutes about half of the year in Quebec.

With those constraints in mind, research of existing audit tools began and HQ quickly came to the conclusion that there were no products available which could already satisfy all requirements. The option to take customize an existing energy audit tool, the Residential Energy Bill Analyzer (REBA) to meet HQ's needs appeared to be the best solution. Having a strong technical expertise regarding electric home consumption models and working with web product specialists, HQ was confident in implementing a reliable tool which would meet all of HQ's major requirements.

# The diagnostic process

### *What it is doing?*

The first step to understanding the analysis process involves a review of the questionnaire. It is divided in to eleven pages: two for basic information (own or rent, detached or not, square footage, etc) and one for each of the nine end-uses to be analysed. There are over 120 possible

[1] In comparison, telephone bill comes with all the details telling customers how long, when and where calls have been made.

questions, but they are selected based on the customer's situation to limit the number of questions presented. Once completed, the customer has access to a personalized energy diagnostic report. All information for the analysis comes from the customer's billing history, weather data for the customer's area and the questionnaire answers.

The diagnostic report first presents a breakdown of the customer's electric consumption by end-use (see table 1). Then the top three saving recommendations are identified to bring the customer's attention to actions that will most reduce energy consumption. The next report sections are organized by end-use category to include all relevant recommendations. Some are best practice recommendations with no specific savings estimates. Other recommendations are more personalized to include savings estimates that are calculated specifically for each customer's situation. When applicable, the analysis takes into account other non electric energy sources. These other fuel-use estimates appear as a total in the main breakdown table but are disaggregated in each relevant section. Savings calculations for all fuels include both direct and indirect cross effect estimates in order to obtain estimated net savings for the relevant recommendations.

**Table 1: List of end-uses in Energy Wise Home diagnostic**

| | |
|---|---|
| Heating | Cooking |
| Air conditioning | Others appliances |
| Water heating | Lighting |
| Fridges/freezers | Pool/Spa |
| Laundry | Unassigned |

### *How it works?*

One challenge was to develop a heating model that would also take into account the internal gains of other usages. A critical requirement was to use a method to generate reliable and consistent results, even when customer responses are not always consistent. To achieve this goal, both an engineering model and a statistical thermal load model were employed. The engineering model provides an estimate of the heating energy based on dwelling type, square footage, age, other usages and hourly weather information during the analysis period,. The statistical model uses a thermal load specification similar to the **PRISM**[2] approach with an additional component to include other estimated seasonal usages such as seasonal variation of water heating, air conditioning and pool & spa electric consumption. A final heating estimate is then computed as a weighted average of the two approaches, with weights based on the standard error of the statistical model.

End-use consumption estimates for the other non-heating uses are specified as a function of the survey factors and weather data. Electric cooling consumption for homes with central systems is specified as a thermal demand model with thermostat settings for different periods of the day. For homes with room cooling units, cooling consumption is specified as a function of time used

[2] PRISM (which stand for PRInceton Scorekeeping Method) can be briefly describe as a statistical non-linear regression method to model dwelling energy consumption based on billing history and weather data [Fels, M.]

and power capacity. Water heating consumption, for both electric and other fuels, is estimated from hot water usage and water heater tank loss, which is also part of the internal gain estimate used for heating calculations. The remaining usages are based on similar models.

Total end-use estimates for specific billing periods are then compared to actual energy consumption on a bill-by-bill basis. The difference between the actual bill consumption and the corresponding total end-use estimate is referred to as unassigned consumption. End-use estimates are adjusted, within a range determined to be reasonable for the specific end-use category, to reduce unassigned consumption. Adjustment factors have been established for three different confidence levels for each end-use. The adjustments factors for the lowest confidence level provide the largest adjustment range and therefore determine the limit to which unassigned consumption can be reduced. The adjustment factors for the heating end-use estimates are specified as a function of the type of heating and the statistical model standard error. Similarly, the adjustment factors for the Pool and Spa end-use estimates are specified as a function of the type of heating.

If, on an annual basis, unassigned consumption exceeds reasonable limits, a warning message is added to the recommendation report. This message informs the customer that there are discrepancies between the model estimates, which are based on the answers provided, and the actual energy consumption. It is advised that the customer review the answers provided.

Once the first end-use section has been completed, approximate results are provided to the user. A first guess estimate of non-heating and cooling usages is computed based on the number of occupants in the dwelling until the customer has completed the relevant section. This feature allows a consumption graph to be displayed at the top of the page (see figure 1). The consumption graph updates each time a new section is submitted, however, the complete personalized report is only accessible after all end-use sections have been completed.

