HOT2.XP: ENERGUIDE FOR HOUSES AND THE NEW HOUSING MARKET

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ABSTRACT

This paper presents the use of HOT2-XP[1] within a 1999 pilot project sponsored by Natural Resources Canada (NRCan), which involved the evaluation and energy rating of 64 new homes in Ontario according to the EnerGuide[2] for Houses Procedures and Guidelines [1].

Prior to the introduction of the EnerGuide for Houses Program, the only formal method for assessing the energy efficiency of new housing was the R-2000[3] Design Approval Procedures and Guidelines [2]. These were tied to the R-2000 Program criteria and relied on a detailed assessment of house characteristics using HOT2000[4]. HOT2.XP was developed as a derivative of HOT2000 for use within the EnerGuide for Houses Program, aimed initially at improving the energy efficiency of older homes. The Ontario pilot project studied the utility of HOT2.XP in capturing the energy rating of new homes at the pre-construction stage.

The core of this paper explores the variation of EnerGuide ratings among typical new homes, and the differences in ratings between pre-construction and post-construction assessments. The sensitivity of airtightness and solar orientation to the house rating are also discussed. Assessments of the utility of HOT2-XP solicited from the pilot project design evaluators are also discussed. The paper concludes with key recommendations for maintaining energy simulation software integrity within the context of consumer information needs and builder marketing realities.

[1] HOT2.XP is a new member of the HOT2000 family of energy analysis software developed by CANMET Energy Technology Centre, NRCan.

[2] EnerGuide is an energy labeling program administered by the Office of Energy Efficiency, NRCan.

[3] R-2000 is a super energy efficient home program sponsored by NRCan since 1982.

[4] HOT2000 is an energy analysis and design software for low-rise residential buildings developed by CANMET Energy Technology Centre, NRCan.

INTRODUCTION

The EnerGuide for Houses Program seeks to improve the energy efficiency of housing in the marketplace by providing an accurate and effective means of rating the energy efficiency of houses. The EnerGuide ratings for household appliances and energy conversion equipment are familiar to consumers, and a rating system for houses represents a logical extension of information that enables informed decision making by homebuyers.

Initially, the EnerGuide for Houses Program was targeted at existing homes, most of which were significantly less energy efficient than homes currently constructed across Canada. This pilot project was intended to apply program guidelines and procedures to the new housing market to assess its suitability.

The pilot project was limited in scope and confined to new housing in Ontario. While a specific number of homes was not targeted, the intent of the project funding was to maximize the number of houses receiving EnerGuide labels. Based on the available funding and the willing cooperation of Ontario builders, a total of 64 houses were evaluated and assigned energy ratings according to EnerGuide procedures. The houses ranged in location, size, style and market segment, and fairly represent the current mix of new housing in Ontario.

TERMINOLOGY

In this paper, the terms "label" and "standard" are used according to the following definitions:

Labels are markings, with supporting promotion and directories, which show products' energy use or efficiency according to a common measure. The EnerGuide for Houses rating is a label

Standards are mandatory programs (regulations) stipulating the minimum efficiency levels or maximum energy-use levels acceptable for products sold in a particular country or region. Minimum requirements for energy efficiency prescribed in the Ontario Building Code represent standards.

METHODOLOGY

This project was managed by EnerQuality Corporation, an authorized agent of Natural Resources Canada, and involved its network of builders and quality assurance evaluators (QAEs). The recruitment of builders came from within EnerQuality Program members, and involved extensive efforts due to the unusually high levels of residential construction activity across most of Ontario. Request for proposals were forwarded to QAEs across Ontario to obtain quotations for conducting EnerGuide evaluations on a per-house basis. The most competitive quotations were used to match QAEs with willing builders to the extent made possible by available funding.

The pilot pool of builders and QAEs were provided with applicable EnerGuide procedures and guidelines during an orientation workshop in July 1999. Subsequently, the construction, evaluation, site visits and airtightness testing were carried out for the sample of 64 new homes.

Documentation of the evaluations was forwarded to EnerQuality Corporation for review, summarization, and submittal to NRCan for the issuing of EnerGuide labels.

EnerGuide ratings for each of the 64 houses were obtained using the HOT2.XP software and associated evaluation procedures established by Natural Resources Canada.

