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ENERGY a computer program for calculating energy consumption in residential buildings.

Narinder. Grewal
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ENERGY : A COMPUTER PROGRAM FOR CALCULATING ENERGY CONSUMPTION IN RESIDENTIAL BUILDINGS

by

Narinder Grewal

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ABSTRACT

ENERGY : A COMPUTER PROGRAM TO CALCULATE ENERGY CONSUMPTION IN RESIDENTIAL BUILDINGS

by

Narinder Grewal

The objective of this project was to develop a simple to use yet accurate computer program to carry out a complete energy and retrofit analysis for residential buildings based on a degree-day method. This objective was achieved in the following steps.

a) The various physical models to determine; solar gains, solar utilization factors, internal gains, infiltration loads, heating and cooling degree-days, etc. were formulated and analysed in detail.

b) The methodolgy, computer modelling and the logic adopted in the computer program ENERGY were developed. The new program ENERGY was written on LOTUS 1-2-3, a spread sheet calculation program, which is available on release 2.01 and 1.A.

c) Finally, ENERGY was validated against the other simulation programs, CIRA and DOE 2.1a.

In ENERGY the solar utilization factors were determined to estimate the actual useful solar gain entering the house through the windows. The program accounted for internal heat gains from lights, appliances, and occupants. It also approximates the heating and cooling periods based on UA-value, location, solar and internal gains, and indoor temperature setting of the residence. The infiltration model accounted for both the stack and wind effects.

The ENERGY program is essentially directed to people who are familiar with heating and cooling load calculations of residential buildings. The spread sheet nature of the program makes it flexible and easy to use. The program can be run on IBM compatible computers. A complete energy and retrofit analysis can be performed in a short period of time, approximately one minute.

The comparative study of ENERGY revealed that the monthly heating loads predicted by ENERGY and those predicted by CIRA and DOE 2.1a were generally within a 10% range. The agreement was found to worsen for tight, highly insulated houses. This discrepancy was due to the simplifying assumption that the solar effect on the opaque surfaces is cancelled by sky radiation. Further, for highly insulated houses the heating degree-day values are low and therefore, have a high percentage error. However, in case of tight, well insulated houses a very accurate energy and retrofit analysis is not required. In general the seasonal heating load comparison of ENERGY with CIRA and DOE 2.1a was very good, within a 5% range. The cooling loads comparison with CIRA, for both monthly and seasonal values, was found to be poor, generally within a 20% range.

In conclusion it can be stated that ENERGY is an easy to use and reliable tool for performing heating energy analysis. The cooling energy analysis should not be considered any more than a rough estimate.

DEDICATION

To my parents

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LIST OF ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BEPS	Building Energy Performance Standards
CIRA	Computerized, Instrumented, Residential Audit
DOE	Department of Energy
GLR	Gain Load Ratio
HVAC	Heating Ventilation and Air Conditioning
MGR	Mass Gain Ratio
NRC	National Research Council
SERI	Solar Energy Research Institute
SUF	Solar Utilization Factor
TMM	Typical Meteorological Month
TMY	Typical Meteorological Year
TRY	Test Reference Year
WYEC	Weather Year for Energy Calculations

CHAPTER I

INTRODUCTION

The rapidly rising cost of energy has made buildings' heating and cooling operating costs, taken over the expected life span of building, often exceed the first costs of construction. Accordingly, building designers have been increasingly considering energy conservation during design, and are attempting to determine the optimum investment of construction funds into energy-conserving design options.

One fifth of the energy consumption in Canada occurs in residential buildings. The current housing stock in Canada is four million units and, annually, approximately one hundred thousand new houses are built [1.1]. Energy conservation in residential buildings thus has a great potential for reducing energy demand.

With the increased concern for energy conservation, a need for a simple method to perform energy analysis of residential buildings is widely recognized. Such an estimating method could be used for carrying out energy conservation analysis, comparing alternatives in the design process, evaluating house designs to determine their compliance with energy standards etc.. A number of methods are available for this purpose, but almost all of them lack either in accuracy or in simplicity.

The existing methods, such as Degree-Day, or Basic Bin method, are not sufficiently comprehensive to account for the various factors affecting the energy usage of buildings. On the other hand, the comprehensive computerized procedures are complex, time consuming, and may not be necessary for every analysis. Thus, there is a definite need for a procedure that is simple and accurate yet accounts for the significant parameters affecting the energy usage of residential buildings. Such a procedure would enable engineers, contractors, etc. to perform a quick energy analysis. This project is a direct result of current demand for simplified solutions for estimating energy consumption of residential buildings.

In this project a computer program to carry out energy and retrofit analysis for a residential building has been developed. The title of this residential energy analysis program is ENERGY and it will be referred as ENERGY in the rest of the report. The program is essentially directed to people who are familiar with heating and cooling load calculations of residential buildings and assumes that the conduction coefficient (UA) of the building is known.

1.1 LITERATURE SURVEY

1.1.1 Review of Existing Methods:

At present there are a number of energy estimating methods available, each having its strengths and weaknesses. A brief discussion of these methods and their drawbacks is included:

1.1.1a Degree-Day Method:

The degree-day method of energy analysis is an attractive approach to residential energy analysis when time does not permit the use of computer energy analysis procedures. This simplified method has been used for some time for heating energy analysis but has not been an accepted procedure for cooling energy analysis. Latent loads due to infiltration and occupants, and internal gains due to occupants, lighting and equipment, and direct solar heat gain form the main portion of the cooling load and are not directly dependent on outdoor temperature as assumed in degree-day method.

The traditional degree-day procedure for estimating heating energy requirements is based on the assumption that, on a long-term average, solar and internal gains will offset heat loss when the mean daily outdoor temperature is 18.3 °C or higher and that the fuel consumption will be proportional to the difference between the mean daily temperature and 18.3 °C. This basic concept can be represented in an equation, [1.2]:

$$E = \frac{H_l \cdot DD \cdot 24}{\Delta t \cdot \eta \cdot V} \qquad 1.1$$

where:

E is fuel consumption for the estimate period, units consistent with V.

H_l is the design heat loss, including infiltration and mechanical ventilation (W).

DD is number of degree-days for the estimate period to base 18.3 °C (°C-day).

Δt is design temperature difference (°C).

η is the efficiency of the heating system.

V is heating value of fuel, units consistent with H_l and E.

The applicability of this procedure is limited to residential buildings, where the envelope transmission and infiltration are the dominating factors contributing to the building load. It gives only a rough estimate of residential heating requirements and is unable to account for variation in solar gains. Therefore, the Degree-Day Method is less accurate than is desirable to perform energy and retrofit analysis at the initial design stage.

1.1.1b <u>Modified Degree-Day Method</u>:

Buildings today are using more insulation, storm windows, and weather stripping, and builders are generally upgrading the quality of construction relative to air tightness and heat loss. In addition, more energy-consuming household appliances are used in homes, and there has been a nationwide effort in recent years to adjust the thermostat settings to further reduce energy consumption. The base temperature, which was selected in the years before these changes, may not adequately represent the present residential construction and usage practices. This method adjusts the inherent errors in the 18.3 ^{o}C-based degree-day method by using an empirical factor C_d. These values of C_d are calculated using typical modern single-family construction (ASHRAE Standard 90-1980), and generally agree with electric utility experience. The correction factor C_d is incorporated in the energy equation as follows, [1.2]:

$$E = \frac{H_1 \cdot DD \cdot 24}{\Delta t \cdot \eta \cdot V} \cdot C_d \qquad 1.2$$

where:

C_d is an empirical correction factor for heating effect vs. 18.3

days.

Although this method is an improvement over the degree-day method, still it is not an accurate tool to carry out design and retrofit analysis, since the value of C_d is difficult to determine.

1.1.1c Basic Bin Method:

In this method instantaneous energy calculations at many different outdoor dry bulb temperature conditions are performed. It can account for the part load performance of HVAC equipment. Additionally, variations of indoor loads with time and operating schedules of HVAC systems can be considered. The principal drawback of this procedure is interpolation between end points corresponding to the summmer and winter design envelope loads. The summer loads are based on the design hour and do not account for the variation in the transmission and solar loads, which on the average, are much lower than the design hour values. These loads could be further reduced by cloud cover and other effects. Conversely the winter design envelope loads ignore solar effects which could significantly reduce the total losses through the envelope. Due to these drawbacks the standard bin method has limited applicability in estimating savings due to retrofitting.

1.1.1d TC 4.7 Method:

This method is more suitable for commercial buildings but can also be used for residential buildings. The load calculations are performed at four temperature bins, judged to be significant for the given building and location. The temperature bins are at peak cooling, intermediate cooling, intermediate heating and peak heating.

Calculation of solar loads is a major drawback, the linear relationship of solar load with outside air temperature is an over simplifying assumption at the expense of accuracy. Solar gain is a complex function of direction, glazing type, thermal mass; building surroundings etc. Considering it to be only a function of temperature may give inaccurate results. Further, infiltration calculations do not take into account shielding, terrain and wind direction effects. This procedure is too lengthy and complicated to be considered as a quick and simple method.

1.1.1e <u>Computerized, Instrumented, Residential Audit (CIRA)</u>:

CIRA is an energy analysis program developed at the Lawrence Berkeley Laboratory, U.S.A., specifically for residential buildings. It calculates monthly and annual heating and cooling loads for single family structures. Some prominent features of the program are:

It is user oriented. It is an interactive program, i.e. if the user does not understand a question, he can ask for " help " from the program, to which the program responds by providing a detailed explanation of the question. Similarly, if the user cannot answer a question, he can get a list of possible answers as well as a default answer to the question from the program. Further, CIRA also appears to be attractive from the perspective of cost, ease of use and simulation time.

A critical evaluation of CIRA program as an energy analysis program for residential buildings [1.3] was made by Patwardhan, A.G.

It was found that CIRA-predicted energy consumption agreed within 22% of the metered energy use on an annual basis. The comparative study of CIRA revealed that large discrepancies between the CIRA and DOE 2.1a-predicted heating loads occurred during the swing months. The agreement was found to worsen when airtight structures with passive solar features and high insulation levels were modelled. This was attributed to the fact that CIRA always used a 100% solar and internal gain utilization. The comparison of underground heat losses predicted by CIRA and HEATING5 showed that CIRA could be expected to yield reliable results for seasonal heat loss only. Therefore, CIRA is not recommended for modelling very tight houses with high insulation levels, and high solar and internal gains.

1.1.1f <u>HOTCAN</u>:

HOTCAN is a program developed by the Division of Building Research of the National Research, Council, Ottawa. This program performs design heat loss calculations and month-by-month energy analysis. HOTCAN has improved and well developed basement heat loss [1.4], solar [1.5] and internal gain [1.6] calculation procedures. However, the infiltration model and heat loss calculation procedure being used in the program have been overly simplified. The heating season for the residential building is assumed, which could cause discrepancies in the predicted results. Further, the program is not very user friendly. The input data could be long and difficult to comprehend. Therefore, HOTCAN could not be considered to be an accurate and a simple computer program.

1.1.1g <u>Initial Approach</u>:

Initially, in this research project, an attempt was made to develop an energy calculation method based on a generalized curve between ΔUA-value and ΔDD for locations in Canada. This would provide a quick and simplified means of performing energy and retrofit analysis. Such a curve would enable the user to read off the change in degree-days for any variation in the UA-value directly from the graph. The UA-value was varied with reference to a chosen base (reference house). The corresponding change in the degree-days was plotted on a ΔUA versus ΔDD curve for eight Canadian cities; Toronto, Montreal, Windsor, Winnipeg, Edmonton, Port Hardy, Charlottetown and Bad Lake. However, after the analysis it was found that the curves were non linear and had a random behaviour from city to city. Therefore, the idea of a generalized curve was finally dropped as it would had been an inaccurate approach to energy analysis.

1.2 OBJECTIVE

There are not many easy to use methods which provide accurate energy calculations for residential buildings. Complex and sophisticated programs can be used for energy analysis of residential structures. However, their complexity, results in drawbacks such as cost, running time, large computer memory requirements etc.

Therefore, there is a need for a new energy analysis program, specifically for residential buildings, which calculates monthly and seasonal heating and cooling loads. Some of the desired features of the program are outlined:

a) The program should be simple and user friendly. The input data should be easily available. The user should not have to spend time in feeding the input data or learning any specific language to model a house.

b) An extremely short running and simulation time, of the order of a few seconds, is desired. This would allow a quick energy analysis to be carried out.

c) It should be easily accessible, e.g. microcomputer (preferably IBM compatible) based program available on a 5 1/4 inch floppy disk.

d) It should be inexpensive.

e) The program should be easy to edit and modify.

The objective of this project is to develop a simple yet accurate computer program to carry out a complete energy and retrofit analysis for a residential building. In other words a simple computerized building simulation program which calculates both monthly and seasonal heating and cooling loads accurately. This objective will be achieved in three stages:

a) The various physical engineering models; solar gains, solar utilization factor, internal gains, infiltration loads, heating and cooling degree-days etc.; to be used in the energy simulation program will be formulated and discussed in detail.

b) The methodolgy, computer modelling and logic adopted in the new program, ENERGY will be developed. Further, the calculation algorithms will be discussed in detail to provide insight into the programs strengths and weaknesses. The computer program will be written on LOTUS 1-2-3, a spread sheet calculation program, and will be available on both versions, Release 2.01 and 1.A*.

c) As ENERGY is a new program and has not been thoroughly validated, it becomes necessary to make a complete and thorough validation. Finally, the program will be validated against other simulation programs, CIRA and DOE-2.1a. This validation would allow a comparison between ENERGY, CIRA and DOE-2.1a, which would reveal areas that are not adequately treated by ENERGY and hence need further improvement.

CHAPTER II

ENGINEERING METHODS

INTRODUCTION

A complete energy analysis can be performed on a house using the ENERGY program. It can also be extended to perform an accurate and a quick retrofit analysis. In this chapter the engineering fundamentals of the (energy simulation) models used in ENERGY are discussed in detail. The chapter has been divided into three sections.

a) The first section describes the energy calculation method. It also includes a procedure to carry out a retrofit analysis on a residential building.

b) The second section describes the various physical models used in energy calculations.

c) The third section outlines some of the prominent features of ENERGY. It also includes a summary flow diagram of the ENERGY program.

2.1 ENERGY CALCULATION & RETROFIT ANALYSIS

A house at the design stage is chosen. The monthly load on the house is then determined by the following equation:

$$Load_{mon} = ((UA_{cond} + UA_{inf}).DD(@T_i).(0.0864) \pm Q_f)_{mon} \qquad 2.1$$

Where:

UA_{cond} is the conduction UA-value (W/^oC).

UA_{inf} is the monthly infiltration equivalent UA-value (W/^oC). It is described in detail in chapter III.

$DD(@T_i)$ is the monthly heating or cooling degree days to the base T_i (^oC-day/month).

T_i is the heating or cooling season indoor temperature setting (^oC).

0.0864 is the conversion factor in (MJ/W/day).

Q_f is the monthly free heat, and consists of monthly solar and average monthly internal gains, +ve for cooling and -ve for heating season (MJ/month).

Subscript 'mon' denotes a monthly value.

The total seasonal load is determined by adding the monthly loads in that season.

$$\text{Total Seasonal Load} = \sum_{n} Load_{mon}$$

where:

n is the no. of months in the heating or cooling season.

When the retrofits are applied to the house; the UA-values, free heat and the length of the heating season may change. These changes were accommodated by introducing delta values, i.e. ΔUA_{cond}, ΔUA_{inf} and ΔQ_f. Thus, the post-retrofit monthly load on the house is given as follows.

$$(Load_{mon})_r = \{[(UA + \Delta UA)_{cond} + (UA + \Delta UA)_{inf}].DD(@T_i).(0.0864) \pm (Q + \Delta Q)_f\}_r \qquad 2.2$$

Subscript 'r' denotes the house in post-retrofit condition i.e. a retrofitted house.

The monthly load savings due to retrofitting can then be determined from the difference between monthly pre- and post-retrofit loads.

$$\text{Monthly Load Savings} = (Load_{mon})_o - (Load_{mon})_r$$

Subscript 'o' denotes the house in pre-retrofit condition i.e. an original house.

