Housing and Society
Vol. 15, No. 1, 1988

An Extension Note on:

THE HOME HEATING INDEX

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ABSTRACT

The Home Heating Index (HHI) is a single number that characterizes the energy efficiency of a home or other dwelling unit during the winter heating season. It can be determined quite easily for existing homes from energy records and weather data. It can also be predicted for unbuilt homes from their designs. Random surveys of homes in Iowa show that the HHI ranges from under 3 to over 21 BTU/degree-day per square foot of the heated floor area of a home. An Extension Service questionnaire and a computer program with weather data for several winters have enabled members of the general public to determine their homes' HHI. The state of Iowa recently incorporated the HHI into the energy portion of its building code.

INTRODUCTION

One result of the dramatic increases in energy prices over the past decade is that most consumers now pay more attention to energy efficiency when purchasing many items. Whether the selection is a new car, a room air conditioner, a replacement furnace or even a light bulb or electrical appliance, consumers often want to know how much energy an item will use and how costly it will be to operate. This information is not necessarily the most important factor in a purchasing decision, but it often plays a significant role.

It is very helpful to the average consumer in making a wise energy decision to have a simple measure of energy consumption, such as the miles per gallon rating for a car or the fuel efficiency rating of a gas furnace. Table 1 lists several examples of useful available energy-efficiency measures.

There is, however, one conspicuous absence from this list--a measure of the energy efficiency of an entire house. Most of the energy used in a home on an annual basis is used for heating and cooling. In Iowa, as in many other parts of the United States, home owners are primarily concerned about heating costs. Nationwide, space heating is the second major energy use by families (after gasoline use in automobiles). In the northern states, space heating is sometimes the top user of energy. It is, therefore, unfortunate that no good measure of a

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home's heating energy efficiency has been available.

Table 1. Common Measures of Energy Efficiency or Consumption

Energy use	Measure
Motor vehicles	Miles per gallon
Room air conditioners	Energy Efficiency Ratio (EER)
Central air conditioners	Seasonal EER
Refrigerators and freezers	kWh per month
Natural gas furnaces	Annual Fuel Utilization Efficiency
Light bulbs	Lumens per watt

THE HOME HEATING INDEX (HHI)

Interest in the problem of assessing a home's heating energy efficiency started in 1980 when Iowa Extension specialists were advising clientele about energy consumption and solar energy. Many of the home owners seeking advice were considering the purchase of a solar heating system. In the course of the consultations, it was often discovered that the home owner had not done a good job of caulking and weatherstripping or of adding insulation to the home. Because these ordinary energy conservation measures are usually more cost-effective than solar energy, it was felt that an energy-efficiency index for homes would be helpful. Such an index could be used to identify those homes that needed energy conservation improvements.

Several measures for determining and expressing a home's energy efficiency exist in the literature. One example is the Thermal Integrity Factor. All such measures were rejected as unsuitable, however, because they do not give consistent results from year to year or do not consider the energy implications when a family with a different lifestyle moves into a home. A new measure, Home Heating Index (HHI) was, therefore, developed.

The HHI is a single number that ranges from under 3 for the most energy-efficient homes to over 20 for extremely energy-inefficient homes (see Table 2.) Most homes have an HHI between 5 and 10.

Because it is a single number, the HHI can be easily remembered and easily compared with the HHI of other homes. It is a characteristic of the home itself, independent of the occupants' habits and the heating system efficiency. The Home Heating Index (HHI) and a related measure, the Home Heating Requirement (HHR), can be determined for existing homes from their energy records and can be estimated for unbuilt homes from their construction drawings and energy features.

For an existing home, the HHI is calculated as follows:

1. From utility bills or other records, the energy brought into and used in the home during mid-winter (December through February) is determined---natural gas, electricity, wood, propane, fuel oil, or whatever else is used. Each energy source is converted into British thermal units (Btu) using appropriate heat conversion factors (such as 3412 Btu per kWh of electricity or 135,000 Btu per gallon

Table 2. Values of the Home Heating Index

20	Extremely energy inefficient, such as a mobile home with very little insulation
15	Energy inefficient, characteristic of poorly-insulated single-family homes whose owners have little in the way of energy conservation improvements
10	Typical of many existing homes, but worse than average; probably close to the average of all homes in the early 1970s
8	Average in early 1980s of existing homes of all types in Iowa
5	Reasonably energy efficient, either a well-insulated new home or an older home whose owners have done an excellent job of retrofitting it for energy efficiency
2-4	Extremely energy-efficient; typical of the most efficient new homes, such as those combining good insulation and passive solar heating

of kerosene). Efficiency factors are applied when appropriate. For example, in a home with an 80-percent efficient gas furnace, the conversion factor for natural gas is abut 80,000 Btu per CCF (Btu per one hundred cubic feet). The reason for including all energy sources and applying efficiency factors is to determine the total amount of heat supplied to the interior of the home during those three months, excluding heat lost up the flue which does not contribute to interior warmth.

