RATING THE HEATING ENERGY EFFICIENCY OF HOMES AND SMALL BUILDINGS

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ABSTRACT

Existing measures of the heating energy efficiency of buildings, such as the Thermal Integrity Factor, are unsatisfactory because they do not give consistent results for identical homes, due to occupants' lifestyles and other factors.

Two related new, more satisfactory indexes, developed by the Iowa State University Energy Extension Service, have been used since 1981 for research purposes and with the general public. The Home Heating Requirement (HHR), which has units of W/C^{o} [watts per Celsius degree] or Btu/F^{o}-day [Btus per degree-day], is the ratio of the total amount of heat from all sources actually delivered to the interior of the home during the coldest months divided by the heating degree-days (or equivalent) based on the average indoor temperature. The Home Heating Index (HHI), which has units of W/C^{o}-m^{2} or Btu/F^{o}-day-ft^{2}, is the HHR divided by the interior area of the home.

The HHR and HHI can be determined for unbuilt homes from design drawings and can be estimated for existing homes from readily-available energy records such as utility bills.

This paper will describe:

* the definition and calculation of the HHR and HHI,

* several related measures which incorporate the effects of heating system efficiency and thermostat settings,

* experiences in using the HHI with the general public,

* the results of two random surveys in central Iowa, one of 440 existing homes and the other of 50 newer homes, and

* possible uses of the HHI and related quantities by homeowners, builders, designers, realtors, lenders, and government agencies and building code officials.

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INTRODUCTION

In carrying out its mission of providing energy assistance to owners of residences and small businesses, the Iowa State University Energy Extension Service has found it useful to provide simple but technically sound measures of the energy consumption and efficiency of homes and other small buildings. These measures are intended to provide information similar to that provided for cars by the miles-per-gallon rating, for natural gas furnaces by the Annual Fuel Utilization Efficiency, and for air conditioners by the Energy Efficiency Ratio.

For this purpose one would like to have a measure which deals with the year-round energy use needed to provide environmental comfort in the building. In Iowa, however, a measure for space heating alone is very useful because the energy requirement for space heating is substantially greater than the energy requirement for other types of conditioning, such as space cooling and dehumidification. Also, a meaningful measure which deals with space heating alone turns out to be simple to define.

We originally surveyed the research literature to find a suitable measure of the heating efficiency of a home. We wanted one which would be an absolute measure of the heating energy efficiency - allowing direct comparison of homes of all types, such as conventional, superinsulated, passive solar, or earth-sheltered - and which could be determined for existing homes in a manner that corrected for the severity of the winter and the habits of the occupants. We found a wide variety of different quantities in use, such as the annual energy cost, the annual space heating energy cost, the annual space heating energy use, the Thermal Integrity Factor, and the Solar Savings Fraction. None of these proved satisfactory because none met our criteria.

As a result, in 1981 we developed two new measures, the Home Heating Index and the Home Heating Requirement. While they have some limitations, these quantities have been found to be excellent measures for many purposes. We have recently defined several new measures which are also useful in certain situations. We have used these measures in analyzing two random surveys in central Iowa, one of 440 homes of all types and ages, and one of 50 new homes. This paper describes these different measures, and their uses.

DEFINITIONS OF THE HOME HEATING REQUIREMENT AND THE HOME HEATING INDEX

The Home Heating Requirement (HHR) and Home Heating Index (HHI) are defined operationally as follows:

1. Determine the total amount of heat energy which must be supplied to the home (or other small building) to maintain its interior at exactly 18.3° C (65° F) during the three winter months of December, January and February. The heat included may be provided by the space heating system or by lights, cooking, appliances, and so forth - the exact source is immaterial. Convert the energy into a consistent unit, such as joules or Btu.
2. Divide by the total number of heating degree-days (to the usual base of 18.3° C = 65° F) over the same three-month period. This result is the Home Heating Requirement, or HHR, which has units of W/C° in the SI system or Btu/F°-day in the "engineering system".
3. Divide by the area of the interior of the home. This result is the HHI, whose units are W/C°-m^2 (SI system) or Btu/F°-day-ft^2 (engineering system).