Total seasonal load savings can then be determined by the following equation:

$$\text{Seasonal Load Savings} = \sum_{n_o} (\text{Load}_{mon})_o - \sum_{n_r} (\text{Load}_{mon})_r \qquad 2.3$$

where:

n_o is number of heating or cooling months in the pre-retrofit condition.

n_r is number of heating or cooling months in the post retrofit condition.

2.2 ENGINEERING MODELS

2.2.1 Free Heat:

Free heat is defined as the utilizable energy from sources other than the heating system of the building. An accurate analysis of free heat is essential to predict the actual energy consumption for heating of the building. Free heat consists of two componenets, solar gains and internal gains. An accurate and proper analysis followed by the effective use of the energy associated with these gains could result in considerable savings to the home owner.

2.2.1a Solar Gain:

Solar gains form a major part of the free heat available in a house. There are many methods to estimate the solar contribution to the space heating, but almost all of them are quite complex and time consuming. In ENERGY the solar gain calculation has been simplified to a considerable extent.

Solar energy reduces the energy consumption for heating of the house by two processes. First, the solar energy enters the house through the transparent surfaces and is absorbed by the floor, furniture, inside wall etc., causing their surface temperature to rise. This in turn causes heat to be convected from the surface to the space air. Second, the solar radiation raises the temperature of the outside opaque surfaces of the house. This results in a reduced heat loss through the building opaque surfaces. The solar gain model used in ENERGY takes into account only the solar radiation entering through the transparent surfaces.

The solar effect on the opaque portion is assumed to be cancelled by the sky radiation. This assumption has been based on the results of the study done on four houses (House A, Villages of Riverside, Passive Solar Ranch House case 1 and case 2) using computer program CIRA. A detail description of the houses can be found in chapter IV. In the first run energy calculations were performed on the original house and the calculated sky-radiation was noted. In the second run the energy calculations were performed for the same house except for the following change. The solar gain factor for all the windows was made equal to zero to eliminate the direct solar gain through the transparent surfaces. The calculated solar gain in the second run therefore included only the solar effect on the opaque portion of the house. The monthly and seasonal values of opaque solar obtained from the second run were then compared with the sky-radiation values obtained from the first run as a percentage of heating and cooling loads. This procedure, for all the four houses, was carried out for five different cities; Ottawa, Toronto, Winnipeg, Edmonton and Detroit. The results have been included in appendix A.

The monthly comparison of opaque solar and sky radiation loss was generally within 10% for heating season. The comparison for the swing months was found to be within a 25% range. The high percentage difference in swing months is due to low heating loads in these months. The monthly cooling season discrepancy was found to be high, about 15 to 25%. This is generally due to low cooling load values.

The seasonal comparison of opaque solar and sky radiation loss was generally within 4% for heating season. The heating season comparison worsened for low heating load values, within 8%. This is quite evident from PSRH case 2 results. Case 2 is a tight, well insulated house and thus has very low heating load values. The cooling season comparison was also poor, within 15%. In general, it can be concluded, except for tight well insulated houses, that the simplifying assumption of solar effect on opaque surfaces is cancelled by sky radiation over a heating season.

The monthly solar gain through the windows, [2.1], has been calculated as follows:

$$(\text{Solar Gain})_{mon} = \sum_{i} A_i . SC_i . SGD_i . NDAY . (0.87) . F_s . S_{exp} \qquad 2.4$$

Where:

A is the area of the window in m^2.

SC is the shading coefficient and is a dimensionless quantity. It is defined : SC = (Solar Heat Gain of Fenestration)/(Solar Heat Gain of Double-Strength Glass).

SGD is the solar irradiance in $MJ/(m^2.day)$.

'i' is the index for the window orientation; east, west, north, south & horizontal.

NDAY are the number of days in the month (days/month).

0.87 is the solar gain coefficient for single pane of double strength sheet glass.

F_s is a factor to account for shading from overhangs, awnings, etc. in the south orientation only [2.2]. It is calculated for each month separately.

S_{exp} is the solar exposure modifier for the south, east and west orientation. It is defined as the fraction of total possible heating season solar radiation that reaches the house through any obstacles, such as trees, adjacent buildings or hills [2.3].

The shading coefficient accounts for the different types of fenestration and shading devices used, relating the solar heat gain through a glazing system under a specific set of conditions to the solar heat gain through the reference glazing material under the same conditions.

In general, the total solar radiation entering through the windows may not be effective in reducing the heating load of a building. The useful solar contribution could be significantly lower depending on a number of parameters such as building load, thermal storage mass, glazed area and allowable indoor temperature swings. A solar utilization factor, defined as the fraction of the total solar energy entering the house through the windows which directly contributes to the heating demand, can be calculated for each combination of these parameters.

The utilization factor may differ significantly for a building with a different combination of the above mentioned parameters. Generally, for a particular building with a very small glazing area, all the solar gain will be useful as no overheating of the space is expected to occur. Increasing the glazed area beyond a certain limit will cause space overheating and part of the solar gain has to be vented to the outdoors. This will show as a decrease in the utilization factor. The utilization factor for incremental area will reach zero at a point where all the solar gain from this area has to be vented to maintain the space at the prescribed comfort temperature level. Increasing the thermal storage capacity of the building will increase the utilization factor, as a fraction of the excess heat goes to storage to be released at a time of higher heating load (overnight).

In ENERGY the solar utilization factor has been expressed as a function of two normalized parameters, namely the "gain-load ratio" (GLR) and the "thermal mass-gain ratio" (MGR) [2.4].

The gain-load ratio is the ratio of the solar gain to the net heating load, where the heating load is the amount of heating energy required, in the absence of solar gains, to maintain the house temperature at the thermostat setting. It is defined as:

$$GLR = \frac{G_s}{HL - N_i . G_i} \qquad 2.5$$

Where:

G_s is monthly solar gain through the windows in MJ/month.

HL is the monthly total heat loss in MJ/month.

N_i is the internal gain utilization factor.

G_i is the monthly internal gain in MJ/month.

The internal gain utilization factor in ENERGY is taken equal to unity based on the following assumptions.

a) The internal gains are utilized before the solar gains.

b) Most of the internal gains in a house are released in morning and/or in evening, refer to figure F2.1, when the outside temperature is generally low.

c) The internal gains compared to the solar gains form a small fraction of the heating load.

These assumptions result in a high value of the internal gain utilization factor. Therefore, it is reasonable to take it equal to unity.

The monthly thermal mass-gain ratio is defined as:

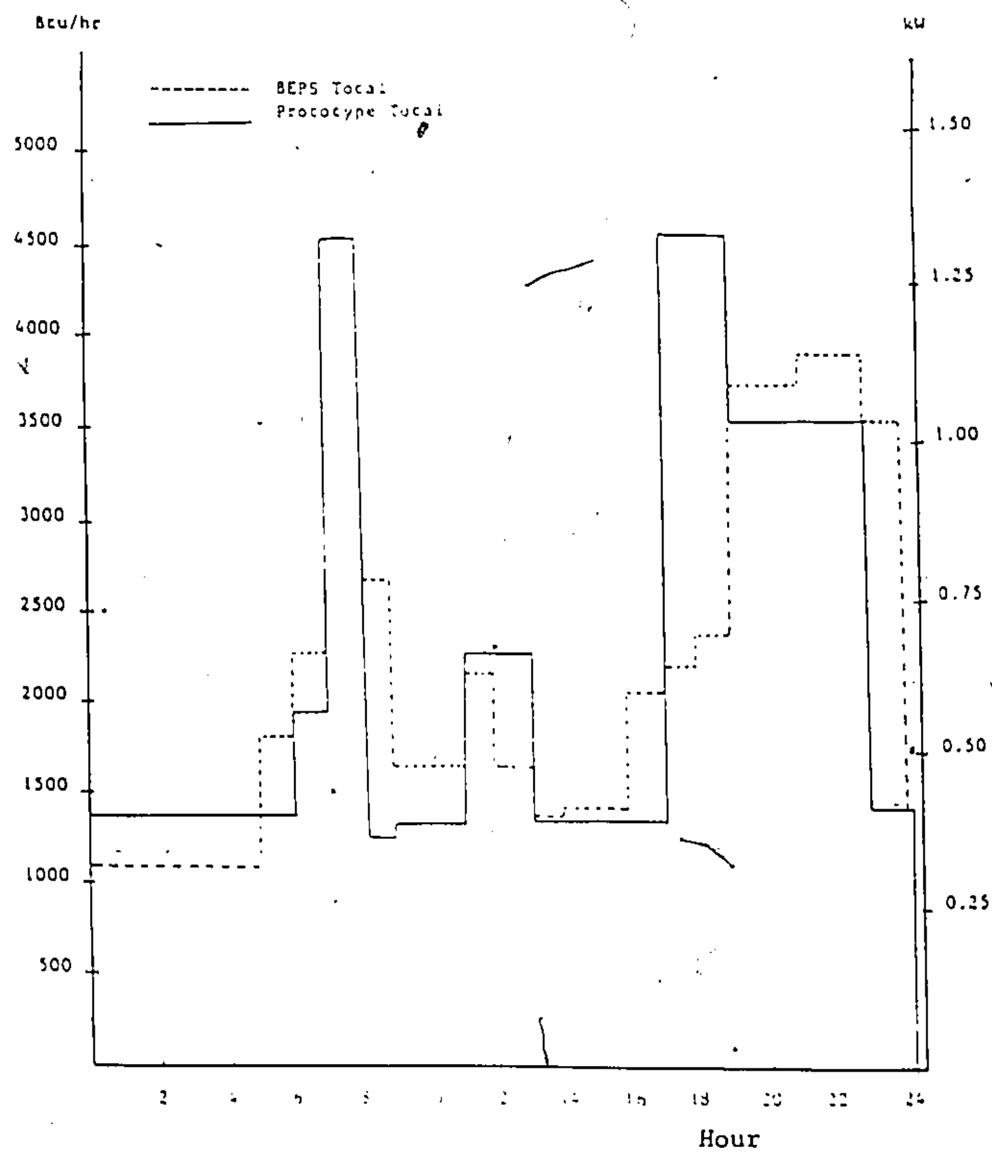
$$MGR = \frac{C}{g_s} \qquad 2.6$$

where:

C is the thermal capacity of the building interior (MJ/K.m^2 of floor area).

g_s is the average hourly solar gain for the month (MJ/hr) i.e. the average total daily solar gain for the house/24 hours.

The thermal capacity 'C' is calculated as the effective mass of the building multiplied by its specific heat. The effective mass is the mass actually available to store heat as a result of direct solar



F2.1 Representative Internal gains profile over a period of 24 hours
Source: 2.5

gains or in close contact with the room air so that any change in the room air temperature affects the mass temperature. It is taken to be the mass of the building interiors i.e. the mass on the inside of the insulation of walls and ceiling such as partition walls, gyproc layer, furniture, carpet over floor, wooden floor, fireplace bricks, etc. Typical values of thermal capacity per unit floor area are presented in the Table T3.8 for different types of construction.

The solar utilization factor N_s is a function of the allowable temperature rise, the mass-gain ratio (MGR) and the gain-load ratio (GLR). The curve fit equations are of the following form, [2.2]:

$$N_s = \frac{a + b.(GLR)}{1 + c.(GLR) + d.(GLR)^2} \qquad 2.7$$

Values of a, b, c & d are presented in table T2.1.

A comparison has been made between the solar utilization factors as calculated by the above equation and those calculated using DOE 2.1a, [appendix D]. The DOE data was from the National Research Council (NRC) report, [2.6]. It was found that the solar utilization factors calculated for different values of GLR, house mass and indoor temperature rise using Barakat's equation were always smaller than those calculated by DOE 2.1a. Based on this analysis a correction factor was added to Barakat's solar utilization factor:

$$N_s' = N_s/C_f \qquad 2.8$$

where:

C_f is defined as the ratio of solar utilization factor calculated by Barakat's equation (eq. 2.7) to solar utilization factor determined by DOE 2.1a. The variation of the C_f with different values of GLR,

TABLE T2.1 : PARAMETERS FOR CURVE FIT EQUATIONS FOR SOLAR UTILIZATION FACTOR AS A FUNCTION OF MASS GAIN RATIO (MGR) AND GAIN LOAD RATIO (GLR)
Source: [2.2]

Mass Unit	a	b	c	d
Constant Temperature 0 °C				
Light MGR = 1 hr/°C	1	6.498	5.505	12.38
Medium MGR = 2.6 hr/°C	1	5.751	5.038	7.724
Heavy MGR = 7.2 hr/°C	1	2.891	2.571	2.711
Very Heavy	1	0.5958	0.4981	0.6907
Temperature Rise 2.75 °C				
Light MGR = 1 hr/°C	1.156	-0.3479	1.117	-0.4476
Medium MGR = 2.6 hr/°C	1	4.838	4.533	3.632
Heavy MGR = 7.2 hr/°C	1	0.2792	0.245	0.423
Very Heavy	1	0.05526	-0.01721	0.3121
Temperature Rise 5.5 °C				
Light MGR = 1 hr/°C	1.112	-0.2334	0.866	-0.2611
Medium MGR = 2.6 hr/°C	1.010	0.4038	0.5574	0.4394
Heavy MGR = 7.2 hr/°C	0.995	0.0822	0.04319	0.3084
Very Heavy	0.9863	0.07736	-0.05354	0.3437
Zero Mass MGR = 0 hr/°C	1	5.04	4.013	14.18

house mass and allowable temperature rise is shown in figures F2.2 to F2.4. The curve fitting equations for the correction factor C_f are listed in the Table T2.2.

The useful solar gain for a month is therefore defined as:

$$(\text{Useful Solar Gain})_{mon} = (\text{Solar Gain})_{mon} \cdot (N_s{}')_{mon} \qquad 2.9$$

Subscript 'mon' denotes a monthly value.

Solar utilization factor for the summer season is taken to be equal to zero, as all solar gains in the cooling period contribute to the cooling load.

2.2.1b <u>Internal Gains</u>:

An accurate estimation of heating energy consumption in a building requires a proper evaluation of internal gains. The magnitude of such gains, due to people, appliances, lights, and hot water, may be estimated from occupant use data.

Calculation of internal gains is straightforward compared to solar gains. These gains are contributed by the following three sources; lights, people, and appliances.