HOT2.XP evaluation criteria were established by Natural Resources Canada corresponding to assessment scenarios which were investigated to determine:

i. the voluntary energy efficiency improvements found in typical new housing which exceeded 1997 Ontario Building Code (OBC) minimum requirements for energy efficiency (both for the building envelope, and energy conversion equipment, such as furnaces and water heaters);

ii. the sensitivity of the EnerGuide energy ratings to envelope airtightness levels; and

iii. the sensitivity of the EnerGuide energy ratings to the solar orientation of the building.

In order to efficiently assess the variables, QAEs were instructed to perform HOT2.XP simulations involving 7 separate cases, as described in Table 1.

CASE	HOT2.XP EVALUATION CRITERA
1	OBC minimum energy efficiency requirements + HOT2.XP default blower door value (3.57 ach @ 50 Pa)
2	Actual levels of energy efficiency + HOT2.XP default blower door value (3.57 ach @ 50 Pa)
3	Actual + "as operated" blower door test (as per *EnerGuide* procedures)
4	Actual + CGSB procedure blower door test
5	Actual + "as operated" + vary orientation (cardinal direction)
6	Actual + "as operated" + vary orientation
7	Actual + "as operated" + vary orientation
CGSB - Canadian General Standards Board. [3] **Note:** Case 2, blower door values depend upon values specified in the structures library.	

Table 1 HOT2.XP Evaluation Criteria for 7 Cases Assessed in Pilot Study

In all 7 cases, the EnerGuide rating (ER) was derived according to the following equation:

$$ER = 100 - \frac{\text{Estimated Energy Consumption}}{\text{R-2000 Energy Target}} \times 20$$

When the energy consumption of a constructed home is estimated above the R-2000 energy target, its rating falls below 80. If the estimated energy consumption is equal to that of the R-2000 target, the rating is exactly 80. As the estimated energy consumption decreases below the R-2000 target level, the energy rating increases beyond 80 to the point where a home with zero purchased energy consumption attains a rating of 100. Typical energy ratings for Canadian housing stock are listed in Table 2.

TYPICAL RATING	HOUSE CHARACTERISTICS
0 to 50	Old house not upgraded
51 to 65	Upgraded old house
66 to 75	More energy efficient upgraded old house or typical new house
68 to 82	Energy efficient new house
80 to 90	Highly energy efficient new house
91 to 100	Approaching zero purchased energy house
Source: Office of Energy Efficiency, NRCan.	

Table 2 Typical EnerGuide Ratings for Canadian Houses

RESULTS

The data in Table 3 reflect the 7 simulation cases described in Table 1, and represent the summarized EnerGuide ratings data for the 64 houses assessed in the pilot project. Due to space limitations, these data have not been included in this paper, but are available in the final report to this project [4].

	ENERGUIDE ASSESSMENT CASE						
	1	2	3	4	5	6	7
Avg.	68	74	74	74	73	73	74
Min	58	69	69	69	69	69	69
Max	77	82	82	83	82	82	82
St. Dev.	3.08	2.38	2.49	2.69	2.53	2.61	2.60

Table 3 Summary of EnerGuide Ratings Corresponding to 7 Assessment Cases for 64 Pilot Project Houses

The data from the computer simulations were also used to derive the level of energy efficiency improvements beyond minimum levels prescribed in the 1997 Ontario Building Code for the sample of 64 pilot study homes. In addition, an assessment of the current level of the sample homes' airtightness was performed.

The results have been summarized in Table 4 according to the following parameters:

OBC '97 - the estimated annual energy consumption of each home assuming it was constructed to the minimum levels of energy efficiency prescribed in the 1997 Ontario Building Code;

ASOP - the estimated annual energy consumption of each home given its actual as-built condition;

CHANGE – (GJ) the improvement in GJ/year between the minimum and actual levels of energy efficiency, and (%), the percentage improvement beyond the minimum levels of energy efficiency prescribed in the 1997 Ontario Building Code; and

ASOP: ACH @ 50 Pa - the measured airtightness of each home based on the "as operated" blower door test required under EnerGuide procedures.

This information was processed in order to gain an estimate of the energy savings captured by energy labeling of voluntary energy efficiency improvements, and to compare HOT2.XP default airtightness levels with those measured in the field.