For a new home that exists only as a design, it is possible to estimate these quantities from the construction drawings, using standard calculation procedures of different levels of sophistication, such as building modeling programs or the Solar Load Ratio method for passive solar homes.

For an existing, occupied home it is theoretically possible to monitor the home precisely, performing a complete energy balance study, and thereby determine the HHR and HHI. This is expensive and time-consuming, however. Fortunately, it appears that a reasonably accurate determination of the HHI of an existing home is possible using utility bill information and a few other pieces of information, as the following example shows.

EXAMPLE

The example home is located in Ames, Iowa, and has a total heated area of 2300 ft^2 on three levels of equal area. During the 1970-71 heating season the two upper levels were kept at 70° F and the basement level at 60° F; thus the average indoor temperature, weighted by area, was 67° F. The only energy sources used in the home were electricity and natural gas. A total of 1352 kWh of electricity was metered between 10 December 1970 and 9 March 1971; electricity was used for lights and appliances. A total of 1482 CCF of natural gas was metered between 10 December 1970 and 11 March 1971; natural gas was used for space heating, water heating, cooking and clothes drying. An estimated 100 percent of the electric energy and 67 percent of the natural gas energy was released into the interior.

Table I. Results in engineering units for the example home described in the text.

	Natural Gas	Electricity
A. Beginning read date	12/10/70	12/10/70
B. Ending read date	3/11/71	3/9/71
C. Total consumption	1482 CCF	1352 kWh
D. F^o-days (65^o base)	4179	4117
E. F^o-days (67^o base)	4361	4295
F. Home consumption factor	67,000 Btu/CCF	3412 Btu/kWh
G. Home consumption (Btu)	99,294,000	4,613,000
H. Contribution to Home Heating Requirement	22,769	1,074
I. Contribution to Home Heating Index	9.9	0.5
J. Home Heating Requirement	= 23,843 Btu/F^o-day	
K. Home Heating Index	= 10.4 Btu/F^o-day-ft^2	

NOTES: Lines A through E are original data
Line F values are estimated
Line G = [C x F] = line C times line F
Line H = [G/E] = line G divided by line E
Line I = line H divided by area (2300 ft^2)
Line J = sum of contributions from line H
Line K = sum of contributions from line I

Table I lists the basic information presented above and the calculations for this home. Several practical difficulties show up in trying to apply the definitions of the HHR and HHI to such an example; let us discuss these in turn.

First, the energy records of a home may not exactly coincide with the three-month period from December 1 to February 28 or 29. The reason for choosing the three coldest months is that during these months the internal heat generation for purposes other than space heating - i.e., for lights, cooking, electric appliances, and so forth - is always useful in maintaining the desired indoor temperatures, and never in excess. During warmer months, when the internal heat generation may exceed the heating requirements, the heating needs of the home may be incorrectly overestimated. The recommended procedure is to use a period of approximately three months, as close to the months of December through February as possible, and then to use the heating degree-days for the same period. The example of Table I uses actual utility bills, read around the 10th of each month. The January, February and March bills were chosen in this case.

Table II. Energy sources to include or exclude from calculations of the Home Heating Index and related quantities

Include:	Natural gas, fuel oil, propane, coal, wood, kerosene
	Electricity purchased from a utility
	Electricity from wind generators, photovoltaic systems, or other systems not part of the house itself
	Solar energy collected by systems that are not part of the house itself (such as solar collectors elsewhere on the site)
	Heat from human metabolism
Exclude:	Solar energy collected by the house itself, such as by a passive solar system or a roof-top active solar collector
	Solar electricity from a photovoltaic array mounted on the house structure

Second, what energy sources should be included? Since the purpose of the HHI calculation is to determine the amount of heat that must be added to the home to maintain the desired temperature, one should include all energy sources that are brought into the home from the outside, but exclude any energy sources collected by the home itself. Table II lists examples of energy sources to include and exclude in this sort of calculation. We refer to the included energy sources as "imported" energy. For the example home of Table I, natural gas and electricity are the only two energy sources to include.