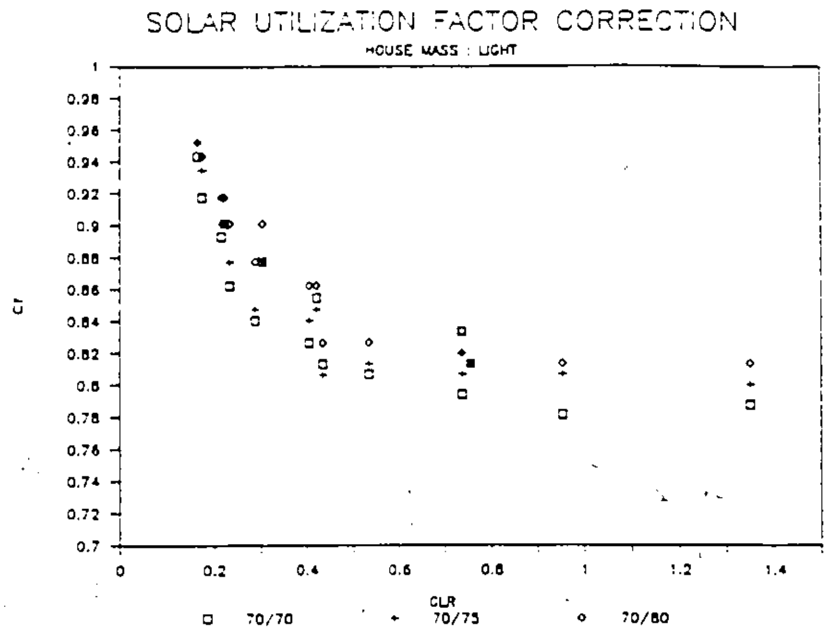
<u>Lighting</u>:

The average monthly heat gain from lights [2.7] can be calculated using the following equation :

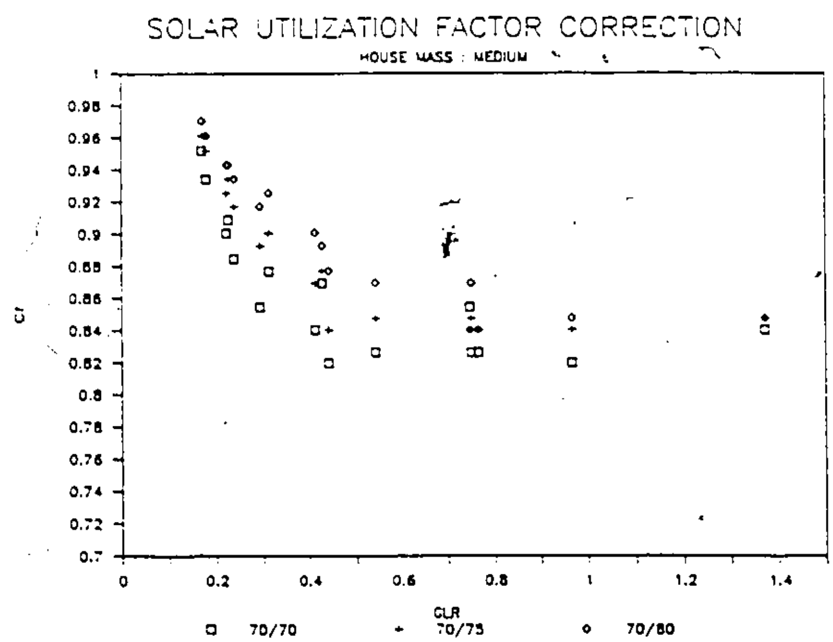
$$G_l = (\text{Total light wattage}).(\text{Use factor}).(\text{Special allowance factor}).$$
$$.(365/12).(24).(3600/10^6) \qquad 2.10$$

where:

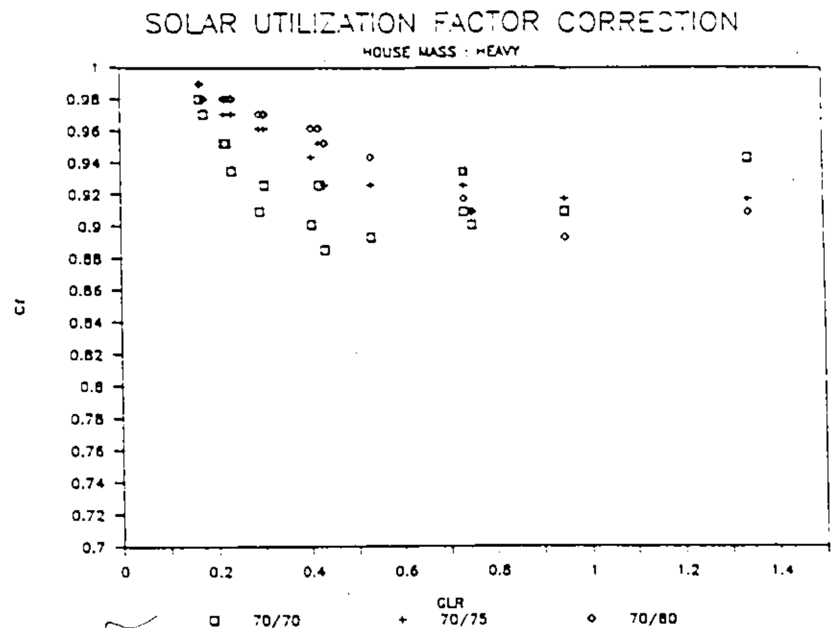
Use Factor is the ratio of the wattage in use, for the conditions under which the load estimate is being made, to the total installed wattage.



F2.2 C_f as a function of GLR for a Light house mass as determined by DOE 2.1a



F2.3 C_f as function of GLR for a Medium house mass as determined by DOE 2.1a



F2.4 C_f as a function of GLR for a Heavy house mass as determined by DOE 2.1a

TABLE T2.2 : PARAMETERS FOR CURVE FIT EQUATIONS FOR CORRECTION FACTOR C_f AS A FUNCTION OF MASS GAIN RATIO (MGR) AND GAIN LOAD RATIO (GLR)

$$C_f = A_0 + A_1.GLR + A_2.GLR^2 + A_3.GLR^3 + A_4.GLR^4 + A_5.GLR^5$$

Temperature Rise		0 °C	2.75 °C	5.5 °C
Light MGR = 1.105 hr/°C	A_0	1.16241	1.237847	1.08995
	A_1	-2.02911	-2.7211	-1.12098
	A_2	4.519666	7.139719	1.788202
	A_3	-4.49415	-9.32464	-1.29307
	A_4	1.772665	5.939912	0.34888
	A_5	-0.15687	-1.46389	0
Medium MGR = 1.99 hr/°C	A_0	1.22217	1.091534	1.46273
	A_1	-2.46657	-0.96762	-0.5608
	A_2	6.027903	1.122417	0.527374
	A_3	-6.93945	-0.0371	-0.1768
	A_4	3.70441	-0.65547	0.009639
	A_5	-0.72996	0.285672	0
Heavy MGR = 5.45 hr/°C	A_0	1.138645	1.032355	0.988754
	A_1	-1.13126	-0.31025	0.033977
	A_2	2.275972	0.220684	-0.40806
	A_3	-0.97319	0.022881	0.407051
	A_4	-0.71523	-0.04684	-0.11534
	A_5	0.491658	0	0

Special Allowance Factor is introduced for fluorescent fixtures and fixtures requiring more energy than their rated wattage.

G_1 is average monthly internal gain contributed by the lighting in MJ/month.

People:

Some practical values of the rates at which heat is given off by human beings in different states of activity and environmental conditions have been listed in the table T3.6. The values in the table T3.6 are for an adult male, the heat gain from an adult female is 85 % of that for an adult male and the gain from a child is 75 % of that for an adult male.

Appliances:

To estimate a value for heat gain from household appliances refer to the Table T3.7. It also includes an average value of internal gains from lighting energy and the occupants. The lighting energy is assumed to increase in proportion to the floor area. Note, the value of lighting energy in the table T3.7 is for a floor area of 1176 ft^2 (109 m^2). For other floor areas, scale lighting energy by floor area. The gains from the occupants are taken to be equal to 930 KWhr/yr on the assumption that there are 3.2 persons per household. For the gains from any other household appliance not included in the table T3.7 refer to tables in ASHRAE, Handbook of Fundamental 1985, [2.7].

The above calculations are for sensible internal heat gains only. The latent portion of the internal gains for a residential building is assumed to be 25% of calculated sensible internal gains and is included as load in the cooling season, [2.7].

2.2.2 <u>Weather Data</u>:

In this project, generalized weather data, [2.8], has been used to estimate energy consumption. A normalized temperature distribution over a twelve month period developed by using thirty-two years of hourly weather data has been used. In order to use this normalized distribution, three temperatures for a specified location are required. These are : T_{max}, the highest monthly average temperature, T_{min}, the lowest monthly average temperature and T_{avrg}, the yearly average temperature.

Heating and cooling degree-days to any base temperature may be calculated or determined graphically based on the above three known temperatures. Based on the degree days, an approximate length of the heating or cooling season may be determined for a building whose monthly balance point temperature is known.

In ENERGY the monthly heating or cooling degree days were calculated based on the seasonal indoor temperature setting, assuming the free heat is zero.

$$\theta_i = \frac{T_i - T_{avrg}}{T_{max} - T_{min}} \qquad 2.11$$

Where:

T_i - average seasonal (Heating or Cooling) indoor temperature setting (^oC).

T_{avrg} - average annual temperature (^oC).

T_{max} - maximum monthly average temperature for a given location (^oC).

T_{min} - minimum monthly average temperature for a given location

(^oC).

The degree days to any indoor temperature base can then be calculated for any location and period of time using the following equation :

$$DD(@T_i) = 2. \int_{N_1}^{N_2} (T_i - T)\, dN \qquad 2.12$$

or

$$= 2.(T_{max} - T_{min}) \int_{N_1}^{N_2} (\theta_i - \theta)\, dN$$

where:

T is outside temperature represented by the sinusoidal curve (^oC).

$$\theta = \frac{T - T_{avrg}}{T_{max} - T_{min}} \qquad 2.13$$

also

$$\theta = -0.5 \cos(\frac{2\pi}{365})N \qquad 2.14$$

or

$$N = \frac{365}{2\pi} \cos^{-1}(-2\theta) \qquad 2.15$$

Integrating the equation 2.12 from the start to the end of heating or cooling of the month would give us the value of the heating or cooling degree days of that month to the base θ_i. The above degree day equation is valid for any location provided that

$-0.5 < \theta_i < 0.5$

When $\theta_i > 0.5$ then $DD(@T_i) = 365(T_{max} - T_{min})\theta_i$ and if $\theta_i < -0.5$ then $DD(T_i) = 0$.

There are two equally accurate ways to arrive at the values of

T_{avrg} and $(T_{max} - T_{min})$ [2.8]. The first way is to establish these values from the daily average temperature plot working from the hourly weather tape. The second way is to use monthly average temperatures as provided by local weather stations. It should be noted, however, that when monthly average temperatures are used, the accuracy of relating the temperature curve to actual calendar dates is somewhat reduced. The accuracy can be improved by introducing a numerical constant (d = 1.0115) to fit the sine curve, [2.9]. The $(T_{max} - T_{min})$ values are multiplied by the constant " d ". The DD(@Ti) are then given by the following equation.

$$DD(@Ti) = 2.d.(T_{max}-T_{min}) \int_{N_1}^{N_2} (\theta_i - \theta)\, dN \qquad 2.16$$

ENERGY uses the daily average temperature values and the date on which the minimum temperature occurs. Monthly average temperature values and 15th of the month have been used wherever the daily average temperature values and the actual date of minimum temperature were not available. Initially, in the program the date on which the minimum temperature occurs is chosen as the reference day. The calendar year is then re-arranged evenly on the both sides of the reference day, ranging from 0 to ±182.5. The monthly T_{bal} values are calculated using the following equation

$$T_{bal} = T_i - (Q_f).(0.3807)/(UA_{cond} + UA_{inf}) \qquad 2.17$$

where:

0.3807 is the conversion factor in (W.Month/MJ).

T_{bal} is monthly balance point temperature in (^{o}C).

Monthly θ_{bal} is defined as:

$$\theta_{bal} = \frac{T_{bal} - T_{avrg}}{T_{max} - T_{min}} \qquad 2.18$$

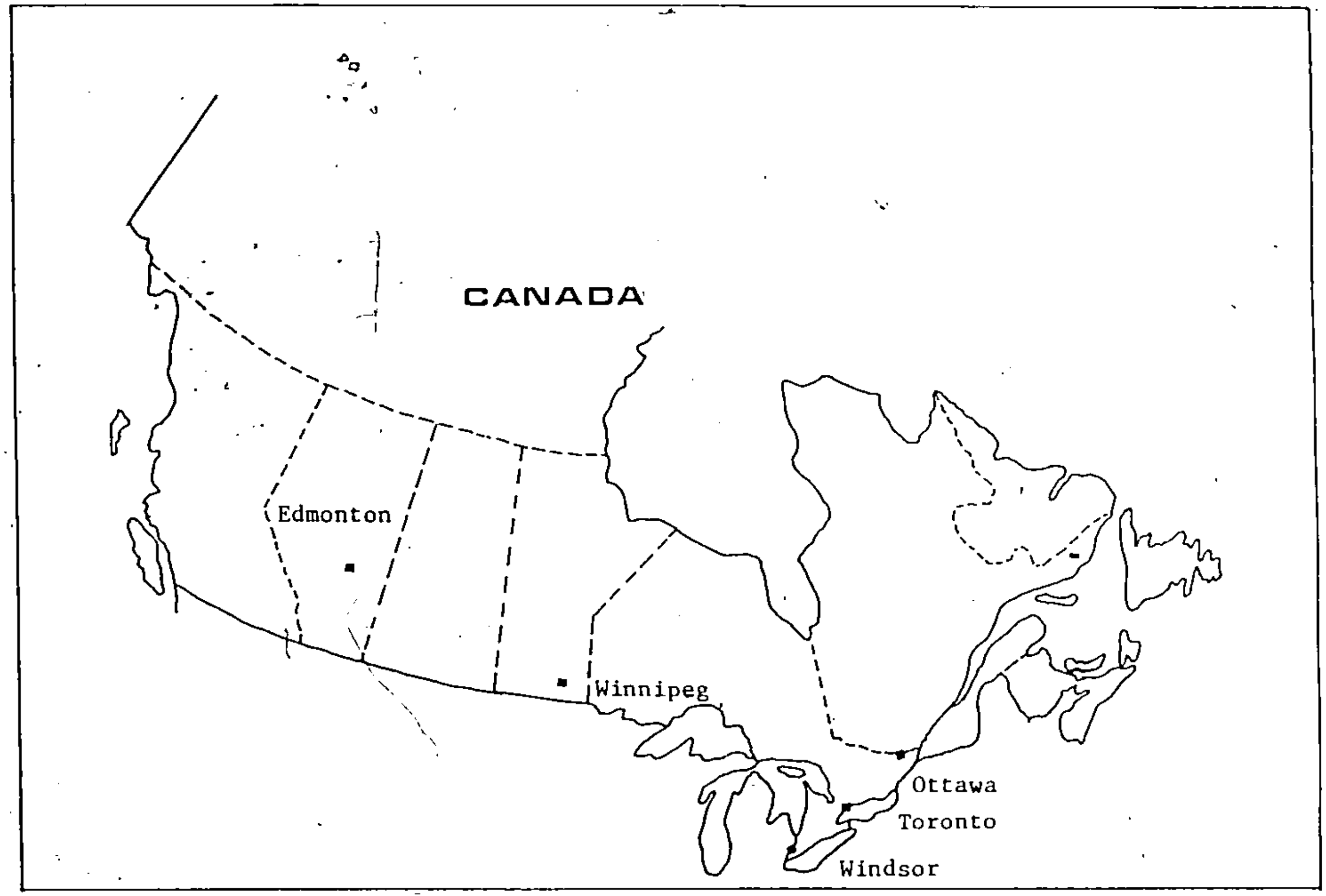
Intersection of monthly θ_{bal} and the sinusoidal temperature curve determines the start and the end of the heating season. The cooling season is determined by the intersection of the cooling θ_{bal} with the sinusoidal temperature curve.

ENERGY weather files for five different locations; Detroit (Windsor), Toronto, Winnipeg, Ottawa, and Edmonton; are presented in appendix E. These locations are shown on the map of Canada in Fig F2.5. A plot of the normalized sinusoidal curve based on daily averages of temperature is shown in the Fig F2.6.