	OBC '97	ASOP	CHANGE		ASOP
	(GJ)	(GJ)	(GJ)	%	ACH @ 50 Pa
Avg.	**202.7**	**165.3**	**37.4**	**18.4%**	**3.81****
Min	110.6	89.4	-29.5*	-26.7*	1.17
Max	317.2	226.6	152.6	53.5	13.20
St. Dev.	40.76	30.39	27.43	11.1	1.66

* One anomalous house was tested to an airtightness of 13.2 ach @ 50 Pa, resulting in a difference in rating of 8 points on the EnerGuide scale.

** Removing this anomaly from the sample translated into an average airtightness of 3.66.

Table 4 Comparison of Simulated Energy Performance of 64 Pilot Study Houses

Based on the evaluations of the 64 homes in the pilot study, several significant findings emerged:

1. The lowest actual rating among the 64 homes was 69, and the highest rating was 82.
2. The voluntary levels of energy efficiency improvements evidenced in this pilot study translate into an average improvement of 6 points on the EnerGuide rating scale beyond the average energy efficiency rating of 68 for the minimum requirements prescribed in the 1997 Ontario Building Code.
3. The estimated average annual energy consumption of the pilot study homes, assuming they were constructed to OBC minimum levels of energy efficiency, was 202.7 GJ/year. The estimated average annual energy consumption of the actual, as-built condition was 165.3 GJ/year. This average difference of 37.2 GJ represents a 18.4% improvement over minimum levels of energy efficiency. The maximum individual difference observed between the OBC base cases, and the as-operated cases, was 152.6 GJ, a 53.5% improvement.
4. The average airtightness levels in the 64 homes was 3.81 ach @ 50 Pa, compared with the HOT2.XP default value of 3.57 ach @ 50 Pa. The averaged measured airtightness, when corrected for explainable anomalies, was 3.66.

5. The EnerGuide for Houses rating for airtested houses in the "as operated" condition, and those that were evaluated using the HOT2.XP default airtightness of 3.57 ach was virtually identical when comparing ratings across the 64 homes in the pilot study. Of the 64 sets of ratings, 41 (64%) were identical, with 60 (94%) having a difference in rating of 2 or less. The maximum deviation, discounting anomalous data, was 3. This suggests that the difference between default and measured levels of airtightness in new housing does not significantly affect the EnerGuide for Houses rating.

6. The average difference in energy consumption when considering HOT2.XP default airtightness levels versus actual, "as operated" airtightness levels is 0.52 GJ/year, representing less than 1% of annual energy consumption. For any individual building, the maximum difference was 19.5 GJ representing 10% of annual energy consumption, well within the 15% tolerance permitted by the EnerGuide for Houses Technical Guidelines.

7. The differences between ratings due to the effect of orientation for the pilot study homes was insignificant owing to a tendency of these house designs to disregard passive solar potential.

These findings were derived directly from the data appearing in Tables 3 and 4, except for the results discussed in Item 6 above, which were derived from the complete data set appearing in the study report.

ANALYSIS

A number of issues emerged from the findings of this pilot study. These can be categorized as issues relating to the utility of HOT2.XP software, and issues relating to the EnerGuide for Houses Program. The two are interrelated insofar as the results obtained from the HOT2.XP analysis are used to derive an EnerGuide for Houses rating. The utility of the HOT2.XP software should not be confused with consumer and builder perceptions of the EnerGuide ratings. This becomes obvious when the numerous physical measures provided by the software are compared to a single non-dimensional measure.

The issues related to software integrity, accuracy of simulation tools for house energy rating systems (HERS), and the suitability of HOT2.XP are explored later in this paper. The next section of the analysis deals with HOT2.XP as a home energy rating system evaluation tool

Technical Evaluation Using HOT2.XP

HOT2.XP is an express version of HOT2000 which embodies similar modeling capabilities, including:

- Above and below grade envelope heat transfer (opaque and transparent elements);
- Air leakage and ventilation energy loads;
- Solar and internal gains;
- Space and domestic water heating equipment performance; and
- Energy use for appliances and lighting

It is important to note that the HOT2.XP below-grade heat loss modelling capability is not as sophisticated as that provided within HOT2000, however, it is sufficient to accurately model typical basements in older houses.