Third, it is necessary to know how much of the energy supplied to the home actually provides heat to the interior. It is necessary to know the efficiency factors that characterize the amount of heat that is actually released into the home. Examples might be 100 percent for a gas range or a clothes dryer with no outside venting, perhaps 60 percent for a gas water heater, anywhere from under 50 percent to over 90 percent for a gas furnace, 160 percent for an electric heat pump with a coefficient of performance (during the three-month period) of 1.6, and so forth. The more accurately one determines these quantities, the more accurate the HHR and HHI will be. It is often necessary in practice to rely on a homeowner's guess of the efficiency of a gas furnace, and apply it to total gas consumption. For the example in Table I, the estimated "Home consumption factors" are 67,000 Btu/CCF for natural gas and 3412 Btu/kWh for electricity. We have normally neglected the heat from human metabolism or the heat lost down the drain in gray water. These are difficult to estimate; fortunately their contributions are opposite in sign, similar in magnitude (about 8 MJ or 8000 Btu per day per person), and somewhat correlated (more people, more water usage). It is preferable, of course, to estimate these quantities if possible.

Fourth, the typical home is not kept at exactly 18.3° C (65° F). We have found from surveys in central Iowa that some people maintain their indoor temperatures above 70° F while others maintain them below 60° F. Since the heating requirements of a home are approximately, though not exactly, linearly dependent on the indoor-outdoor temperature difference, we estimate the HHR and HHI using degree-days determined to a base equal to the average indoor temperature. This is defined to be the average over time and space of the actual temperatures (not the same as thermostat settings). For example, if half the home is kept at 60° F and the other half is kept at 62° F for 8 hours a day and at 68° for 16 hours a day, the average indoor temperature is $(1/2) \times 60 + (1/2) \times (62/3 + 2 \times 68/3) = 63°$ F. Again, it is often necessary to rely on homeowner's estimates of these quantities. In the example of Table I, the heating degree-days to the base of 67° F (the average indoor temperature) are used in the calculation of the HHR and HHI.

Fifth, there is the question (for the Home Heating Index, but not for the Home Heating Requirement) of what area to use. Logically, one wants to include all heated areas, but in many homes some areas are directly heated and others are only indirectly heated. When do you count the latter? After much discussion, we have settled on the following definition:

> The area to use in calculating the Home Heating Index is the area of all spaces in the building that remain at 50° F (10° C) or above during cold weather, whether by direct heating or indirect heating (such as heat losses from directly heated spaces). This would include ordinary living and bedroom areas, basement spaces, enclosed porches, and so forth, so long as they remain above 50° F (10° C) during cold weather. Basements (or portions thereof), storage areas, closed-off rooms, garages, and other spaces that become or remain colder than 50° F (10° C) are not included in the area. Spaces not usable by adults, such as crawl spaces or low basements, should not be included regardless of their temperature. The floor area of exterior walls is not included, but no subtractions for the floor area of interior walls are made.

The average indoor temperature of the home should, of course, be calculated for exactly this same area.

COMPARISON WITH THERMAL INTEGRITY FACTOR

The Home Heating Index (HHI) has the same units as the widely-used Thermal Integrity Factor (TIF), but differs from it in significant respects. The TIF is calculated by determining the total heat provided to the interior of the home by the space heating systems (but not lights or other non-space heating sources) during the whole heating season, dividing by the total heating degree-days (65° F base) for the season, and then dividing by the floor area of the home. The difficulties with the TIF should be obvious: it depends critically upon the occupants' internal heat generation and thermostat settings; it may also vary considerably from a mild winter to a harsh one.