2. The total Btu from step 1 are divided by the total number of heating degree-days (DD) for the same period of time (which might differ for different energy sources). The degree-days are obtained for each day by subtracting the average outdoor temperature from the average indoor temperature maintained in the home. Adding the results obtained for all energy sources gives the Home Heating Requirement in Btu per degree-day (Btu/DD).

3. Dividing the Home Heating Requirement by the floor plan (in square feet) of the heated part of the home gives the Home Heating Index in Btu/DD-ft^2. Calculations for determining the HHI vary from most other energy calculations in four important ways:

a. Electrical energy and other internal gains are included.

b. Only the heat delivered to the interior is included.

c. The period of analysis is restricted to those times when the exterior temperature in consistently below the interior temperature.

4. The heating degree-days are adjusted from 65° F base to a base that reflects the average interior temperature.

Because of these four steps, the HHI closely reflects the net wintertime heat flow (including both heat flow out and solar radiation heat flow in) through the interior of the home. Thus, the HHI can be used to compare any home, whether it is poorly insulated, super-insulated, or passive solar. Any home using less purchased energy will have a lower HHI and any home using more energy will have a higher HHI.

Both the Home Heating Requirement (HHR) and the Home Heating Index (HHI) are useful measures and are significant to Extension clients. The HHR is an energy consumption measure, while the HHI is more of an energy-efficiency measure because it is on a per-square-foot basis. The automobile analogs would be gallons per mile (energy consumption) and gallons per passenger mile (energy efficiency).

Table 3 shows a HHI calculation for a home with a total area of 2300 square feet, with two stories kept about 70° F and a basement kept about 60° F. The average indoor temperature, weighted by floor area, is, therefore, 67° F. Energy used in the homes includes electricity (lights and appliances) and natural gas (space heating, cooking, water heating, and clothes drying). All the electric energy eventually becomes heat inside the home. It is estimated that about 67 percent of the heat of combustion of the natural gas is delivered to the interior of the home. The rest of the natural gas combustion is lost up the flue.

Table 3. Calculation for a 2300-ft^2 home in Ames, Iowa for 1970-71

	Natural Gas	Electricity
Meter read dates	12/10/70 & 3/11/71	12/10/70 & 3/9/71
Degree-days (67°F base)	4361	4295
Total consumption	1482 CCF	1352 kWh
Purchased energy (million Btu)	148.2	4.6
Fraction delivered to interior	67 %	100 %
Delivered energy (million Btu)	99.3	4.6
Btu/DD-ft^2	9.9	0.5
Home Heating Requirement:	23,844 Btu/DD	
Home Heating Index:	10.4 Btu/DD-ft^2	

For a home having utility bill records, this procedure is relatively straightforward. Occasionally, utility meters also record energy used for other structures, such as farm buildings. It is then not possible to determine a Home Heating Index unless separate meters are installed to record the home's energy consumption.

It is possible to predict the HHI for unbuilt homes from a knowledge of their wall areas and R values, window sizes and locations, roof area, and construction. There are many thermal performance calculation methods, ranging from worksheets that require only the use of construction drawings and a hand calculator, to complex computer-based energy simulation models. The information developed by these methods can be easily used to calculate the Home Heating Index.

THE USE OF THE HHI IN EXTENSION

The HHI has been widely used in Iowa Extension activities. Computer programs and spreadsheet templates that allow the calculation of the HHI for existing homes (based on their energy records) and for unbuilt homes (based on their design) have been developed. The primary computer program was originally written for an Apple III computer. Its data files have weather records for all parts of the state of Iowa for the past seven years.

County Extension offices in Iowa have a questionnaire entitled "The Home Heating Index: How Efficient Is Your Home?" (Publication EES-38) that home owners can fill in and return. The questionnaire asks for information about the home (such as location, size, and indoor temperatures) and its electricity and natural gas consumption. The form also asks for records on less common fuels, such as propane, fuel oil, wood, kerosene, and coal. After the questionnaire is returned, the information is entered into the computer and the calculation carried out. Iowa home owners receive computer printouts about their home's energy efficiency and suggestions for improvement. Home owners whose homes have a HHI of greater than 10, for example, are informed they should have an energy audit. They are also told they should institute appropriate energy conservation improvements. While the HHI calculation can identify a home as energy inefficient, it cannot determine the reason(s) why. Home owners with a low HHI are congratulated and told they are in a position to consider solar retrofit if appropriate to their situation. All home owners are told how their home compares to the state average.

The questionnaire has occasionally been published in newspapers in advance of energy fairs and other events in which the micro-computer is actually on hand to provide home owners with instant feedback. The Extension staff than have an excellent opportunity to visit with the home owners, answer their questions, and provide them with publications appropriate to their needs.

Hundreds of home owners have filled out the questionnaire and had their HHI determined. Because the respondents' homes have an average HHI value of about 7, below the state average, the results may reflect the fact that a home owner who asks for an HHI calculation is more likely to be knowledgeable about energy and to have done more to conserve energy than has the average consumer.

How stable is the HHI over the years? Results show that for homes with high HHI's, the HHI values determined for different seasons do not vary much, typically by about 5-to-10 percent. These are explained by variations in windiness (not accounted for in degree-days) and in solar radiation through south-facing windows.

