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Comparing HOT2000 results to actual, metered data

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You have been using HOT2000 to determine if house designs meet the R-2000 energy target and have always believed that it does a good job. One day you decide to model your own home and compare the results to the utility bills. You find that the predicted and measured energy usage differs by a significant amount! Does this sound familiar? What's going on? Why the difference?

Does this mean the utility meters are no good (*unlikely*); that you don't know how to perform take-offs (*shudder*); or that HOT2000 is no good (*shriek*)? Don't panic. There are a number of reasons why HOT2000-predicted energy consumption may differ from utility-measured consumption. Most of these are not caused by HOT2000 but in the way the house is interpreted by you, the user, for input to the program.

The same issues are applicable with any energy analysis program. Some utilities have their own in-house programs that are claimed to be more accurate, but what they've done is put in some general 'fudge' factors based on system wide averages to make the results tie in with what they see on their billings.

Before we explore these issues, it is important to distinguish between compliance testing and actual house modelling. When HOT2000 is used for R-2000 compliance testing, standardized default values are required for things like interior temperatures, base loads, weather, etc. to permit a fair comparison between the house and target. When modelling a real house, these default values are no longer appropriate; actual values must be used.

This is a brief description of some of the reasons why actual, measured energy usage data and HOT2000-predicted results can differ.

1. Actual vs. Long-Term Weather

HOT2000 uses 30 year (1951-1980) average weather data which is supplied with the program. It consists of mean monthly values for air temperature, solar radiation, wind speed, etc. When determining compliance with the R-2000 energy target, these are appropriate since the average performance of the house is desired, not that during one specific year. However, if you are comparing actual to modelled performance, then real weather data for the monitoring period must be used.

2. Actual Appliance Loads, DHW Usage and Metabolic (people) Gains

This can be a big one. Indoor appliances, domestic hot water and people all give off significant amounts of heat which reduce the space heating load. Unfortunately, the magnitude of these base loads varies tremendously between houses and is largely determined by lifestyle. They are also difficult to predict.

A house owned by a bachelor, who spends most days at work and most nights roaming the streets looking for trouble, will receive little free gains. Now consider the house next door, which is otherwise identical, but occupied by a family of eight whose hobbies (and supplementary income sources) are bathing baking and ironing. The base loads in the latter dwelling might be five to ten times those of the bachelor's place. To model an actual house, realistic estimates are required for the base loads.

3. Supplemental Heating

If you have supplemental heating such a wood stove, it can make a huge contribution towards the gross heating load and must be accounted for prior to the HOT2000 analysis. One of us recently completed a study in which HOT2000 was used to model a number of houses which had been monitored at the utility meter level. Several of these contained wood heaters of various types. Using homeowner-reported wood usage data, we estimated that about 25% of the total energy load was supplied by the wood heaters.

4. Interior Temperatures

What temperature is your house really kept at? HOT2000 requires two interior air temperatures to be entered: the main floor(s) and the basement (or crawl space). A small error here can have a big effect. For example, we took a typical Winnipeg house file and reduced temperature by 4°C from the R-2000 default values of 21°C and 18°C to account for night setback and the three weeks the owners spend every January getting skin cancer in Jamaica. The effect was 26% reduction in the space heating load.

To simulate an actual house, the temperatures entered into HOT2000 should be "effective" values which include the time-weighed effects of night set-back, weekend and holiday setback, zoning (i.e. keeping different areas of the house at different temperatures) and horizontal and vertical stratification (an important issue for poorly insulated houses). In most cases, the "true" effective temperature is quite different from the thermostat setting.

5. Exterior Shading

HOT2000 assumes that the house is totally unshaded by exterior trees, buildings, mountains, urban sprawl and low-flying aircraft, i.e. it is plopped down in the middle of an infinitely large, flat piece of real estate where every bit of solar radiation which can reach it does reach it. You may say that can't be correct since the program asks the user to input the percentage of south-side obstructions. Want to know a secret? Nothing is done with that number. It is used for documentation purposes only but does not affect the calculations. Prove it to yourself by taking a house file, adjusting the south-side shading and watch the change in the space heating load.

6. Interior Shading of Windows

Interior shading devices such as venetian blinds, drapes, etc. can increase or decrease the heating load depending on their usage. If they are closed during the day, they will reduce the solar gains by reflecting a portion of the incoming solar radiation back outdoors and by absorbing some of the radiation, thus heating the air next to the window thereby increasing the temperature difference across the window and hence increasing the heat loss. If closed at night, shading devices will reduce heat losses. HOT2000 assumes there is no interior shading.

7. Adjacent Structures

This one is a problem for poorly insulated houses, especially those in older neighbourhoods where the houses may only be a few feet apart. HOT2000 assumes that the house is stuck in the ground with no other buildings nearby. However, if a heated dwelling is located beside the house being modelled, below-grade heat losses from your house will be reduced courtesy of the adjacent structure. The neighbour's house will conduct heat to the soil between the two structures which will raise its temperature which will in turn reduce the below-grade losses from the house being modelled.

8. Nominal R-Values

Nominal R-values are used to speed up take-offs by allowing the plans examiner to assume that the effective thermal resistance of a built-up assembly is equal to the R-value of the insulation. The effects of thermal bridging, series and parallel heat flow paths, interior and exterior surface films, etc. are all lumped together by this assumption. For well-insulated assemblies this may not be a perfect solution, but is not bad. The problem occurs with low R-value components such as those in older houses.