Table III. Calculation of the Thermal Integrity Factor (TIF) and the Home Heating Index (HHI) for a home assuming different amounts of internal heat and different indoor temperatures. The home is assumed to have 2000 square feet living area, a heat loss coefficient of 10,000 Btu/F°-day, and no solar contribution. The calculations are for an average winter in Ames, Iowa (6755 F°-days September through May).

	INDOOR TEMPERATURE					
INTERNAL HEAT	60° F		65° F		70° F	
	TIF	HHI	TIF	HHI	TIF	HHI
50,000 Btu/day	3.2	5.0	4.0	5.0	5.0	5.0
100,000 Btu/day	2.5	5.0	3.2	5.0	4.0	5.0
150,000 Btu/day	1.9	5.0	2.5	5.0	3.2	5.0

Table III lists the TIF and HHI calculated for a hypothetical non-solar home under different assumptions about internal (non-space) heat generation and indoor temperatures, using extremes well within the range actually encountered. Note that the HHI is a constant 5.0 while the TIF varies from 1.9 to 5.0.

EXTENSION PROGRAMS INVOLVING THE HHR AND HHI

The HHR and HHI have been used with the Iowa public since the summer of 1981. A questionnaire was prepared and printed in an extension publication available throughout the state at county extension offices. The current questionnaire asks for the location of the home, the utility bill records (meter read dates and consumption figures for electricity and natural gas), the square footage of heated and unheated areas, the indoor temperatures in the home, and the estimated heating system efficiency (for which a full-page table of representative values is provided). If propane, fuel oil, wood, kerosene, or coal is used, the homeowners must use their own records to provide the necessary information, such as tank fill dates and gallonage.

Information from the questionnaire is entered into a computer which has heating degree-day information for the whole state of Iowa for the past few heating seasons. The homeowner receives an output providing the HHI and another quantity (the Primary Heating Consumption, described below) and comparing them with the low, average, and high values found in the random survey of 440 homes described later. Those with high values are told they need to institute more energy conservation improvements and are told where to obtain information about them. Normally this output is mailed back to the homeowner. In some cases, the questionnaire has been printed in newspapers in advance of an energy fair or similar event; the homeowners who brought in the filled-out form received instant output at an extension booth at the event and were able to consult with extension staff. To date, over 1000 homeowners have asked for a calculation of their HHI.

The HHR and HHI are dependent on the energy efficiency of the structure of a home: its insulation, caulking, weatherstripping, and so forth. As energy conservation improvements are made to a home, these quantities are observed to decrease. Some examples of these changes are the following:

House #1:	9.9	initial HHI
	9.3	after adding ceiling insulation
	6.7	after adding wall and basement insulation
House #2:	10.4	before adding sidewall insulation
	7.2	after adding sidewall insulation
House #3:	7.3	initial HHI
	6.0	after adding basement insulation
House #4:	9.0	with uninsulated two-story brick walls
	6.0	after installation of new siding with 3.5 inches of styrofoam underneath

In theory, and in practice if correctly calculated, the HHR and HHI are independent of the heating system efficiency. Although they have been well received by homeowners, some homeowners who have bought high-efficiency furnaces or lowered their thermostats have asked for a quantity that shows them how much progress they have made including these changes. As a result we have developed a systematic "taxonomy" of energy rating measures and begun using several new quantities.

A TAXONOMY OF ENERGY RATING MEASURES

The energy rating measures we use have names of the form "X Y Z," such as Home Heating Index or Primary Heating Consumption. Those currently fully defined have units of either W/C^{o} (or Btu/F^{o}-day) or W/C^{o}-m^{2} (or Btu/F^{o}-day-ft^{2}), as determined by the choice for "Z."

The middle word ("Y") is either Heating, Cooling, or Energy.