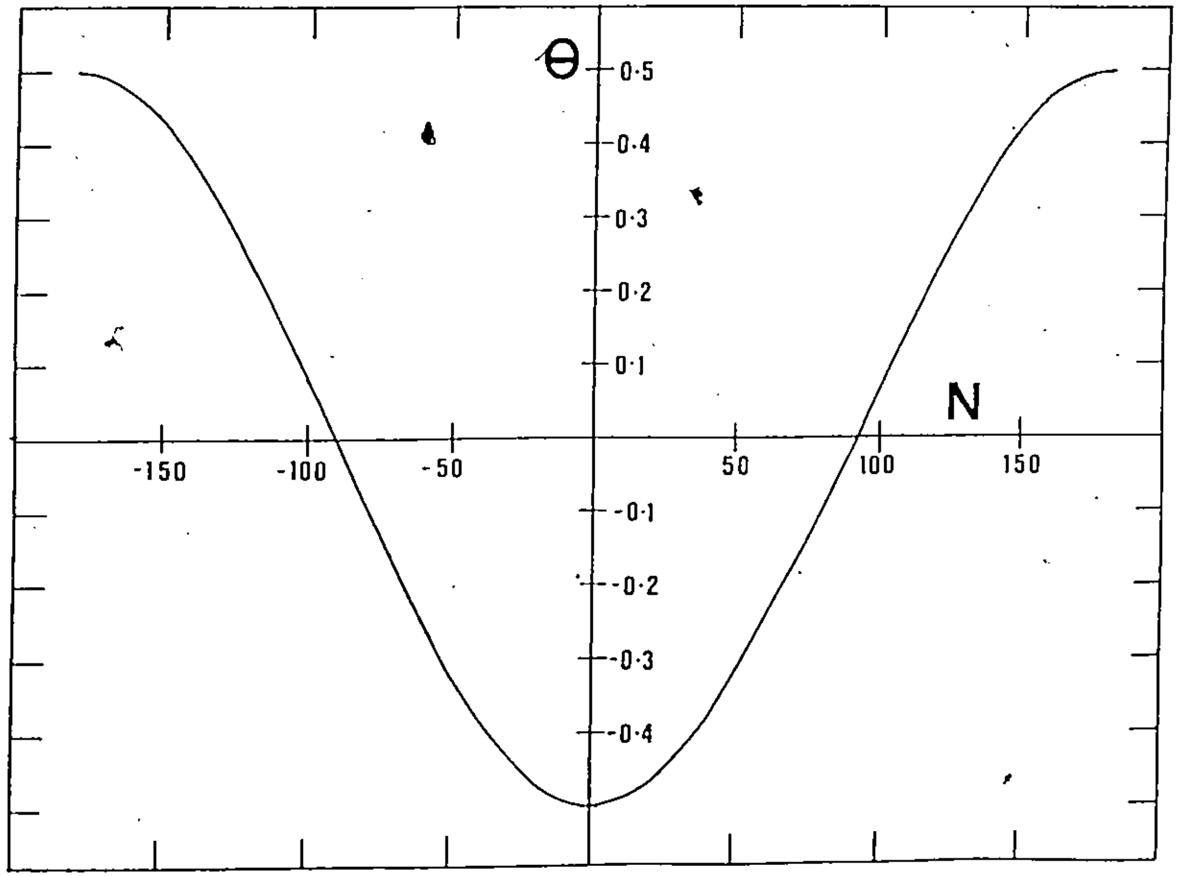
In the computer program, in addition, to T_{avrg}, T_{max}, T_{min}, and the date on which the minimum temperature occurs the following data is required; infiltration, solar radiation and latitude.

Infiltration:

The approach to determining infiltration includes precalculated monthly average specific infiltration due to the stack effect and wind effect for a reference house in reference surroundings in ($m^3/hr\text{-}cm^2$), [2.10]. The reference house is a single-story dwelling (height = 2.5m) with ceiling and floor leakage areas together equal to the wall leakage area. The reference surroundings are rural areas with low buildings and trees, and some obstructions within two house heights. Stack and wind effects for actual circumstances and actual temperature difference are determined by applying correction factors to specific infiltration values for the reference house. The correction factors are described in detail in 2.2.3 section of this chapter.



F2.5 Locations of the five cities on map of Canada



F2.6 Normalized temperature distribution over a 12 month period by using 32 years of hourly weather data
Source: 2.8

Solar Radiation:

Monthly total solar radiation on the vertical surfaces in South, North, East and West directions and monthly total solar radiation on a horizontal surface is the required solar data ($MJ/(m^2.day)$).

Latitude:

The latitude of the city in which the house is located is provided in order to determine shading from overhangs on south windows (degrees).

2.2.3 Infiltration Model:

An accurate estimation of infiltration is very important for a proper energy analysis. On the other hand, there is almost no method which would predict infiltration accurately without any measurement. The air infiltration model used in ENERGY was developed by Sherman and Grimsrud, [2.11]. The model calculates infiltration for a structure for any weather condition if leakage area and distribution are known. The functional form of the model, along with a description of the important assumptions, is presented below.

The total monthly infiltration for any house is given by:

$$Q_{inf} = L.((C_s.q_s)^2 + (C_w.q_w)^2 + (q_u)^2)^{1/2} \qquad 2.19$$

where:

Q_{inf} is the total infiltration in (m^3/Hr).

q_s is the monthly specific stack induced infiltration in ($m^3/(Hr.cm^2)$).

q_w is the monthly specific wind induced infiltration in ($m^3/(Hr.cm^2)$).

q_u is the unbalanced mechanical ventilation flow in ($m^3/(Hr.cm^2)$).

L is the total equivalent leakage area in cm^2.

C_s and C_w are factors to correct for the non-standard house in non-standard surroundings.

$C_s = 8.15.C'.(1-R)^{1/3}.\alpha.(Ht/10)^{\gamma}$

$C_w = 1.60.(1+R/2)(1-(X/(2-R)^2)^{3/2}./Ht/10$

$R = (L_c + L_f)/L$

$X = (L_c - L_f)/L$

L_c is the ceiling leakage area in (cm^2).

L_f is the floor leakage area in (cm^2).

α and γ are the terrain parameters for the house; refer to the Table T3.23.

C' is a local shielding parameter; refer to the Table T3.24.

Ht is the house height from grade level in m.

From the definition of R and L it can be seen that the floor and ceiling leakage areas have to be calculated or measured. In principle, to determine the leakage areas of the floor and ceiling could be a cumbersome and time-consuming procedure. Instead, position of the major leakage sites in the building shell are noted, and the leakage areas of these sites are subtracted from the total value measured for the house. The remaining leakage area is assumed to be distributed uniformly over the shell. A more rigorous measurement procedure is not required, since the model predictions are insensitve to changes in R and X. Further, it is reasonable to assume a value of R = 0.5 and X = 0.0 if the floor and ceiling leakage areas cannot be determined, [2.12]. In other words, the floor and ceiling leakage areas each are 1/4 of the total leakage area.

The model does not consider the directional effects of wind. For a house in an urban site, the wind direction may not be a critical factor since the surrounding buildings provide a good shielding and deflection of wind. For an isolated building, however, this can be a major limitation, since the wind direction would have a significant effect on infiltration.

2.3 COMPUTER PROGRAM : ENERGY

With the widespread availability of inexpensive computers, it is now possible to automate routine calculations. This section describes prominent features of the computer program ENERGY written on LOTUS 1-2-3 spreadsheet and can be run on versions 1A and 2.01. The program is capable of estimating the space heating and cooling requirements of residences. The method involves a month-by-month calculation of the space heating or cooling load of a residential building. Some features of the program are as follows:

1. The input data is in SI units.
2. Weather data for five Canadian cities are included.
3. The program accounts for internal heat gains from lights, appliances, and from occupants.
4. Passive solar gains through windows are accounted for using a technique developed by Barakat and Sander [2.4]. Their method allows one to account for different thermal capacities of the house.
5. The program approximates the heating and cooling periods based on UA-value, location, solar and internal gains, and indoor temperature setting of the residence.

6. Retrofit energy analysis can be performed in a short period of time.

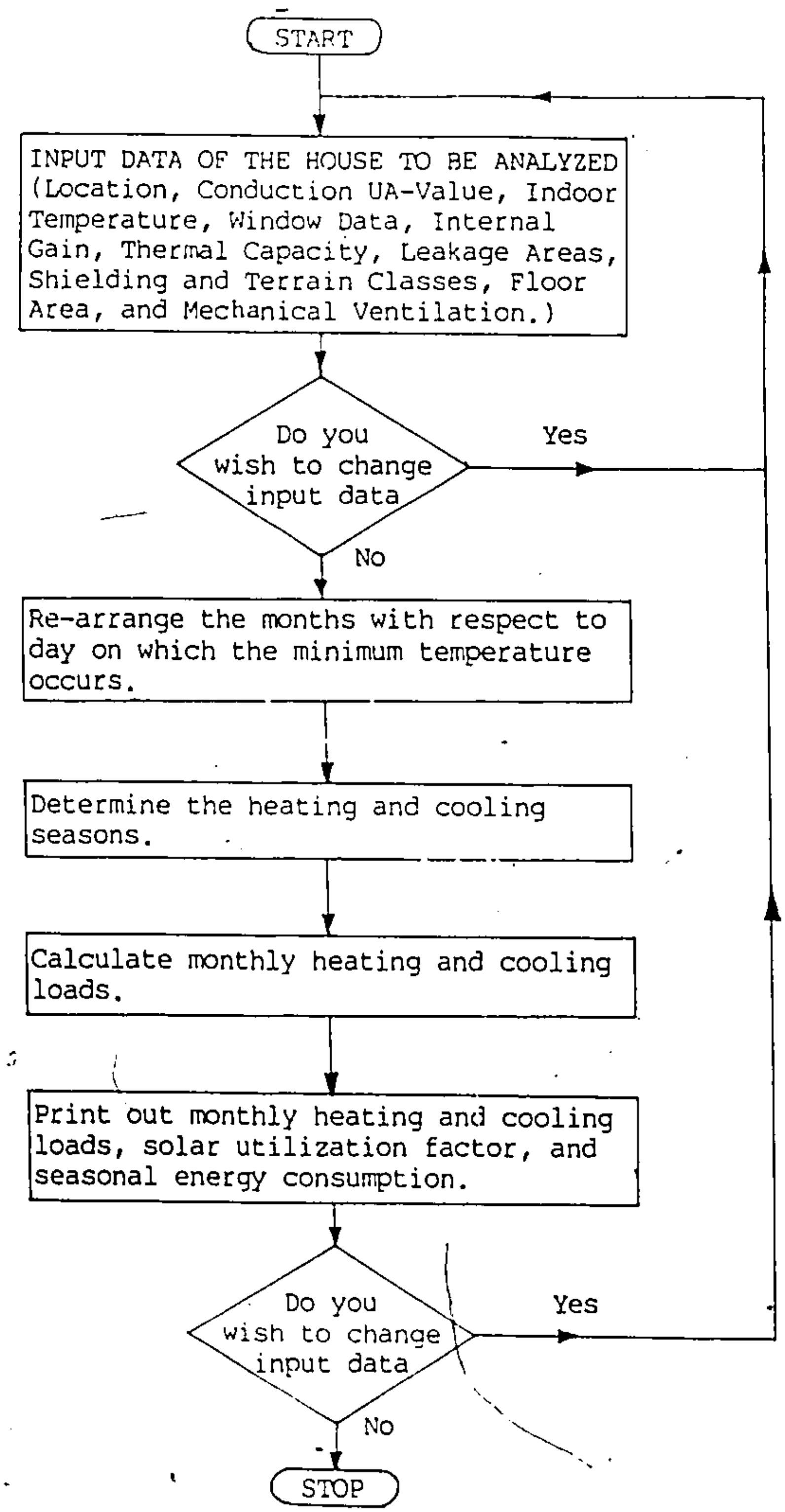
7. The program can be run on IBM compatible computers. With some modifications, however, the program could be translated for use on software like Symphony, Dbase III, etc. The source listing of the program has been supplied to the supervisor of the thesis.

8. A very short time is required to perform energy calculations (approximately one minute).

9. Graphics package of LOTUS 1-2-3 can be used for visual comparison.

2.3.1 Computer Program Structure:

The computer program structure is presented in flow chart figure F2.7. The user can return to the input section at two locations to alter input data. This feature is useful both to correct any possible errors in typing in the data and to perform parametric variations to determine the effect of varying the values of certain components. Further, the house data can be stored and saved on the disk for future use.



F2.7 Summary Flow Diagram

CHAPTER III

USER GUIDE

INTRODUCTION

This chapter includes step by step instructions for running the ENERGY program. A sample run has been included in the appendix I to illustrate the various features of the program.

The chapter has been divided into two sections:

1) Input guide and execution.

2) Output guide and interpretation of the results.

Note: The ENERGY program can only be used with LOTUS 1-2-3 spreadsheet and is directed to users who already own LOTUS 1-2-3 program.

3.1 INPUT GUIDE AND EXECUTION

3.1.1 Getting Started:

ENERGY has been designed to be as user friendly as possible. The best way to become familiar with the ENERGY program is to turn on the micro-computer and start using the program, but before using the program read this chapter thoroughly.

To Start:

1. Switch on the computer and load the DOS.
2. Then insert the LOTUS disc in drive " A " and ENERGY disc in the drive " B ".
3. Type " LOTUS " and press return, this should load LOTUS on the computer.

4. The main menu of LOTUS 2.01 will appear on the screen.

Display:

```
1-2-3  PrintGraph  Translate  Install  View  Exit
Enter 1-2-3 -- Lotus Worksheet/Graphics/Database program

                     1-2-3 Access System
                        Copyright 1986
                 Lotus Development Corporation
                     All Rights Reserved
                         Release 2.01

The  Access  System lets you choose 1-2-3,  PrintGraph,  the  Tranlate
utility the Install program, and A View of 1-2-3 from the menu at  the
top  of  this screen.  If you're using a diskette system,  the  Access
System may prompt you to change disks.  Follow the instructions  below
to start a program.

o   Use [RIGHT] or [LEFT] to move the menu pointer (the highlight  bar
    at the top of the screen) to the program you want to use.

o   Press [RETURN] to start the program.

You  can also start a program by typing the first letter of  the  menu
choice.  Press [HELP] for more information.
```

5. Use right or left arrow keys to highlight '1-2-3'. Then press RETURN.

Display :

```
A1:                                                               READY

           A        B        C        D        E        F        G        H
1
2
```

6. Press '/' (slash) key to display the menu.

Display:

```
A1:                                                                MENU
Worksheet  Range  Copy  Move  File  Print  Graph  Data  System  Quit
Global, Insert, Delete, Column, Erase, Titles, Window, Status, Page
           A      B      C      D      E      F      G      H
1
2
```

7. Highlight 'File' using the arrow keys and press RETURN.

Display:

```
A1:                                                                MENU
Retrieve  Save  Combine  Xtract  Erase  List  Import  Directory
Erase the current worksheet and display the selected worksheet
           A      B      C      D      E      F      G      H
1
2
```

8. Highlight 'Retrieve' and press RETURN.

Display:

```
A1:                                                                EDIT
Name of file to retrieve: ENERGY

           A      B      C      D      E      F      G      H
1
2
```

9. Type ENERGY and press RETURN.

<u>This menu should now appear on your screen</u>:

COMMAND MENU	Display	Print
House Data Input Section ----------------------------	A	B
Command and Report Menu ----------------------------	Z	R
Load Previously Entered House Data -------------	P	
Calculate Energy --------------------------------	C	
Save and Quit -----------------------------------	Q	
Quit Without Saving -----------------------------	W	

REPORT MENU

		Display	Print
Pre-Retrofit	Heating Report # 1 -------------	D	J
	Heating Report # 2 -------------	E	K
	Cooling Report -----------------	F	L
Post-Retrofit	Heating Report # 1 -------------	G	M
	Heating Report # 2 -------------	H	N
	Cooling Report -----------------	I	O

(Press 'Alt' & corresponding letter key simultaneously)

10. At this point the user can choose the desired section by pressing 'Alt' and the corresponding letter keys simultaneously.