From a practical perspective, quality assurance evaluators reported difficulties deploying the HOT2.XP software, particularly in the case of less conventional house designs. In comparisons with HOT2000, QAEs indicated that the HOT2.XP software lacked the robustness needed to deal with unusual conditions, especially basement configurations. In general, HOT2000 was preferred by this group - an understandable finding given the many years of experience each evaluator has had with the HOT2000 software. (It is interesting to note that R-2000 Program experience indicates an initial level of resistance to the adoption of new versions of HOT2000 since the 1980s.)

A key observation echoed by most of the QAEs was that the use of HOT2.XP did not appreciably reduce the time, and hence the cost, of performing the technical evaluation. The data requirements for modeling new houses are virtually identical within the EnerGuide and R-2000 Programs, hence the express features geared towards existing homes, which are measured in the field and not from plans, provided no appreciable benefit for new home applications.

A key suggestion for improving HOT2.XP utility within the new home sector of the EnerGuide for Houses Program was to enable HOT2.XP to generate room-by-room heating/cooling load calculations, or to accept inputs from other heating/cooling load calculation software. Heating/cooling load calculations are now required by most Ontario municipalities' building departments prior to issuing permits. Development of a multi-functional tool would better serve the interests of regulatory authorities, mechanical contractors, quality assurance evaluators and the EnerGuide for Houses Program. Issues related to the EnerGuide rating system are now presented within the context of HOT2.XP evaluation.

Airtightness Testing

As previously discussed under the results of the pilot study, changes in airtightness levels within the normal range achieved by Ontario builders in new houses, did not significantly affect the EnerGuide rating. It is important to appreciate that within the existing home market, air sealing and weatherization represent cost effective improvements to the energy efficiency of the home with a correspondingly significant improvement in the EnerGuide rating.

The increased potential for interstital condensation problems leading to degradation of wood-frame house structures is well understood for homes employing high levels of cavity insulation [5]. This aspect of envelope integrity is guarded by stringent airtightness requirements in R-2000 homes. Earlier studies of airtightness levels in Canadian housing, and this pilot study, indicate that new homes are being constructed with higher levels of airtightness [6]. However, the energy implications of airtightness between R-2000 levels, and those evidenced in typical new housing, are not significant. During evaluations of new houses at the design stage, the validity of the HOT2.XP software may be mistakenly questioned by builders who cannot see an appreciable difference in EnerGuide ratings associated with improved airtightness measures. Failure by the rating system to recognize practices, employed for reasons of envelope durability and integrity, conflicts with builder perceptions of the super energy efficient status of R-2000 homes. As a result, confidence in the evaluation software may become eroded among new homebuilders. The relationship of airtightness to envelope integrity, and hence embodied energy, deserves further examination. The energy implications of poorly performing building envelopes are significant when considering repair of defects and possibly retrofit of moisture damaged envelopes. Economic implications to homeowners can easily dwarf the cost of purchased energy. To paraphrase the R-2000 program, perhaps the EnerGuide for Houses rating should be more than operating energy efficiency.

Unrelated to the software, but impacting the EnerGuide program within the new housing market, is the cost effectiveness of mandatory airtightness testing. The testing accounted for between $250 and $300 of the total $450 cost for each house rating assessment, and did not seem to significantly affect the rating when compared with use of the default blower door airtightness of 3.57 ach @ 50 Pa. Again, within the existing home market, airtightness testing is useful in identifying sources of air leakage, as well as confirming the quality of air sealing, but its usefulness within the new home market was questioned.

The requirement to perform an airtightness test caused logistical problems in terms of coordination with builders to ensure that the house was suitably complete to perform a meaningful test. Unlike site visits, which are intended to confirm as-built with submitted plans and specifications, and offer a much wider window of time, airtightness testing requires that the house is substantially complete - shortly thereafter it becomes occupied, hence the window of opportunity is significantly narrower.

QAEs reported that the simplified EnerGuide blower door test procedure was not significantly more economical than the CGSB method, and in general, airtightness testing was seen as a major barrier to widespread uptake of the EnerGuide labeling program within the pilot study participant markets.

Clearly, a qualitative correlation between airtightness and envelope integrity should be provided within the HOT2.XP software to offset views that improved airtightness does not provide homebuyers with added value beyond energy savings alone.

Passive Solar Opportunities

Historically, one of the major advantages of computerized energy evaluation tools has been the ability to predict the utilization of passive solar gains. HOT2.XP provides an accurate and reliable solar utilization model inherited from HOT2000.