1. "Heating" is used for quantities related to winter space heating. Normally only the three coldest months (December, January, February) are included in the determination of this quantity, as described earlier.
2. "Cooling" we have reserved for as-yet-undefined quantities related to summer space cooling.
3. "Energy" is reserved for as-yet-undefined quantities related to overall energy use for year-round environmental comfort.

All the quantities we have used are thus of the form "X Heating Z."

The first word ("X") is either End-use, Home, or Primary.

1. "End-use" quantities, as the name suggests, are obtained by considering all the energy sources imported into the home and converting them into the same units (normally joules or Btus). No efficiency factors are included.
2. "Home" quantities involve only those joules or Btus which are provided to the interior of the home from imported energy sources, as defined earlier. Because only the energy that

goes into the home is included, these quantities involve measured or estimated efficiency factors.

3. "Primary" quantities are similar to End-use quantities, except that they include transmission losses en route to the home, generating losses at plants providing the energy used in the home, transportation of fuel to the home or a power plant serving the home, and so forth; this energy should be determined as accurately as possible for the local situation, so that, for example, generating losses would vary from community to community.

The third word ("Z") can be Requirement, Consumption, Index, or Factor. These are presently defined only for heating, as follows:

1. "Requirement" means the units are W/C^o (or Btu/F^o-day), with the degree-days or equivalent based on the home's average indoor temperature.
2. "Consumption" means the units are W/C^o (or Btu/F^o-day), with the degree-days or equivalent based on 65^o F (18.3^o C).
3. "Index" refers to the Requirement divided by the heated floor area. Its units are W/C^o-m^2 (or Btu/F^o-day-ft^2).
4. "Factor" refers to the Consumption divided by the heated floor area. Its units are W/C^o-m^2 (or Btu/F^o-day-ft^2).

In addition to the quantities formed as described above, one can form a per-capita quantity for each Requirement or Consumption. (A per-capita Index or Factor does not appear to be a useful quantity.) Examples would be the Per-capita Home Heating Requirement or the Per-Capita Primary Energy Consumption.

Table IV shows the values of the new energy rating measures for the example home used in Table I. The End-use quantities are calculated using the conversion factors of 100,000 Btu/CCF for natural gas and 3412 Btu/kWh for electricity. For the Primary quantities, we have estimated 110,000 Btu/CCF and 11,000 Btu/kWh, respectively; these correspond to an electric power plant heat rate of 10,000 Btu/kWh and a 10 percent "surcharge" for production and transportation of natural gas to Ames and for mining and transporting the coal used by the Ames Municipal Electric Utility.

The Home quantities are calculated using the actual amounts of energy furnished to the interior of the home. They are thus independent of the heating system efficiency, assuming the latter has been properly taken into account in the calculations. The Home Heating Requirement is thus a function only of the building structure (mainly its envelope, but also its thermal mass in the case of a passive solar home); it will be decreased by improvements in the building structure, but not by improvements in the heating system. The Home Heating Consumption is decreased by improvements to the building structure or by lowered thermostat settings.

Table IV. Further results for the example home described in the text. Lines C through G are taken from Table I.

	Natural Gas	Electricity
C. Total consumption	1482 CCF	1352 kWh
D. F°-days (65° base)	4179	4117
E. F°-days (67° base)	4361	4295
F. Home consumption factor	67,000 Btu/CCF	3412 Btu/kWh
G. Home consumption (Btu)	99,294,000	4,613,000
L. Contribution to Home Heating Consumption [G/D]	23,760	1,120
M. End-use consumption factor	100,000 Btu/CCF	3412 Btu/kWh
N. End-use consumption (Btu)	148,200,000	4,613,000
O. Contribution to End-use Heating Requirement [N/E]	33,983	1,074
P. Contribution to End-use Heating Consumption [N/D]	35,463	1,120
Q. Primary consumption factor	110,000 Btu/CCF	11,000 Btu/kWh
R. Primary consumption (Btu)	163,020,000	14,872,000
S. Contribution to Primary Heating Requirement [R/E]	37,381	3,463
T. Contribution to Primary Heating Consumption [R/D]	39,009	3,612