3.1.2 <u>Input Section</u>:

Data for a residential structure can be entered in the HOUSE DATA INPUT SECTION. This section can be accessed from the report menu by pressing 'Alt' & 'A' keys at the same time. There are thirteen self-explanatory inputs required to run ENERGY successfully. The user can also input retrofit data in the retrofit column. The retrofit values can be either a +ve or a -ve change in the component. Once all the house data has been entered, the program can continue to the energy calculation. As it calculates, it displays a short message: 'Calculating, please wait'. The energy and retrofit calculation takes about one minute to complete. After the calculation the program returns to the REPORT MENU, at this point you can print or display heating and cooling load reports. Details of the output are given in the 'Output Guide' section. The input questions asked are shown below:

```
     RESIDENTIAL BUILDING ENERGY CONSUMPTION CALCULATION
     ----------------------------------------------------
1) Location (enter a number from 1 - 5)  ........   'G4'
1-Detroit,2-Toronto,3-Ottawa,4-Winnipeg,5-Edmonton

HOUSE NAME :    'C7'      'D7'                    HOUSE    RETROFIT
HOUSE VARIABLE                                    DATA     (DELTA)
-------------------------------------------------------------------

2) Conduction Coefficient in W/C ................  'G11'     'H11'

3) Indoor Temperature in C
   Heating Season ...............................  'G14'     'H14'
   Cooling Season ...............................  'G15'     'H15'

4) Window Data
   Area                Horizontal ................  'G18'     'H18'
   (in sq.m)           East ......................  'G19'     'H19'
                       West ......................  'G20'     'H20'
                       South .....................  'G21'     'H21'
                       North .....................  'G22'     'H22'

   Shading             Horizontal ................  'G24'     'H24'
   Coefficient         East ......................  'G25'     'H25'
   (0 to 1)            West ......................  'G26'     'H26'
                       South .....................  'G27'     'H27'
                       North .....................  'G28'     'H28'

   Solar Exposure      East ......................  'G30'     'H30'
   (0 to 1)            West ......................  'G31'     'H31'
                       South .....................  'G32'     'H32'

   South Window        Overhang Protrusion .......  'G34'     'H34'
   (all in m)          Height above top of Window.  'G35'     'H35'
                       Average Window Height .....  'G36'     'H36'

5) Average monthly Internal Gains in MJ/Month ...  'G38'     'H38'

6) Thermal Capacity of the house in MJ/(K.sq.m) .  'G40'     'H40'

7) Temperature Rise in C (Enter 0, 2.75 or 5.5)..  'G42'     'H42'

8) Leakage areas
   Ceiling Leakage Area in sq.cm ................  'G45'     'H45'
   Floor Leakage Area in sq.cm ..................  'G46'     'H46'
   Total Leakage Area in sq.cm ..................  'G47'     'H47'
```

9)	Terrain Class (enter 1 to 5 only)	'G49'	'H49'
10)	Shielding Class (enter 1 to 5 only)	'G51'	'H51'
11)	Living Space Height in m	'G53'	'H53'
12)	Mechanical Ventilation in Cu.m/Hr	'G55'	'H55'
13)	House Floor area in sq.m	'G57'	'H57'

Have you fed in all the data? If yes then :
Press the 'Alt' key and letter 'C' simultaneously

3.1.2a An input session with ENERGY:

1. Location:

Enter a corresponding whole number from 1 to 5 for the selected city in cell 'G4'. The following five cities are available:

Number	City
1	Detroit
2	Toronto
3	Ottawa
4	Winnipeg
5	Edmonton

2. Conduction Coefficient in W/°C:

Enter conduction UA-value for the house in W/°C in cell 'G11'. Retrofits can also be included in cell 'H11', make sure to indicate +ve (increase) or -ve (decrease) change.

3. Indoor Temperature in °C:

Heating Season

Enter heating season indoor temperature setting in °C in cell

'G14'. In cell 'H14' enter a +ve or -ve retrofit change in the indoor temperature setting.

Cooling Season

Enter cooling season indoor temperature setting in ^oC in cell 'G15'. In cell 'H15' indicate +ve or -ve retrofit change in the indoor temperature.

5. Window Data:

Area in m^2

Enter total area of the windows for different orientations; i.e. Horizontal, East, West, South, and North; in cells 'G18' to 'G22'. In corresponding 'H18' to 'H22' cells indicate a +ve or -ve retrofit change in the window area.

Shading Coefficient

Enter shading Coefficients for the windows in the column 'G24' to 'G28' and indicate any +ve or -ve change in corresponding column 'H24' to 'H28'. The shading coefficient values can be found in tables T3.1 to T3.5. In a situation where one (or more) orientation has two (or more) SC values then input an average SC value, i.e. weighted average with respect to the window area, for example:

$$SC_{avg} = \frac{SC_1.WA_1 + SC_2.WA_2 + \ldots\ldots}{WA_1 + WA_2 + \ldots\ldots} \qquad 3.1$$

where:

SC_1 and SC_2 are the shading coefficient values of the windows with areas WA_1 and WA_2 respectively.

SC_{avg} is the shading coefficient value which should be entered in

TABLE T3.1 : SHADING COEFFICIENTS FOR SINGLE GLASS AND INSULATING GLASS(a)
Source: [3.1]

Type of Glass	Nominal Thickness(b)	Solar Trans.(b)	Shading Coefficient h_o=22.7	Shading Coefficient h_o=17.0
A. Single Glass				
Clear	3 mm	0.86	1.00	1.00
	6 mm	0.86	0.94	0.95
	10 mm	0.72	0.90	0.92
	12 mm	0.67	0.87	0.88
Heat Absorbing	3 mm	0.64	0.83	0.85
	6 mm	0.46	0.69	0.73
	10 mm	0.33	0.60	0.64
	12 mm	0.24	0.53	0.58
B. Insulating Glass				
Clear Out, Clear in	3 mm(c)	0.71(e)	0.88	0.88
Clear Out, Clear in	6 mm	0.61	0.81	0.82
Heat Absorbing(d) Out, Clear in	6 mm	0.36	0.55	0.58

(a) Refers to factory-fabricated units with 5, 6 or 12 mm air space or to prime windows plus storm sash.
(b) Refer to manufacturer's literature for values.
(c) Thickness of each pane of glass, not thickness of assembled unit.
(d) Refers to gray, bronze and green tinted heat-absorbing float glass.
(e) Combined transmittance for assembled unit.

TABLE T3.2 : SHADING COEFFICIENTS FOR SINGLE GLASS WITH INDOOR SHADING BY VENETIAN BLINDS OR ROLLER SHADES
Source: [3.1]

	Nominal Thickness mm	Solar Trans.(b)	Type of Shading: Venetian Blinds		Roller Shade: Opaque		Roller Shade: Translucent
			Medium	Light	Dark	White	Light
Clear	2.5 - 6	0.87-0.80					
Clear	6 - 12	0.80-0.71					
Clear Pattern	3 - 12	0.87-0.79	0.64	0.55	0.57	0.25	0.39
Heat-Absorbing Pattern	3	--					
Tinted	5 - 5.5	0.74,0.71					
Heat-Absorbing(d)	5 - 6	0.46					
Heat-Absorbing Pattern	5 - 6	--	0.57	0.53	0.45	0.30	0.36
Tinted	3 - 5.5	0.59,0.45					
Heat-Absorbing or Pattern	--	0.44-0.30	0.54	0.52	0.40	0.28	0.32
Heat-Absorbing(d)	10	0.34					
Heat-Absorbing or Pattern	--	0.29-0.15 0.24	0.42	0.40	0.36	0.28	0.31
Reflective Coated Glass S.C.(c) = 0.30			0.25	0.23			
0.40			0.33	0.29			
0.50			0.42	0.38			
0.60			0.50	0.44			

(a) Refer to manufacturer's literature for values.
(b) For vertical blinds with opaque white and beige louvers in the tightly closed position, SC is 0.25 and 0.29 when used with glass of 0.71 to 0.80 transmittance.
(c) SC for glass with no shading device.
(d) Refers to gray, bronze, and green tinted heat-absorbing glass.

TABLE T3.3 : SHADING COEFFICIENTS FOR INSULATING GLASS(a) WITH INDOOR SHADING BY VENETIAN BLINDS OR ROLLER SHADES
Source: [3.1]

Type of Glass	Nominal Thickness Each Light mm	Solar Trans.(b) Outer Pane	Solar Trans.(b) Inner Pane	Type of Shading: Venetian Blinds (c) Medium	Venetian Blinds (c) Light	Roller Shade Opaque Dark	Roller Shade Opaque White	Roller Shade Translucent Light
Clear Out Clear In	2.5,3	0.87	0.87	0.57	0.51	0.60	0.25	0.37
Clear Out Clear In	6	0.80	0.80					
Heat-Absorbing(d) Out Clear In	6	0.46	0.80	0.39	0.36	0.40	0.22	0.30
Reflective Coated Glass S.C.(e) - 0.20				0.19	0.18			
0.30				0.27	0.26			
0.40				0.34	0.33			

(a) Refers to factory-fabricated units with 5, 6 or 13 mm air space or to prime windows plus storm windows.
(b) Refer to manufacturer's literature for values.
(c) For vertical blinds with opaque white and beige louvers in the tightly closed position, SC is approximately the same as for opaque white roller shades.
(d) Refers to gray, bronze, and green tinted heat-absorbing glass.
(e) SC for glass with no shading device.

TABLE T3.4 : SHADING COEFFICIENTS FOR DOUBLE GLAZING WITH BETWEEN-GLASS SHADING
Source: [3.1]

Type of Glass	Nominal Thickness Each Light mm	Solar Trans.(a) Outer Pane	Solar Trans.(a) Inner Pane	Type of Shading: Venetian Blinds Light	Venetian Blinds Medium	Louvered Sun Screen
1) Clear Out, Clear In	2.5,3	0.87	0.87	0.33	0.36	0.43
2) Clear Out, Clear In	6	0.80	0.80	--	--	0.49
1) Heat-Absorbing(b) Out, Clear In	6	0.46	0.80	0.28	0.30	0.37
2) Heat-Absorbing(b) Out, Clear In	6	0.46	0.80	--	--	0.41

Description of Air Space :

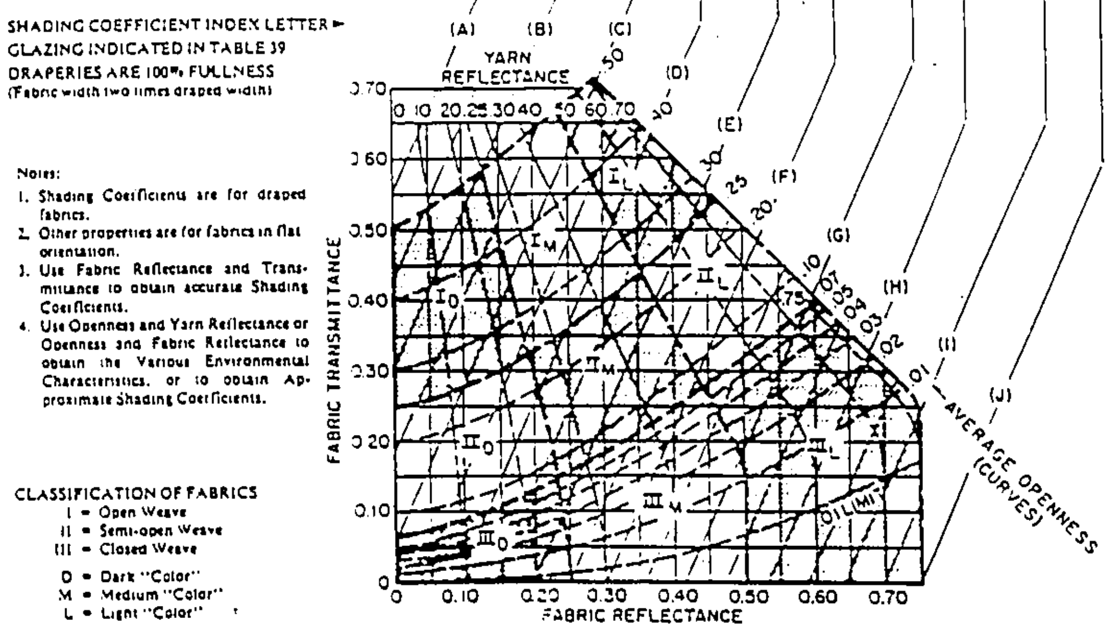
1) Shade in contact with glass of shade separated from glass by air space.
2) Shade in contact with glass-voids filled with plastic.

(a) Refer to manufacturer's literature for values.
(b) Refers to gray, bronze, and green tinted heat-absorbing glass.

TABLE T3.5 : SHADING COEFFICIENTS FOR SINGLE AND INSULATING GLASS WITH DRAPERIES.
Source: [3.1]

Glazing	Glass Trans.	Glass SC[b]	A	B	C	D	E	F	G	H	I	J
			SC for Index Letters in F3.1[a]									
Single Glass												
6 mm Clear	0.80	0.95	0.80	0.75	0.70	0.65	0.60	0.55	0.50	0.45	0.40	0.35
12 mm Clear	0.71	0.88	0.74	0.70	0.66	0.61	0.56	0.52	0.48	0.43	0.39	0.35
6 mm Heat Abs.	0.46	0.67	0.57	0.54	0.52	0.49	0.46	0.44	0.41	0.38	0.36	0.33
12 mm Heat Abs.	0.24	0.50	0.43	0.42	0.40	0.39	0.38	0.36	0.34	0.33	0.32	0.30
Reflective Coated	—	0.60	0.57	0.54	0.51	0.49	0.46	0.43	0.41	0.38	0.36	0.33
(see manufacturers' literature	—	0.50	0.46	0.44	0.42	0.41	0.39	0.38	0.36	0.34	0.33	0.31
for exact values)	—	0.40	0.36	0.35	0.34	0.33	0.32	0.30	0.29	0.28	0.27	0.26
	—	0.30	0.25	0.24	0.24	0.23	0.23	0.23	0.22	0.21	0.21	0.20
Insulating Glass 12 mm Air												
Space Clear Out and Clear In	0.64	0.83	0.66	0.62	0.58	0.56	0.52	0.48	0.45	0.42	0.37	0.35
Heat Abs. Out and Clear In	0.37	0.55	0.49	0.47	0.45	0.43	0.41	0.39	0.37	0.35	0.33	0.32
Reflective Coated	—	0.40	0.38	0.37	0.37	0.36	0.34	0.32	0.31	0.29	0.28	0.28
(see manufacturers' literature	—	0.30	0.29	0.28	0.27	0.27	0.26	0.26	0.25	0.25	0.24	0.24
for exact values)	—	0.20	0.19	0.19	0.18	0.18	0.17	0.17	0.16	0.16	0.15	0.15

[b] For glass alone, with no drapery.
[a] Shading Coefficient values for the SC lines in F3.1 for representative glazings. Substitute for SC index letters in F3.1 values on the line of the glazing selected.



F3.1

F3.1 Indoor Shading Properties of Drapery Fabrics
Source: [3.1]

the input section.

Solar Exposure

The solar exposure, [3.2], is the fraction of total possible solar radiation that reaches the windows through any obstacles, such as trees, adjacent buildings or hills. Enter fraction value (0 to 1) of heating season solar exposure for east, west and south direction in cells 'G30' to 'G32' and the corresponding retrofit values in cells 'H30' to 'H32'.

A house in the middle of a flat desert will have 100% or 1 solar exposure at all times. One on a large pasture in the mountains (or a house with some short trees around it) may still have almost 100% or 1 in the summer, but maybe only 30% or 0.3 fraction in the winter when the sun is low. A house in the middle of Manhattan may have a very low exposure all year.

Solar exposure can be measured directly with a " solar siting meter ", a dome-shaped device that projects the view in any direction on a horizontal surface, with an acetate overlay showing the solar path in different seasons. The solar path traces are divided into sectors each of which represent 10% or 0.1 of the total daily radiation. So if three sectors are covered up by surrounding trees and hills, the solar exposure will be 70% or 0.7.

If you do not have such a device, try to project the path of the sun from horizon to horizon during the appropriate months (otherwise it must be estimated). Remember, the sun will be quite high in the sky during the summer and low in the winter. Also remember that the greatest insolation occurs during the middle of the day.

South Window

a) Overhang Protrusion in m : An overhang above a window includes awnings, horizontal shades, balconies or the roof itself. It is measured horizontally out from the plane of the window. Enter the house data value in cell 'G34' and the retrofit value in cell 'H34'

b) Height above top of window in m : It is measured vertically from the top of the sash to the height of the outer tip of the overhang. Enter the house and retrofit data values in cells 'G35' and 'H35' respectively.

c) Average window height in m: It is the average distance from sill (bottom) to header (top). Enter window height in cell 'G36' and the corresponding retrofit value in cell 'H36'.

5. Average monthly internal gains in MJ/month:

Input average monthly internal gains in MJ/month in cell 'G38'. The internal gains include the heat gain from appliances, occupants, lighting, etc. An approximate estimate of internal gains can be made by using tables T3.6 & T3.7. Enter the +ve or -ve retrofit change in cell 'H38'

6. Thermal capacity of the house in MJ/(^{o}K.m^{2}):

Enter thermal capacity of the house in MJ/(^{o}K.m^{2} of the floor area) in cell 'G40' and any retrofit value in 'H40'. It can be selected from the table T3.8. The retrofit column should include any +ve or -ve change in the thermal capacity.