An interesting relationship identified in the study involved the absence of passive solar opportunities captured by the sample of houses. Varying the solar orientation of the sample houses did not significantly change their EnerGuide ratings.

Acknowledging that this issue does not directly involve HOT2.XP, it appears from the study that energy efficiency improvements related to passive solar opportunities have not been influenced by this or any other any energy evaluation tool. This suggests that unlike the existing home market sector where solar orientation and fenestration are practically fixed, the EnerGuide Program should seriously consider the active promotion of HOT2.XP as a passive solar optimization tool within the new housing market. This is especially important in view of Canada's commitment to reductions in greenhouse gas emissions.

Issues related to airtightness and passive solar heating afford interesting perspectives on the inherent limitations of energy simulation software and the under-utilization of full software capabilities. As such, HOT2.XP accurately and reliably generates data which is often more sophisticated than the information demands of the new housing market.

DISCUSSION

A recent International Energy Agency publication entitled *Energy Labeling and Standards* [7], has identified the key elements of successful labeling and standards programs as being:

- coherent packages of multiple policy instruments;
- open, transparent and systematic program development procedures -- with extensive stakeholder consultation and thorough engineering and market analysis;
- program elements that reflect product and market realities; and
- solid program credibility -- including conformity assessment and enforcement and program evaluation activities.

The importance of these elements was validated during facilitation of a consumer focus group forming part of the pilot study. EnerGuide for Houses represents an evolving energy labeling program for Canada's low-rise residential buildings, and continues to address each of the key elements listed above. Program credibility is largely founded on the integrity of the HOT2.XP software and accompanying technical guidelines which are intended to reasonably minimize the risk of an inaccurate home energy rating system (HERS).

"*Another form of risk is the risk that HERS will suffer serious and long-term credibility problems if consumers, builders, lending institutions, funding agencies or other stakeholders conclude that HERS are significantly less accurate than they were led to believe*." [8]

The accuracy and reliability of energy modelling capabilities within HOT2.XP, which is derived from HOT2000, is well validated [9], and generally exceeds the margin of error evidenced in construction practices. However, the technical complexity and sophistication of the measures generated by the software, and the non-energy efficiency implications of the data, require effective communication coupled to extensive consumer and builder education. This current situation is perhaps best illustrated by considering builder interpretations of the EnerGuide rating generated by HOT2.XP.

Some confusion was evidenced as to what the EnerGuide for Houses rating actually measures. Presently, the estimated annual energy consumption associated with the building envelope, energy conversion equipment, appliances and lighting is related to the R-2000 energy target. However, new homebuilders wish to have the energy efficiency of their houses distinguished by the quality of the building envelopes they construct. All of the equipment and appliances they, and/or the homebuyers, supply already bear EnerGuide labels, hence the clarity of the house energy rating has been questioned. It may be more meaningful to relate annual energy demand, accounting for solar and internal gains, to the R-2000 energy demand when deriving the energy rating. Again, HOT2.XP is sufficiently flexible to separate these parameters to readily calculate an energy rating which best reflects market realities and stakeholder interests.

CONCLUSIONS

The following conclusions emerged from the pilot study:

1. Consumers and builders value and respect the credibility associated with NRCan's EnerGuide label. It is viewed as providing a high level of assurance in the marketplace.
2. The present EnerGuide for Houses procedures and guidelines are viewed by builders and quality assurance evaluators as requiring modification, and some streamlining for integration within day-to-day business practices.
3. Consumers are very positive about the EnerGuide label, but somewhat confused about its meaning and interpretation. Builders see potential value in an energy label, but remain concerned that the EnerGuide label may be misunderstood within the marketplace. Both stakeholders believe these issues can be constructively addressed.
4. The sensitivity of the EnerGuide rating scale does not appear to reflect many significant energy efficiency improvements, especially airtightness, and builders have reported that it could serve more as a disincentive if the rating leads to less differentiation in the marketplace.
5. Suggested improvements to HOT2.XP represent less formidable challenges than those associated with the development of ratings that not only reflect market and product realities, but also consistently communicate their meaning to consumers. HOT2.XP software remains well positioned to accommodate the evolution of the EnerGuide for Houses Program development.

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