Home Heating Consumption = 24,880 Btu/F°-day
Home Heating Factor = 10.8 Btu/F°-day-ft^2

End-use Heating Requirement = 35,057 Btu/F°-day
End-use Heating Index = 15.2 Btu/F°-day-ft^2
End-use Heating Consumption = 36,583 Btu/F°-day
End-use Heating Factor = 15.9 Btu/F°-day-ft^2

Primary Heating Requirement = 40,844 Btu/F°-day
Primary Heating Index = 17.8 Btu/F°-day-ft^2
Primary Heating Consumption = 42,621 Btu/F°-day
Primary Heating Factor = 18.5 Btu/F°-day-ft^2

Per-capita Home Heating Requirement = 7,948 Btu/F°-day
Per-capita Home Heating Consumption = 8,293 Btu/F°-day
Per-capita End-use Heating Requirement = 11,686 Btu/F°-day
Per-capita End-use Heating Consumption = 12,194 Btu/F°-day
Per-capita Primary Heating Requirement = 13,615 Btu/F°-day
Per-capita Primary Heating Consumption = 14,207 Btu/F°-day

NOTE: Line N = [M x C] and line R = [Q x C]

The End-use quantities are of interest as describing the actual energy use in the home using a consistent unit (Btus in this case). The End-use Heating Requirement would be lowered by energy conservation improvements to the home's envelope (such as better insulation) or by the installation of a more efficient heating system; lowered thermostat settings would also reduce the End-use Heating Consumption. Imagine, however, that an inefficient refrigerator in the home were to be replaced by an efficient model. The reduction in electric heat from the the refrigerator would lead to an increased consumption of natural gas in the furnace, and since the furnace has a thermal or first-law efficiency less than that of electricity, the End-use Heating Requirement and End-use Heating Consumption would increase.

Partly for this reason, we regard the Primary quantities as more meaningful. Since they express the total use of primary resources, they will decrease not only when the building envelope or the heating system is improved (or the thermostat lowered in the case of the Primary Heating Consumption), but also when the efficiency of an electric appliance in the home is increased.

SURVEY OF HOMES IN CENTRAL IOWA

Two random surveys of homes in central Iowa have recently been carried out. The Iowa State University Energy Extension Service studied 440 existing homes chosen randomly with one restriction, that the major heating source be either electricity or natural gas. The Iowa Energy Policy Council carried out a companion random survey of 50 newer homes built in 1981 and 1982. In these studies utility bills were obtained directly from the utilities, area measurements were obtained from county assessor's offices (and checked in the field for about one-fourth of the sample), and a short questionnaire about heating systems and indoor temperatures answered by the occupants.

The HHI values (in Btu/F^{o}-day-ft^{2}) found in the existing home study ranged from 2.9 to 21.5, with an average of 8.2 and a median of 7.7. Those for the new home study ranged from 2.7 to 9.3 with an average of 6.2; three passive solar homes in the new home sample were the three most efficient homes. Other information from the existing home study is shown in Table V.

SUMMARY OF HOME HEATING INDEX SCALE (Btu/F^{o}-day-ft^{2})

20	worst homes found (such as very poor mobile homes)
15	very inefficient home, badly needing energy conservation measures
10	typical of many homes, needing more energy conservation measures; estimated average in early 1970s
8	average found in a study of 440 existing homes in central Iowa
6	average found in a study of 50 new (1981 & 1982) homes in central Iowa
5	energy-efficient home (suggested upper limit)
2-4	characteristic of the most energy-efficient new homes (superinsulated and passive solar)

Table V. Averages and extremes for 440 existing homes of several energy rating measures and other data.