Solar homes with low HHI's show more variation than non-solar homes because of variations in solar radiation. The HHI values of solar homes depend not just on solar radiation. They also depend on the amount of solar radiation per degree-day, either or both of which may change from year to year.

Several Iowa home owners have already used the HHI to determine the effectiveness of energy conservation improvements. Some examples include:

1. One home (to which little had been done) improved from an HHI of 9.9 to an HHI of 9.3 with the addition of ceiling insulation. The HHI then dropped to 6.7 with the addition of sidewall and basement insulation.

2. A home with no sidewall insulation improved from 10.4 to 7.2 when sidewall insulation was added.

3. The addition of insulation to the basement walls reduced the HHI of another home from 7.3 to 6.0.

4. A two-story home with uninsulated brick sidewalls had an HHI of 9. The HHI dropped to 6 after installation of new siding placed over 3.5 inches of styrofoam insulation.

SURVEY OF THE ENERGY EFFICIENCY OF IOWA HOMES

In order to better understand the quality of the existing homes in Iowa, the Iowa State University Engineering Extension Service, with funding from the Iowa Energy Policy Council, surveyed 440 existing homes, randomly selected, from communities in central Iowa (Baker, Hodges, and Thompson, 1984). Only homes whose major auxiliary heating source was electricity or natural gas were included, since for these the cooperating utilities could furnish actual utility records. The HHR values of the 440 homes range from 3,000 to 37,800 Btu/DD with a mean of 13,200. HHI values range from 2.9 to 21.5 with a median of 7.7 and a mean of 8.2.

The Iowa Energy Policy Council also carried out a complementary survey of 50 new homes constructed in 1981 and 1982. The new homes had Home Heating Indexes ranging from 2.7 to 9.3, with a mean of 6.2.

USE OF THE HHI IN THE IOWA BUILDING CODE

The energy provisions of most building codes are prescriptive. They require minimum R-values in walls, attics, and foundations. There are obvious disadvantages to this approach. First, someone has to decide exactly what are the prescriptive standards. Past prescriptive standards often originated with a national groups and were not necessarily relevant to all the different climates and construction practices found across the country.

A second disadvantage of the prescriptive approach is that innovative builders are not allowed the freedom to make their own decisions on a home's energy features and, thereby, perhaps simultaneously improve its energy efficiency and lower its costs. Designers of energy-efficient homes, who use higher levels of insulation, thermal mass, and large amounts of south-facing windows are especially hindered by prescriptive standards. Their designs may not meet all the standards, yet the energy-efficiency of the design may be much superior to some designs constructed to the minimum standards. A builder might know about some new materials or techniques that allow the construction of a home with better performance than one built to the standards, and yet not be able to use them because they do not actually satisfy the prescriptive requirements of the code.

In an effort to avoid these problems, the Iowa legislature in 1985 passed a new law (House File 341) that provides for the use of the Home Heating Index in the state building code. There are two important provisions to the new law. The first is that it allows builders the option of satisfying the energy requirements of the building code using a Home Heating Index (HHI) calculation--a performance standard rather than a prescriptive standard. The second is that it sets the energy efficiency standard at the average HHI of recently constructed new single- and two-family homes.

The first provision of the law allows builders to disregard the prescriptive standards completely and incorporate any energy conservation features of their own choosing as long as they can show that the overall HHI is less than the standard. Builders may use any combination of insulation, air infiltration control, earth-sheltering, passive or active solar, etc., to satisfy the new performance standard.

The second provision of the new law sets the HHI standard as the mean HHI found in a survey of recently built single- and two-family residential homes in Iowa. This means that the new standard will not be unreasonable or in conflict with current construction practices, since about half of the new homes being built will already be satisfying the new standard. It will insure, however, that energy-inefficient homes will not meet the energy code.

The prescriptive standards of the state building code will still remain in effect for builders who feel comfortable with their use and wish to continue using them. However, the prescriptive standards will be revised and chosen to be consistent with the Home Heating Index standard. This means that a dwelling of typical size and layout satisfying the new prescriptive requirements will have an HHI equal to or less than that of the HHI standard.

A survey of new homes completed in Iowa in 1982 and 1983 was carried out in early 1985 by the Iowa Energy Policy Council. Homes were selected in 14 of Iowa's 99 counties, including both urban and rural counties in different locations around the state.

The mean HHI for the 256 homes in the survey is 4.60, with a standard deviation of the mean of 0.105. Based on these results, the 99 percent confidence interval for the mean HHI is 4.33 to 4.87. That means that there is less than one percent chance that the mean HHI is less than 4.33 or greater than 4.87.

On the basis of the survey results, allowing for some uncertainty, the Iowa Energy Policy Council is recommending that the HHI standard in the building code be 5.0. This standard is met by 72 percent of the existing new homes surveyed.

REFERENCES

Baker, K., Hodges, L., Thompson, R. (1984, September). Random surveys of existing and new homes in central Iowa. *Proceedings of the Ninth National Passive Solar Conference*, Columbus, Ohio, 268-273.