TABLE T3.6 : RATE OF HEAT GAIN FROM THE OCCUPANTS OF CONDITIONED SPACES
Source: [3.3]

Degree of Activity	Total heat Adult, Male (W)	Sensible Heat (W)
Seated at rest	115	60
Seated, very light work writing	140	65
Seated, eating	150	75
Seated, light work, typing	185	75
Standing, light work or walking slowly	235	90

TABLE T3.7 : ESTIMATED AVERAGE 1981 INTERNAL LOADS FOR A HOUSE HAVING 1176 SQ.FT. (109 SQ.M.) FLOOR AREA
Source: [3.4]

Source of Internal Loads	Saturation	Total Energy per unit (kWh/yr)	% Indoors	Sensible Heat Loads (kWh/yr)
New Refrigerator	1.00	1125	100	1125
Old Refrigerator	0.15	600	50	45
Cooking Range	1.00	1200	100	800
Freezer	0.45	950	50	214
Lighting/1176 sq.ft.	1.00	1150	90	1038
Water Heater	1.00	3400	50	940
Television 2000 set hr/yr		200	100	200
Clothes Dryer	0.60	900		90
Dishwasher	0.70	250		0
Misc. Appliances				300
People	3.2/household			930
Total				5680

TABLE T3.8 : REPRESENTATIVE THERMAL CAPACITIES FOR DIFFERENT CONSTRUCTION WEIGHTS
Source: [2.2]

Thermal Capacity MJ/K.(sq.m. floor area)	Description
0.060	Standard frame construction, 12.7 mm gyproc walls and ceilings, carpet over wooden floor
0.153	As above, but 50.8 mm gyproc walls and 25.4 gyproc ceiling.
0.415	Interior wall finish of 101.6 mm brick, 12.7 mm gyproc ceiling, carpet over wooden floor
0.810	Very heavy commercial office building, 304.8 mm concrete floor

7. Accepted Temperature Rise or Swing in °C:

Accepted Temperature Rise or Swing is the allowable temperature rise above the thermostat setting. In ENERGY three temperature rises of 0.0, 2.75 and 5.5 °C can be entered. All the possible answers to this question have been listed:

Temperature Rise in °C

House Data	Possible Retrofit Data
0.0	0.0, 2.75, 5.5
2.75	-2.75, 0.0, 2.75
5.5	-5.5, -2.75, 0.0

Thus, for this particular question choose a temperature rise value from the house data and corresponding retrofit change from the possible retrofit data and enter them in cells 'G42' and 'H42' respectively. If, by mistake, any other value is entered the program will assume a 0 °C temperature swing value for both house data and retrofit data.

8. Leakage Areas:

Ceiling Leakage Area in cm^2

Enter leakage area of the ceiling in cm^2 in cell 'G45' and the +ve or -ve retrofit change in cell 'H45'. If ceiling leakage area is not available then take it as one fourth of the total leakage area of the building.

Floor Leakage Area in cm^2

Enter leakage area of the floor in cm^2 in cell 'G46' and the +ve or -ve retrofit change in cell 'H46'. It can be taken as one fourth of the total leakage area if not readily available.

Total Leakage Area in cm^2

Enter the total leakage area of the building in cm^2. It can be determined by performing a blower door test at a pressure difference of 4 Pa on the building under consideration. The house and retrofit data values should be entered in cells 'G47' and 'H47' respectively.

Note: In absence of the measured values, the leakage area of the house can also be determined using component leakage tables T3.9 to T3.21.

The floor, ceiling and total leakage areas are calculated using specific leakage information on all envelope components:

$$L = \sum_{\text{all } i} l_i \cdot A_i \qquad 3.2$$

$$L_f = \sum_{\text{all } if} l_{if} \cdot A_{if} \qquad 3.3$$

$$L_c = \sum_{\text{all } ic} l_{ic} \cdot A_{ic} \qquad 3.4$$

where:

L, L_f, L_c are the total, floor and ceiling leakage areas (cm^2)

l_i is specific leakage area of the i^{th} envelope component (cm^2) of area A_i (m^2)

f and c indicate that the component is part of the floor or ceiling.

Alternative Approach to Estimate Heating Season Infiltration:

In the absence of both the leakage area values obtained from a blower door test and calculated leakage area from specific leakage information, one can make an approximate estimate of heating season infiltration based on the type of house construction, see table T3.22.

TABLE T3.9 : COMPONENT LEAKAGE AREA
Source: [3.5]

<u>Sill Foundation - Wall</u> (a)

Component	Best Estimate	Max	Min	Unit
Sill, caulked per m of perimeter	0.8	1.2	0.4	cm^2/m
Sill, not caulked per m of perimeter	4	4	1	cm^2/m

(a) Max and Min are not in the literature. The given values of Max and Min are used in the calculations.

TABLE T3.10 : COMPONENT LEAKAGE AREA
Source: [3.5]

<u>Joints Between Ceiling and Walls</u> (a)

Component	Best Estimate	Max	Min	Unit
JOINTS per m of wall; only if not taped or plastered and no vapor barrier	0.8	1.2	0.4	cm^2/m

(a) Max and Min are not in the literature. The given values of Max and Min are used in the calculations.

TABLE T3.11 : COMPONENT LEAKAGE AREA
Source: [3.5]

Wall - Window Frame

Component	Best Estimate	Max	Min	Unit
WOOD FRAME WALL with caulking per m^2 window	0.3	0.5	0.3	cm^2/m^2
Same, no caulking	1.7	2.7	1.5	cm^2/m^2
MASONARY WALL with caulking per sq.m window	1.3	2.1	1.1	cm^2/m^2
Same, no caulking	6.5	10.3	5.7	cm^2/m^2

TABLE T3.12 : COMPONENT LEAKAGE AREA
Source: [3.5]

Wall - Door Frame

Component	Best Estimate	Max	Min	Unit
WOOD WALL with caulking per m^2 door	0.3	0.3	0.1	cm^2/m^2
Same, no caulking	1.7	1.7	0.6	cm^2/m^2
MASONARY WALL with caulking per sq.m door	1.0	1.0	0.3	cm^2/m^2
Same, no caulking	5	5	1.7	cm^2/m^2

TABLE T3.13 : COMPONENT LEAKAGE AREA
Source: [3.5]

Domestic Hot Water Systems (a)

Component	Best Estimate	Max	Min	Unit
GAS WATER HEATER; only if in conditioned space	20	25	15	cm^2 each

(a) Max and Min are not in the literature. The given values of Max and Min are used in the calculations.

TABLE T3.14 : COMPONENT LEAKAGE AREA
Source: [3.5]

Electric Outlets and Light Fixtures (a)

Component	Best Estimate	Max	Min	Unit
ELECTRIC OUTLETS AND SWITCHES Gasketed	0	0	0	each
Same, not gasketed	0.5	1.0	0	cm^2 each
RECESSED LIGHT FIXTURES	10	20	10	cm^2 each

(a) Max and Min are not in the literature. The given values of Max and Min are used in the calculations.

TABLE T3.15 : COMPONENT LEAKAGE AREA
Source: [3.5]

Pipe and Duct Penetration Through Envelope (a)

Component	Best Estimate	Max	Min	Unit
PIPE PENETRATIONS Caulked or sealed	1	2	0	cm^2 each
Same, not caulked	6	10	2	cm^2 each
DUCT PENETRATIONS sealed or with continuous vapor barrier	1.6	1.6	0	cm^2 each
Same, un-sealed and without vapor barrier	24	24	14	cm^2 each

(a) Max and Min are not in the literature. The given values of Max and Min are used in the calculations.

TABLE T3.16 : COMPONENT LEAKAGE AREA
Source: [3.5]

Fireplace

Component	Best Estimate	Max	Min	Unit
FIREPLACE W/O INSERT Damper closed	69	84	54	cm^2 each
Same, damper open	350	380	320	cm^2 each
FIREPLACE WITH INSERT Damper closed	36	46	26	cm^2 each
FIREPLACE WITH INSERT Damper open or absent	65	90	40	cm^2 each

TABLE T3.17 : COMPONENT LEAKAGE AREA
Source: [3.5]

Exhaust Fans

Component	Best Estimate	Max	Min	Unit
KITCHEN FAN Damper closed	5	7	3	cm^2 each
Same, damper open	39	42	36	cm^2 each
BATHROOM FAN, Damper closed	11	12	10	cm^2 each
Same, damper open	20	22	18	cm^2 each
DRYER VENT Damper closed (a)	3	6	0	cm^2 each

(a) Max and Min are not in the literature. The given values of Max and Min are used in the calculations.

TABLE T3.18 : COMPONENT LEAKAGE AREA
Source: [3.5]

Air Conditioner (a)

Component	Best Estimate	Max	Min	Unit
AIR CONDITIONER Wall or window unit	24	36	0	cm^2 each

(a) Max and Min are not in the literature. The given values of Max and Min are used in the calculations.

TABLE T3.19 : COMPONENT LEAKAGE AREA
Source: [3.5]

<u>Heating Ducts and Furnace</u>

Component	Best Estimate	Max	Min	Unit
FORCED AIR SYSTEMS				
DUCTWORK (only if in unconditioned space)				
Duct joints taped or caulked	72	72	32	cm^2 per house
Duct joints not taped or caulked	144	144	72	cm^2 per house
FURNACE (only if in conditioned space)				
Sealed Combustion furnace	0	0	0	cm^2 each
Retention head burner furnace (a)	30	40	20	cm^2 each
Retention head plus stack damper (a)	24	30	18	cm^2 each
Furnace with stack damper (a)	30	40	20	cm^2 each

(a) Max and Min are not in the literature. The given values of Max and Min are used in the calculations.

TABLE T3.20 : COMPONENT LEAKAGE AREA
Source: [3.5]

Doors

Component	Best Estimate	Max	Min	Unit
SINGLE DOOR Weatherstripped per sq.m door	8	15	3	cm^2/m^2
Same, not weatherstripped	11	17	6	cm^2/m^2
DOUBLE DOOR Weatherstripped per sq.m door	8	15	3	cm^2/m^2
Same, not weatherstripped	11	22	7	cm^2/m^2
ACCESS TO ATTIC OR CRAWL-SPACE Weatherstripped per access (a)	18	18	8	cm^2 each
Same, not weatherstripped (a)	30	30	10	cm^2 each

(a) Max and Min are not in the literature. The given values of Max and Min are used in the calculations.

TABLE T3.21 : COMPONENT LEAKAGE AREA
Source: [3.5]

Windows

Component	Best Estimate	Max	Min	Unit
CASEMENT Weatherstripped per sq.m window	0.8	1.2	0.4	cm^2/m^2
Same, not weatherstripped	1.6	2.4	0.8	cm^2/m^2
AWNING Weatherstripped per sq.m window	0.8	1.2	0.4	cm^2/m^2
Same, not weatherstripped	1.6	2.4	0.8	cm^2/m^2
SINGLE HUNG Weatherstripped per sq.m window	2.2	2.9	1.8	cm^2/m^2
Same, not weatherstripped	4.4	5.8	3.6	cm^2/m^2
DOUBLE HUNG Weatherstripped per sq.m window	3.0	4.4	1.6	cm^2/m^2
Same, not weatherstripped	6.0	8.8	3.2	cm^2/m^2
SINGLESLIDER Weatherstripped per sq.m window	1.8	2.7	0.9	cm^2/m^2
Same, not weatherstripped	3.6	5.4	1.8	cm^2/m^2
DOUBLESLIDER Weatherstripped per sq.m window	2.6	3.8	1.4	cm^2/m^2
Same, not weatherstripped	5.2	7.6	2.8	cm^2/m^2

TABLE T3.22 : AIR CHANGE RATE BASED ON HOUSE TYPE
Source: [3.6]

House Type	Infiltration Rate
New energy-efficient construction	0.50 ach
Older, low-income housing	1.05 ach

Using the air change rate values from table T3.22 total house infiltration can be calculated:

$$Q_{inf} = (\text{Air change rate})(\text{House Volume})/\ 3600 \qquad 3.5$$

Q_{inf} is the total house infiltration in (m^3/s)

UA_{inf} is calculated as follows:

$$UA_{inf} = (\rho_{air})(1.005)(Q_{inf}) \qquad 3.6$$

ρ_{air} is the density of the air, in Kg/m^3

1.005 is the specific heat of air, in $KJ/(Kg.^{o}C)$

UA_{inf} can then be added to the UA_{cond} to obtain an overall UA-value for the house. The overall UA-value should be used in place of UA_{cond} in question 2 of the input section.

<u>Note</u>: If the overall UA-value is used then enter all leakage areas equal to zeros.

9. Terrain Class:

Terrain class accounts for the fact that the wind measured on a weather tower will not be the same as the effective wind speed at the structure. To compensate for this effect, standard wind engineering formulae are used to translate the wind in one terrain at one height to the wind in another terrain at another height. Typical values for the terrain parameters are presented in the table . Your answer will be used to adjust the standard values for air infiltration to fit your own location. Answer with a whole number between 1 and 5 in cell 'G49', using the table T3.23. For retrofit data value enter an integer between -5 or +5 in cell 'H49'.

10. Shielding Class:

Enter the shielding class, a whole number between 1 and 5 in cell 'G51', from table T3.24. This class describes the shielding around the structure i.e. by how much a building is shielded by objects in the immediate vicinity (within a few house heights). The description of each shielding class and their respective shielding coefficients are displayed in table T3.24. Your answer will be used to adjust the standard values for air infiltration to fit your own location. For retrofit value enter an integer between -5 and +5 in cell 'H51', using the table T3.24.

11. Living space height in m:

Enter the living space height in metres in cell 'G53'. The height of the living space is the height from exterior grade to the highest ceiling in the living space. This is necessary in order to calculate the infiltration rate caused by stack effect. Input a +ve or -ve retrofit change in cell 'H53'.

12. Mechanical Ventilation in m^3/ hr:

Mechanical Ventilation includes any fans that provide forced ventilation (in addition to natural air infiltration). Included are

TABLE T3.23 : TERRAIN PARAMETERS FOR STANDARD TERRAIN CLASSES
Source: [2.3]

Class	Gamma	Alpha	Description
I	0.10	1.30	Ocean or other body of water with at least 5 km of unrestricted expanse
II	0.15	1.00	Flat terrain with some isolated obstacles (e.g. buildings or trees well separated from each other)
III	0.20	0.85	Rural areas with low buildings, trees, etc.
IV	0.25	0.67	Urban, industrial or forest areas
V	0.35	0.47	Center of big city (e.g. Detroit)

TABLE T3.24 : LOCAL SHIELDING PARAMETERS
Source: [2.3]

CLASS	C′	Description
I	0.324	No obstruction or local shielding whatsoever, e.g. desert
II	0.285	Light local shielding with few obstructions. Perhaps a few trees or a small shed.
III	0.240	Moderate local shielding, some obstructions within two house heights. A thick hedge or a solid fence, or one neighboring house.
IV	0.185	Heavy shielding; obstructions around most of perimeter. Buildings or trees within 30 ft in most directions. Typical suburban shielding.
V	0.102	Very heavy shielding, large obstructions surrounding perimeter within two house heights. Typical downtown shielding.

kitchen fans, whole-house fans or fresh-air systems with air intakes and/or exhausts. Enter average monthly ventilation rate in m^3/hr in cell 'G55' and the corresponding +ve or -ve retrofit change in cell 'H55'.

13. Floor area of the house in m^2:

The Floor Area is the heated or cooled living space area. A two-storey house with 2 floors of 150 m^2 each would therefore have a floor area of 300 m^2. Include the basement floor area if it is heated. Enter the house data and +ve or -ve retrofit change in cells 'G57' and 'H57' respectively.

3.2 OUTPUT GUIDE AND INTERPRETATION OF THE RESULTS

ENERGY produces two different outputs. The first is a pre-retrofit energy analysis, i.e data on month by month heating and cooling loads, solar gain, solar utilization factor and so on. This data is presented in tabular form, it can also be viewed in graphic form using the graphic package of LOTUS. The second output is the post-retrofit energy analysis. Further, the energy analysis is separated into the following output reports.

1. Heating Season Report # 1
2. Heating Season Report # 2
3. Cooling Season Report

These reports may either be viewed on the screen, or hardcopies of reports may be made. An output session in the following sections illustrates the output reports of ENERGY.