Quantity	Units	Low	Average	High
HHI	Btu/F°-day-ft^2	2.9	8.2	21.5
HHR	Btu/F°-day	2,974	13,177	37,785
PHI	Btu/F°-day-ft^2	5.6	15.4	48.3
PHR	Btu/F°-day	5,921	26,610	79,889
PHC	Btu/F°-day	5,530	23,665	74,310
Per-capita HHR		1,545	5,097	21,826
Per-capita PHR		3,314	10,215	50,526
Per-capita PHC		3,469	10,342	51,594
Family size	persons	1	2.7	7
Area	ft^2	325	1,735	5,280
Temperature	°F	53	64.7	72

USES AND LIMITATIONS OF THE DIFFERENT ENERGY RATING MEASURES

Each of the different energy rating measures defined above has its own uses. Most have been used only for research purposes in our studies of Iowa homes. With the general public we originally used the Home Heating Requirement and the Home Heating Index (HHI), but we are now using the HHI and the Primary Heating Consumption (PHC).

The HHI can be used to compare homes of different sizes and homes in different localities. It is the best single-number representation of the heating energy-efficiency of a home, analogous to the Energy Efficiency Ratio for air conditioners or the Annual Fuel Utilization Efficiency for furnaces. However, from the HHI one cannot determine what is right or wrong about a home. Also, while the HHI in theory is independent of occupants' habits, it may sometimes in practice be an overestimate if the occupants tend to leave doors and windows open unnecessarily.

The PHC also depends on the heating system efficiency and the occupants' thermostat settings. The HHI is a measure of the energy-efficiency of the home on an absolute scale, while the PHC is an overall indicator of energy conservation achievements of all types. While the determination of the HHI involves the possibility for several types of errors when determined using occupant records and measurements, the PHC calculation does not depend on the area of the home (which many homeowners do not know accurately), the indoor temperatures, or the estimated furnace efficiency.

There are many possible uses of the Home Heating Index and/or related quantities. Homeowners can use them to determine the absolute heating energy efficiency of a home for comparison with other homes nearby or distant, or to determine the effect of energy conservation improvements made over the years. Designers and builders can use them to determine the heating energy efficiency of their designs and to help market their work, as well as to determine the effects of changes in design (such as different levels of insulation, or the use of triple instead of double glazing). Lending institutions can use them to determine a prospective borrower's ability to repay the mortgage and pay utility bills, and to assist in appraising the value of property on the market. Realtors can use them for similar purposes or as a selling point in marketing energy-efficient homes. Prospective home buyers should find these quantities very useful, too, since most are interested in the energy-efficiency of the homes they are considering. Government agencies can use them as a tool for research or for state energy planning (as in setting energy conservation goals for the future), as a building energy performance standard for new or existing homes (an alternative to prescriptive standards), or to determine the eligibility of a home for state energy conservation tax credits.

The most appropriate energy rating measure depends on the user and the purpose for which the measure is being used. For some purposes it may be desirable to convert the information into economic terms. This has the disadvantage of making comparisons between different years and different locatlities less comparable, but it is often helpful for consumers. We have at times used the concept of an average January utility bill, defined as the cost of all utilities assuming average January weather, a fixed amount of non-space heating electricity use (for example, 500 kWh for the month), a constant indoor temperature (such as 68^{o} F), and current prices for energy (such as 7 cents per kWh for electricity and 60 cents per CCF for natural gas).

CONCLUSION

In conclusion, the Home Heating Index and related quantities, as defined theoretically, are regarded as excellent energy rating measures, with each quantity having its own uses. They have proved useful in Iowa and are becoming better known and appreciated by the general public. Furthermore, reasonably accurate determinations of even the most complex quantity (the Home Heating Index) are possible whenever utility bills or other records are available for the home itself. We believe these quantities and their theoretical and practical calculations merit consideration by the research community and the general public.

ACKNOWLEDGEMENTS

I would like to acknowledge the assistance of my colleagues Patrick Huelman, Thomas Greiner, Mary H. Yearns, and K. Baker, for their collaboration in the development of the Home Heating Index and related measures.