Consider an uninsulated above-grade basement wall, 200 mm (8") thick. What is its R-value? The nominal R-value would be zero since there is no insulation. If you enter "0.0" into HOT2000, it will change that value to RSI 0.2 (R-1.1) for calculation purposes and the heat loss through the basement will be huge.

What is the true R-value? The heat flow phenomenon is quite complex involving two or three-dimensional heat flow, thermal storage, the effects of snow against the wall, the presence of cast-in-place framing members, etc. We developed a calculation procedure for analyzing basements which considers some (not all) of these factors and found that typical RSI values (for our example) would range from about 0.6 to 1.0 (R-3.4 to R-5.7). If the "correct" value were (say) RSI 0.6 and you were using RSI 0.2, the predicted heat loss would be 300% of actual.

9. Snow

Snow is an insulator. When it collects beside a basement wall or on an unvented roof, it will reduce heat losses. For a well-insulated cathedral ceiling, the effect is minor but for a poorly or uninsulated basement wall the presence of snow could double the effective thermal resistance. The problem is that the coverage and thickness of snow varies and is difficult to predict, but still has to be considered when modelling real houses.

10. Heating System Efficiency

What is the seasonal efficiency of the heating system (and the DHW system for that matter)? In houses with electric resistance heating, the efficiency can safely be assumed to be 100%. High efficiency gas furnaces operate with efficiencies of 90% to 94% while mid-efficiency units run at about 80% to 82%. With older, low efficiency units, there is a bigger variation in performance. Assuming 60%, when the correct value is (say) 55% will introduce a 9% error in the predicted space heating load.

11. Ventilation System Utilization

The ventilation rate entered into HOT2000 is used to calculate the heat loss due to mechanical air change rate based on 24 hour/day operation. Real-world ventilation rates can be very different. During the Flair Energy Demo project in Winnipeg, we measured how often people used their ventilation systems over a three year period. We found that HRVs were used an average of 19 hours per day, so if you assumed continuous operation, you wouldn't be too far out. Central exhaust systems, however, were operated an average of only 37 minutes/day giving effective rates of less than 2 l/s.

12. Natural Air Infiltration

The airtightness of older houses is much more variable than that of R-2000 construction. The default airtightness levels in HOT2000 provide reasonable averages but the value for your house can be substantially different. Preferably, an airtightness test should be performed on the house if you are attempting to model it.

13. Utility Bills

This one is a little different. Utility meters are usually read every one or two months even though you may be billed every month. Between readings, the utility may estimate your consumption based on historical patterns and the weather during the billing period. If you are comparing HOT2000 against your bills, make sure you are using actual, rather than estimated, meter readings. Also, note the exact dates of the meter readings since they vary by a few days from month to month which may require some correction to your "actual" data. Finally, on rare occasions, meter readings can also be in error, so be careful.

What does it all mean?

1. HOT2000, like all energy analysis programs, is only as accurate as the assumptions used to generate the input data. Bad assumptions mean poor results.

2. To accurately model a real house, you need good estimates for all the inputs normally handled with default values for R-2000 compliance testing. This includes: interior temperatures, base loads, weather, supplemental heating, mechanical ventilation rates, heating system efficiencies, etc. House modelling requires a lot more information, interpretation and skill than compliance testing.

3. It is generally more difficult to accurately model a poorly insulated, leaky house with an old heating system than a well-insulated, tight dwelling with a heating system of known efficiency.

Explaining the House as a System

Are you having a hard time closing a deal for an R-2000 upgrade? Your customer just can't see why they should pay the extra $3,500 for something they can't see- but will spend the money on a hot tub outside, and a marble entry foyer?

The problem may be how to present the "*house as a system*". An interesting way of doing this was noted in a recent copy of B. C. Hydro Power Smart Home Improvements Program notes. They suggest you use "body parts" as terms when explaining the *House As A System.*

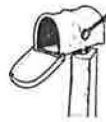
All body parts have to be there for it to work - even if some are more expensive. You don't use lots of kidneys just because they are cheap and refuse to use a heart just because it's expensive!

The point to stress is that it's necessary to cut down on energy needs first - then make the supply of energy appropriate.

The point to make when decisions have to be made is: if you can't afford to do it right the first time, then how come you can afford to do it twice?

(It's not far fetched - as you'll pay higher utility bills and for retrofits later on.)

Letters to the Editor



Sir,

I enjoyed the Water Conservation article in your Oct/Nov issue (Solplan Review No. 53). I was recently looking for a 6-litre flush toilet and was disappointed by the low level of knowledge or interest by the wholesalers and manufacturer's sales staff. The best source/supplier of all turned out to be the local Home Hardware store, which retails the Western Potteries Model ARIS 822 for $159.

In my experience it has proved to be a better toilet than the Eljer Ultra 1.5G (no lined tank, poor flush) and the American Standard Ensign (no lined tank). American Standard and Eljer maintain that the tanks don't have to be lined but they're wrong. In Guelph, in the summer and fall, those tanks sweat. The Western Potteries toilet has a lined tank, a gravity flush ballcock mechanism (simple), and an amazing flush. Stand back, children! And its about $75 less than the others (retail)

The major manufacturers and wholesalers had better start listening to what knowledgable people are saying; until then, I'm not specifying their products.

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