3.2.1 Output Session with ENERGY:

Heating Season Report # 1

House Name		HEATING SEASON REPORT # 1					City
MONTH	MON. #	HEATING START	HEATING END	THETA BALANCE	DD(@Ti) (C-DAY)	HEAT LOSS (MJ)	HEATING FRACTION
JANUARY							
FEBRUARY							
MARCH							
APRIL							
MAY							
JUNE							
JULY							
AUGUST							
SEPTEMBER							
OCTOBER							
NOVEMBER							
DECEMBER							

Title	Description
Month	Month of the year
Mon #	Month number (Jan # - 1, Feb # - 2,....)
Heating Start	The calender day of the month on which heating period starts.
Heating End	The calender day of the month on which heating period ends.
Theta Balance	The balance point temperature written in dimensionless form
DD(@Ti)	Heating degree-days to the base T_i (Heating season indoor temperature) in ^oC-day.
Heat Loss	Heat loss through the building envelope for the month in MJ
Heating Fraction	Heating portion of the month $$\text{Htg Frac} = \frac{\text{No. of Htg days in a month}}{\text{Total no. of days in a month}}$$

Heating Season Report # 2:

House Name			HEATING SEASON REPORT # 2				City
MONTH	MON. #	SGAIN (MJ)	HTG SGAIN (MJ)	SUF	USE SGAIN (MJ)	FRHEAT (MJ)	HTG LOAD (MJ)
JANUARY							
FEBRUARY							
MARCH							
APRIL							
MAY							
JUNE							
JULY							
AUGUST							
SEPTEMBER							
OCTOBER							
NOVEMBER							
DECEMBER							

Title	Description
Month	Month of the year
Mon #	Month number (Jan # - 1, Feb # - 2,....)
Sgain	Solar entering the house through the windows in MJ
Htg Sgain	Solar entering the house through the windows in the heating period in MJ
SUF	Solar utilization factor
Use Sgain	Useful solar gain in MJ Use Sgain - (Htg Sgain)(SUF)
Frheat	The freeheat in MJ Frheat - Use Sgain + Internal gain
Htg Load	Heating Season Load in MJ Htg Load - Heat Loss - Frheat

Cooling Season Report:

House Name		COOLING SEASON REPORT					City
MONTH	MON #	COOLING START	COOLING END	COOLING FRACTION	DD(@Ti) (C-DAY)	CLG SLOAD (MJ)	CLG LOAD (MJ)
JANUARY							
FEBRUARY							
MARCH							
APRIL							
MAY							
JUNE							
JULY							
AUGUST							
SEPTEMBER							
OCTOBER							
NOVEMBER							
DECEMBER							

Title	Description
Month	Month of the year
Mon #	Month number (Jan # = 1, Feb # = 2,....)
Cooling Start	The calender day of the month on which cooling period starts.
Cooling End	The calender day of the month on which cooling period ends.
Cooling Fraction	Cooling portion of the month $\text{Clg Frac} = \frac{\text{No. of Clg days in a month}}{\text{Total no. of days in a month}}$
DD(@Ti)	Cooling degree-days to the base T_i (Cooling season indoor temperature) in ^{o}C-day.
Clg Sload	Solar entering the house in cooling period in MJ Clg Sload = (Cooling fraction)(Sgain)
Clg Load	Cooling Load in MJ

CHAPTER IV

VALIDATION OF ENERGY AGAINST CIRA AND DOE 2.1a

INTRODUCTION

ENERGY is compared to CIRA and DOE 2.1a in this chapter. The validation study has been divided into three sections.

a) In the first section the characteristics of weather files are analyzed and discussed.

b) In the second section the houses used for validation are described.

c) Heating and cooling loads are analyzed and compared with CIRA in the third section.

d) In the fourth section heating loads are analyzed and compared with DOE 2.1a. The effect of variation of thermal mass and indoor temperature swing on the heating load has also been investigated.

4.1 WEATHER FILE ANALYSIS

4.1.1 Weather Selection Methods:

There are a number of different ways in which representative weather data for predicting long term average performance of the buildings can be selected. Three commonly used methods of selection have been described briefly in this section.

Test Reference Year (TRY) format consists of 8760 hours of climatic information for one year selected by eliminating extreme months in order of importance until only one year remains [4.1]. The representative year chosen by this method does not necessarily represent the long-term mean. A given monthly average may not represent a long term monthly average for that month.

Typical Meteorological Year (TMY) format, developed by Sandia Laboratories, is created by concatenating twelve Typical Meteorological Months (TMM), [4.2]. Nine indices (total horizontal radiation, maximum, minimum and mean of dry-bulb and dewpoint and the maximum and mean of wind speed) were identified as critical. They were weighted with the solar index as 50% and the rest 50%. Typical months were identified by their closeness to long-term cumulative distribution function (CDF). Discontinuities between months were machine smoothed. The TMY is made up of typical months selected. These tapes are recommended for active solar design problems.

Weather Year for Energy Calculations (WYEC) is made up of monthly data selected closest to the long term mean, [4.3]. Both temperature and solar radiation were examined for correlation and for closeness to the long term mean. An initial selection of the months was made on closeness of mean monthly dry bulb temperature to the long term mean monthly temperature values. In order to increase the representativeness, adjustments were made by substituting warmer or colder days from other years until a very close proximity to the long term monthly mean temperature was obtained. Similar adjustments were made in the original hourly solar data for each month until the monthly mean values came within one-tenth of the monthly standard deviation as developed from the total historical solar record for that station. At connections (midnight), the temperatures were adjusted to fit. Erroneous data and atypical conditions were replaced with better data. WYEC tape data does not necessarily represent the long term mean for the climatic variables other than temperature and solar.

4.1.2 Weather Files in ENERGY, CIRA & DOE 2.1a:

In order to make a meaningful comparison it is necessary to discuss the inherent differences in the weather files utilized in CIRA, ENERGY and DOE 2.1a. Some of the important differences in weather files have been listed below:

a) CIRA uses average monthly day-time and night-time outside temperatures and daily average solar fluxes for east, west, south, north and horizontal orientations. These are obtained from hourly weather tapes which have been selected to represent long term average weather. CIRA weather file is entirely created from DOE 2.1a weather file.

b) ENERGY uses long term average values of annual maximum, minimum and average outside temperatures. The three temperature values are used to form a sinusoidal temperature variation over the year. The sinusoidal temperature variation is based on the normalized temperature distribution over a twelve month period developed by using thirty-two years of hourly weather data, [2.8]. It is assumed that the average of 32 years of data would be a best representative weather for an average year. Solar data used in ENERGY is the daily average solar fluxes for east, west, south, north and horizontal orientations and has been created from CIRA weather files.

c) DOE 2.1a uses hourly values of outside temperature and solar. These values are obtained from hourly weather tape.

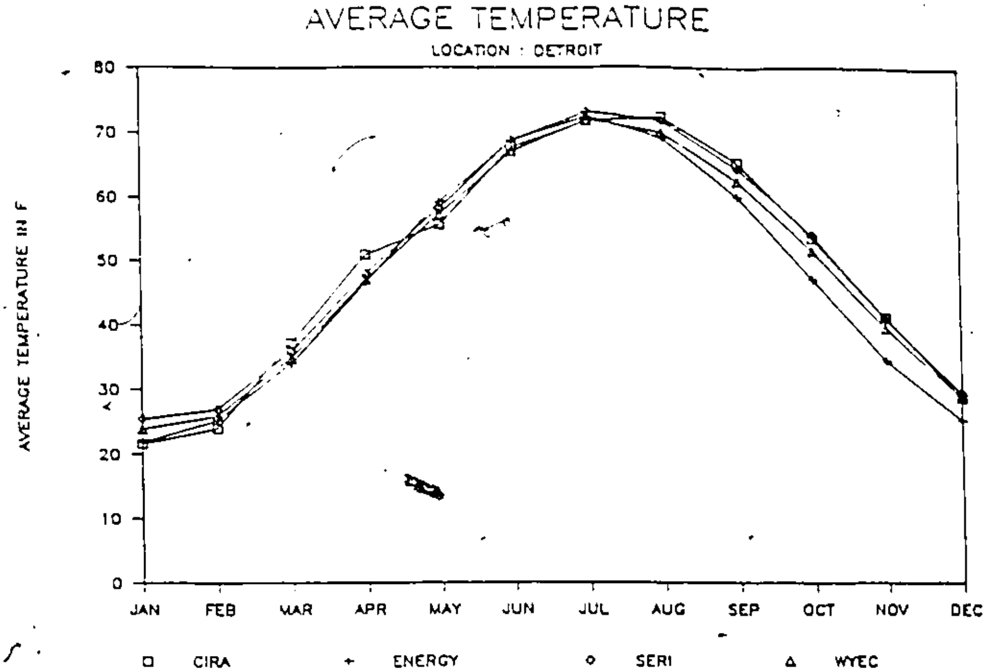
In this project the validation of ENERGY has been made based on the weather data from CIRA weather files instead of long term average data. ENERGY weather file was created by using the maximum, minimum and average outside temperatures from CIRA weather file for Detroit and Ottawa to form a sinusoidal outside temperature variation. Detroit and Ottawa weather files use the TRY weather data for the years 1968 and 1970 respectively. Ottawa file has been created by National Research Council (NRC).

The CIRA weather data, instead of long term data, was chosen for the following reasons:

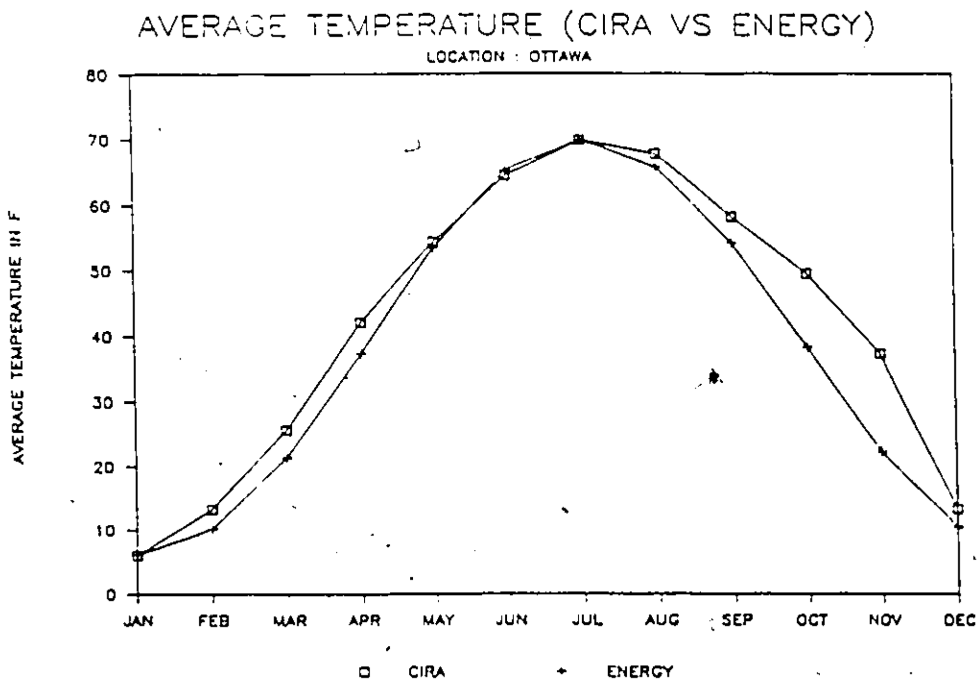
a) A comparison of average monthly outside temperatures of CIRA (TRY), ENERGY, Solar Energy Research Institute (SERI) and WYEC weather data for Detroit, see figure - F4.1, showed that the values of maximum and minimum temperatures of CIRA, SERI and WYEC weather data are very close. Therefore, the sinusoidal curve based on SERI or WYEC temperature data, a long term average, would not be very different from the one based on CIRA (TRY) data.

b) The use of same weather data is essential for a proper validation of ENERGY against CIRA and DOE 2.1a.

The sinusoidal temperature variation used in ENERGY is representative of a long term average. CIRA uses TRY weather data as representative of a long term average. However, depending on the method of selection employed to arrive at TRY weather data it is quite possible that a given monthly average temperature value in CIRA may not represent a long term monthly average for that month. This can be seen in the figures F4.1 and F4.2. The monthly average temperatures



F4.1 Average monthly outside temperature for Detroit



F4.2 Average monthly outside temperature for Ottawa predicted by ENERGY's sinusoidal profile in months of September to December are lower than those used in CIRA weather file. Therefore, it is expected that ENERGY would predict higher heating load in these months than CIRA and DOE 2.1a.

4.2 DESCRIPTION OF HOUSES USED IN VALIDATIONS

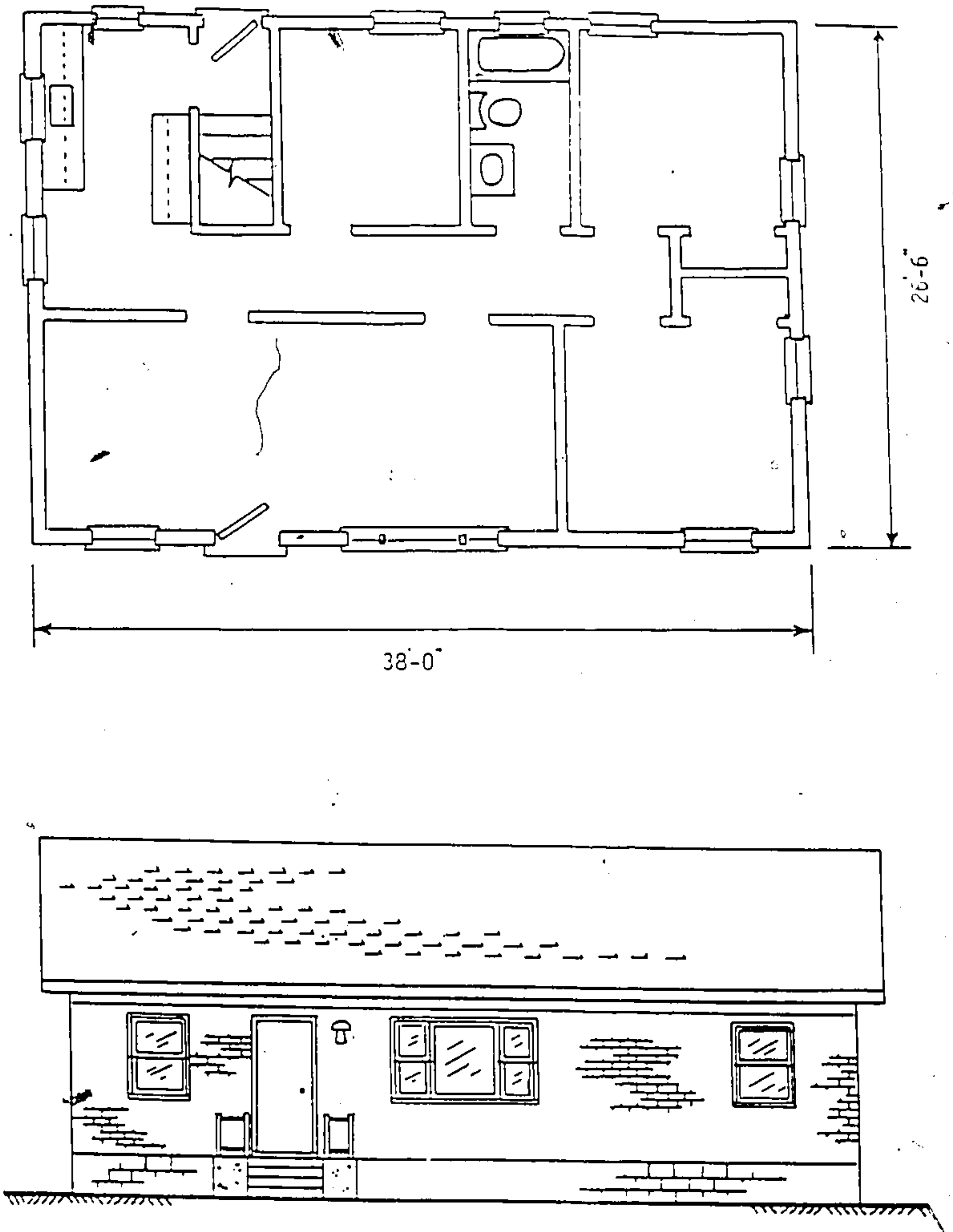
4.2.1 Description of the House A:

House A is a single storey, 91 m^2 floor area house with a heated basement, located in Detroit. A detailed description of this house is given in reference [1.1]. The house has brick veneer finish on the exterior and has wood framed windows. The attic has 330 mm of insulation and the walls contain 50.8 mm insulation. The house is occupied by two adults and one child. Heating is provided by a natural gas-fired furnace and space cooling is provided by a central electric air conditioner. The thermostat setting is maintained at 21 ^oC during winter and at 25.5 ^oC in summer. The floor plan and elevation of the house are shown in the figure F4.3. The structural details are given in Table T4.1.