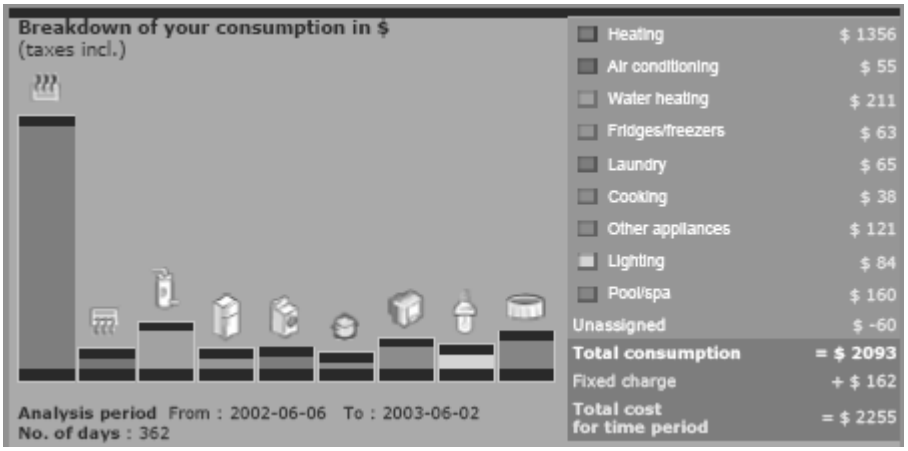


**Figure 1:** Example of end-use consumption graph appearing at the top of page survey

Recommendations to be included in the final report are derived from the customer's answers to the questionnaire. Quantifiable savings are calculated by one of the following methods:

- A proportional estimate of end-use consumption , or
- A new run of the model utilizing new parameters, relevant to the recommendation.

The second method provides a simple means to calculate the recommendation's cross-effect and is used in most cases. For example, take the recommendation of replacing an old refrigerator. A new run of the model would be performed taking in to account the consumption of new refrigerator of the same size in place of the older refrigerator. This new run not only provides a new consumption estimate for the Fridge and Freezer end-use, but also provides a new consumption estimate for heating since the new refrigerator will release less heat than the old one. These new consumptions will then be compared with the base case to estimate the potential savings for this recommendation (see Figure 2).

| Energy source | Potential annual savings | Cost | Payback period |
|---|---|---|---|
| Electricity | $ 13 ( 218 kWh ) | | |
| Propane | $ -4 | | |
| Total | $ 9 | | |

**Figure 2:** Example of a recommendation (Disconnect your freezer if not needed) that includes a cross-effect on other fuels. The estimated net savings includes a $4 increase in Propane heating demand and a reduction in electricity saving according that electricity and propane are both used for heating.

For recommendations involving expenses, a payback calculation is made based on electricity and fuel rates as well as the cost of implementing the recommendation. The recommendation will be displayed only if the payback is below a defined limit (Figure 3). This information resides in a database, making it possible for the Web master staff to adjust rates and costs as required.

| Energy source | Potential annual savings | Cost * | Payback period |
|---|---|---|---|
| Electricity | $ 40 ( 685 kWh ) | $ 40 | 1.0 years |

**Figure 3:** Example of a recommendation (Install a timer on your poll pump) that includes an estimated payback period.

The software also includes a simulation tool that is not constrained by historical consumption. This allows customers the ability to see the energy impact of a "what-if" appliance or of a change in energy usage. This feature is similar to the savings calculation explained above but allows for more than one change at a time. It also allows customers to see the impact of a habit change.

## Results

Energy Wise Home Diagnostic made its on-line debut in October 2003. Following a few months of testing, the energy saving program based on the diagnostic was launched in February 2004. In the following months, updates were implemented in order to address a second rate based on temperature (called "DT rate") and to add new features including the "What-if" simulation tool for the customer.

The paper version of the diagnostic was also made available in February 2004. The paper version shares the same calculation engine as the Web version and allows for the option of mass mailing the survey to targeted customers who otherwise may have been unreachable. Once they have the questionnaire in hand, customers still have the choice to go on-line or to fill out the paper survey and send it back. Returned paper questionnaires are scanned and a personalized recommendation report is generated based on the customer's inputs, just as if the web questionnaire has been completed. Customers who have submitted a paper survey also have the option to retrieve their report on their personal page on the HQ website and to evaluate additional "what-if" scenarios.

As of August 2007, over 835 000 diagnostic surveys have been completed by HQ customers. Over 20 % of those were completed via the internet where the rate of completion has been more than 70 % (which means that for over 245 000 customers who began to answer diagnostic questionnaire on internet, more than 70 % completed it). This is a very high rate of completion for an internet survey. Based on a separate HQ survey to measure the impact of the "Home Wise Diagnostic", Hydro-Quebec estimates an average gain in 2007 of 309 kWh for each survey completed. This brings the total savings to 270 GWh since the beginning of the program. In addition, the "Home Wise Diagnostic" report provides an effective means to promote other HQ programs.

As an example of model accuracy, Figure 4 shows the warning note frequency according to dwelling consumption. As previously explained, a warning note appears on a report if the unassigned consumption is outside an acceptable rate called the "comfort zone." [3]. The warning note frequency is low for dwellings with consumption between 20,000 and 35,000 KWh, which represents the typical consumptions of a single family dwelling that is electrically heated. Warning note frequency tends to increase for lower consumptions, because the "comfort zone" is smaller since it is based on a percentage of total consumption. In addition, low end and high end customer consumption may be the result of a non-typical consumer.

[3] The Comfort zone has been defined has an unallocated consumption of 10 % to -3 % of customer electric consumption, except for very small consumer for which we use a comfort based on absolute value of 300 to -300 kWh

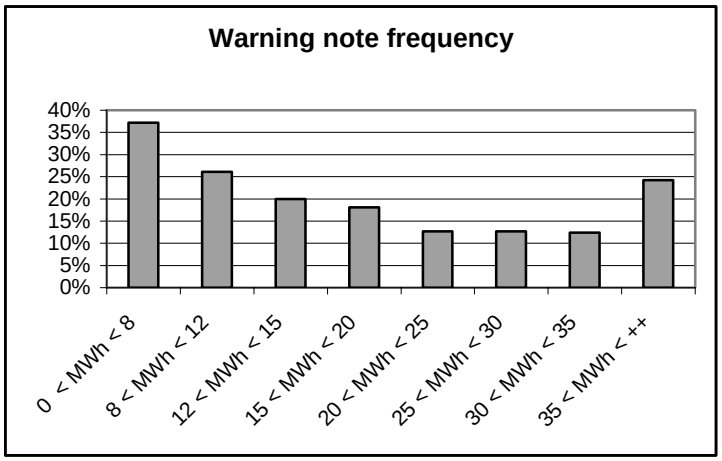


**Figure 4:** Warning note frequency according to dwelling consumption

Figure 5 shows the relationship between the warning note and the PRISM model fit statistic. We can see that the higher this correlation value, the better the model performs thus there is less unassigned consumption and therefore fewer warning notes. This tends to show the importance of utilizing a statistical model in the estimation of home heating loads in a northern climate.

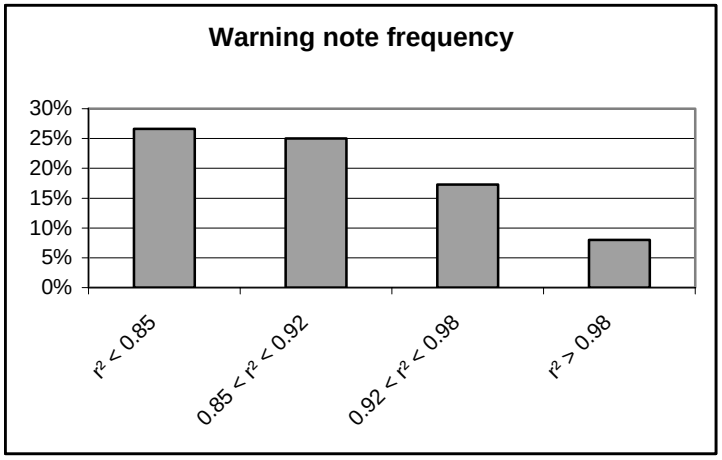


**Figure 5:** Warning note frequency according to quality of PRISM correlation

# Conclusion

This paper presented a software tool implemented to assist customers to better understand their energy consumption. Starting with specific constraints, the development process resulted in a sophisticated tool capable of providing accurate information to customers, including the cross effect on heating. Valuable recommendations are provided to customers to assist in the reduction of their energy consumption. At this time, results obtained by the program are quite impressive and meet the expectations of Hydro-Québec, as well as Régie de l'énergie of Quebec.

## References

Fels, M.; *Measuring Energy Savings: The Scorekeeping Approach*, Special PRISM Issue or Energy and buildings, 9, #1-2, 180 pages [16 papers describing background on PRISM and sample applications; 1986]

Smith, S. and Trumble, D.A. "Empowering Customer Energy Choices With the World Wide Web," paper presented at DA/DSM DistribuTECH '98; January 13-15, 1998; Tampa, Florida.

Smith, S. Thompson, J.L, Trumble, D., and Thieken, J.S. "Salt River Project's Web-based Residential Energy Audit Program for a Deregulated Utility Market Place," paper presented at DistribuTECH '99; February 1999, San Diego, California.

Violette, D., 1993, "Statistically Adjusted Engineering Estimates," in *Proceedings of the 1993 International Energy Program Evaluation Conference*, IEA.