4.2.2 Description of Villages of Riverside House (V OF R):

The house has two floors and a basement. It is located in Detroit. The first floor has a brick veneer outside finish and the second floor has a wood finish. The windows are double glazed. The walls have RSI = 1.94 insulation in the wall cavities and RSI = 3.88 in the ceiling.

The front face of the house is oriented due South. The structural



F4.3 The Floor Plan and Front Elevation of House A

TABLE T4.1 : STRUCTURAL DETAILS OF HOUSE A

Type	Single storey wood frame ranch with basement
Shape	Rectangular, 8 m X 11.6 m
Area	91 m^2 of main floor area
Orientation	Long axis oriented north - south
Exterior Wall	50.8 mm X 101.6 mm truss construction with RSI = 1.5 insulation
Windows	Single-pane double-hung wood frame with exterior aluminum storms
Door	Front and rear wood doors with aluminum storm door for each

details of the house are given in Table T4.2 and 2 elevations are shown in Fig. F4.4.

4.2.3 Description of the Passive Solar Ranch House (PSRH):

Colborne et al have simulated a passive solar ranch house located in Ottawa, see figure F4.5 , for several cases, [2.6]. There were four cases determined by insulation and infiltration levels. Each of these cases was provided with varying thermal mass and four thermostat settings. Two cases were selected from the above study that could be used for investigating the combined effect of large solar gains, tight house construction and high insulation levels. A light construction with the heating and cooling thermostat settings at 21°C and 26°C was chosen and its tightness and insulation levels were allowed to vary. These cases were:

	R-Wall	R-Ceiling	Glazing	Avg. Ach
Case 1	2.29	4.41	Double	0.6
Case 2	5.28	8.80	Triple	0.3

These two cases were modelled on CIRA by Patwardhan, [1.3]. The listings are given in appendix H.

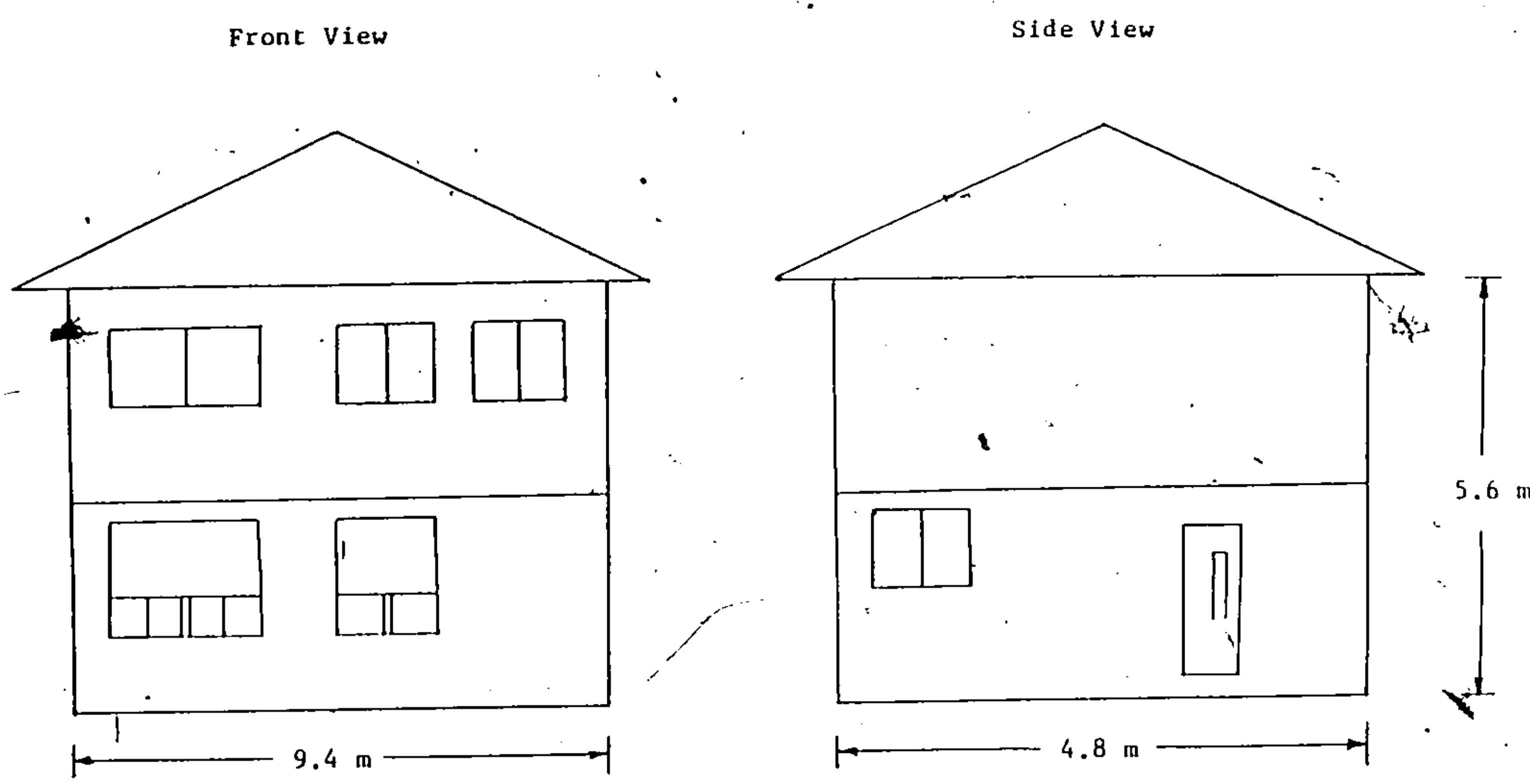
4.3 VALIDATION AGAINST CIRA

4.3.1 Validation Study on House A and Villages of Riverside:

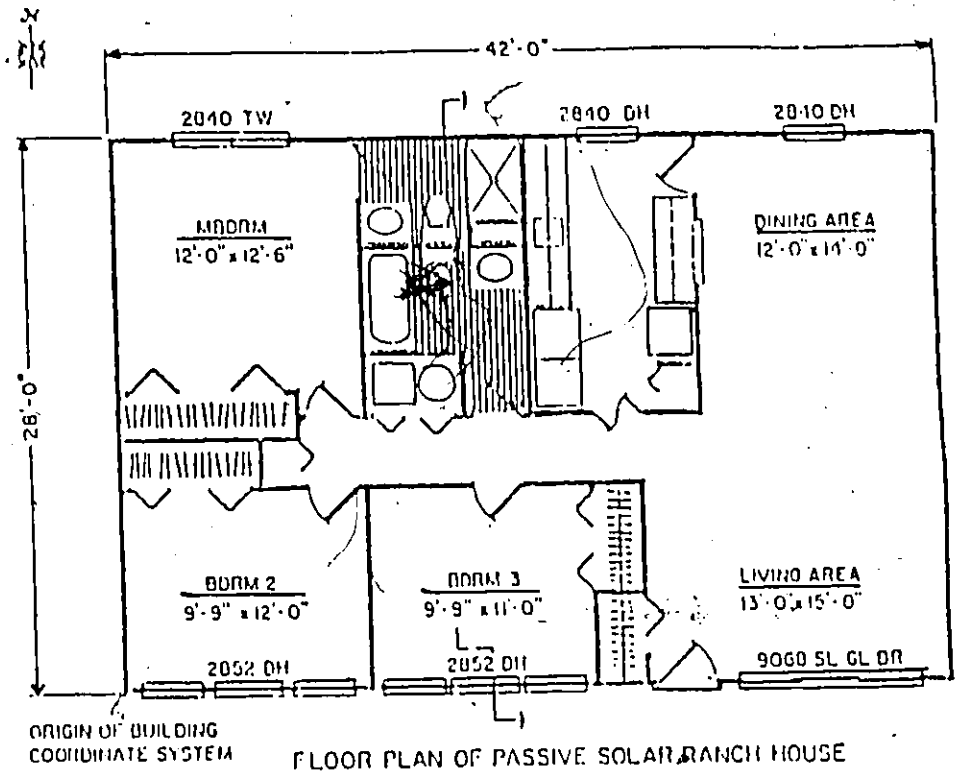
It can be seen from the figures F4.6 and F4.7 that the monthly heating and cooling-loads predicted by ENERGY agree quite well with those predicted by CIRA. Figure F4.10 shows that most of the values of monthly heating loads for House A and Villages of Riverside are within

TABLE T4.2 : STRUCTURAL DETAILS FOR THE HOUSE VILLAGES OF RIVERSIDE

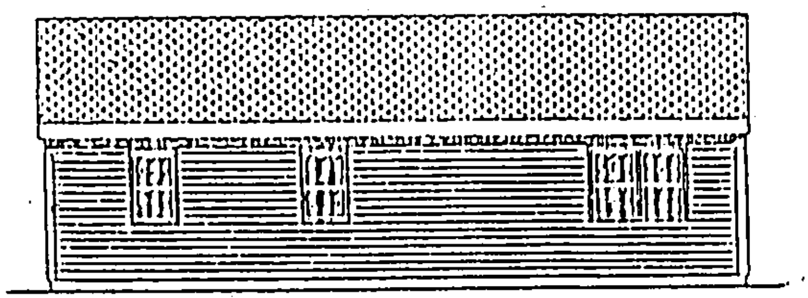
Type	Two storey house with basement
Shape	Rectangular, 5.94 m X 8.2 m
Area	44.7 m^2 for each floor
Orientation	Front faces south
Exterior wall	50.8 mm X 101.6 mm stud construction with RSI = 1.94 insulation
Ceiling	50.8 mm X 101.6 mm truss construction with RSI = 3.88 insulation
Windows	Double glazed, wood framed.



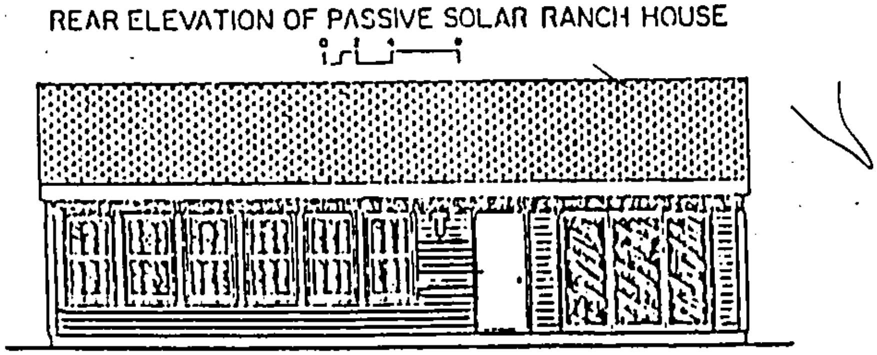
F4.4 The Front and the side view of the " Villages of Riverside " House.



FLOOR PLAN OF PASSIVE SOLAR RANCH HOUSE

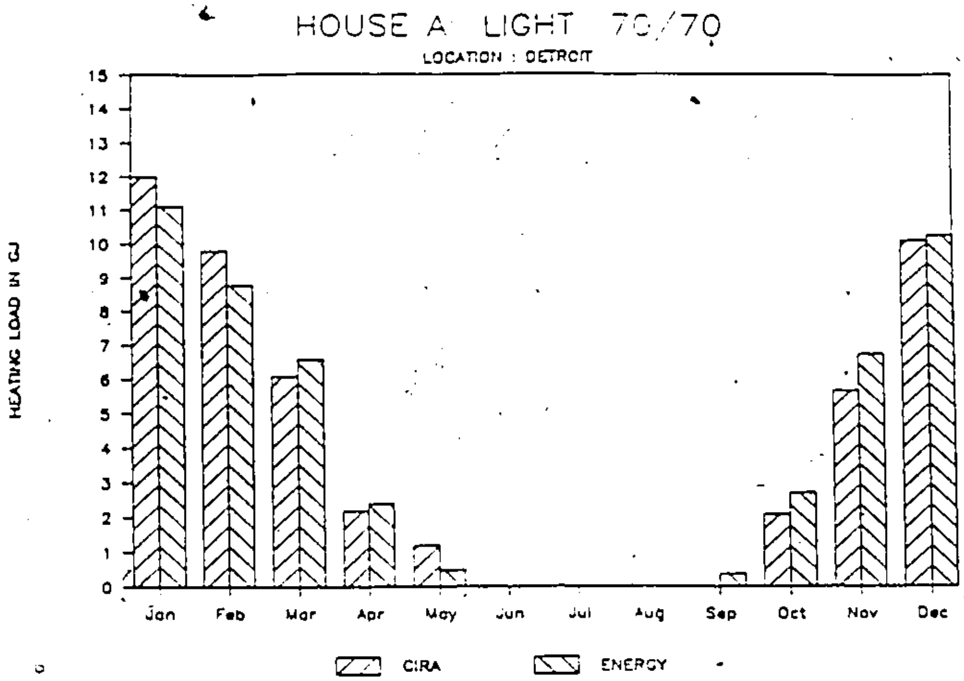


REAR ELEVATION OF PASSIVE SOLAR RANCH HOUSE

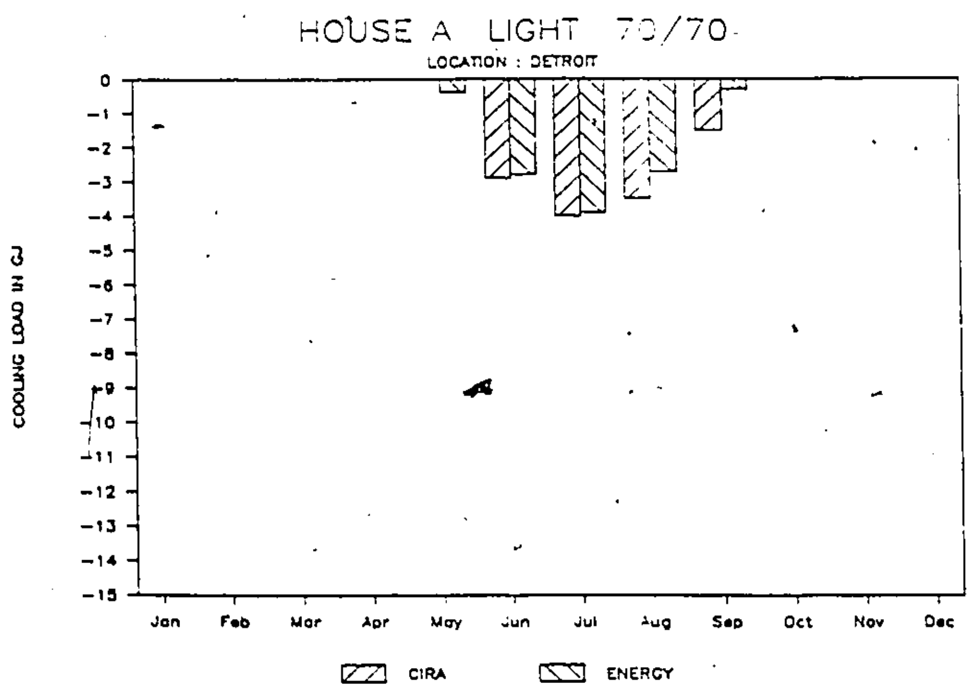


FRONT ELEVATION OF PASSIVE SOLAR RANCH HOUSE

F4.5 The Floor Plan, Front and Rear Elevation of Passive Solar Ranch House (PSRH)

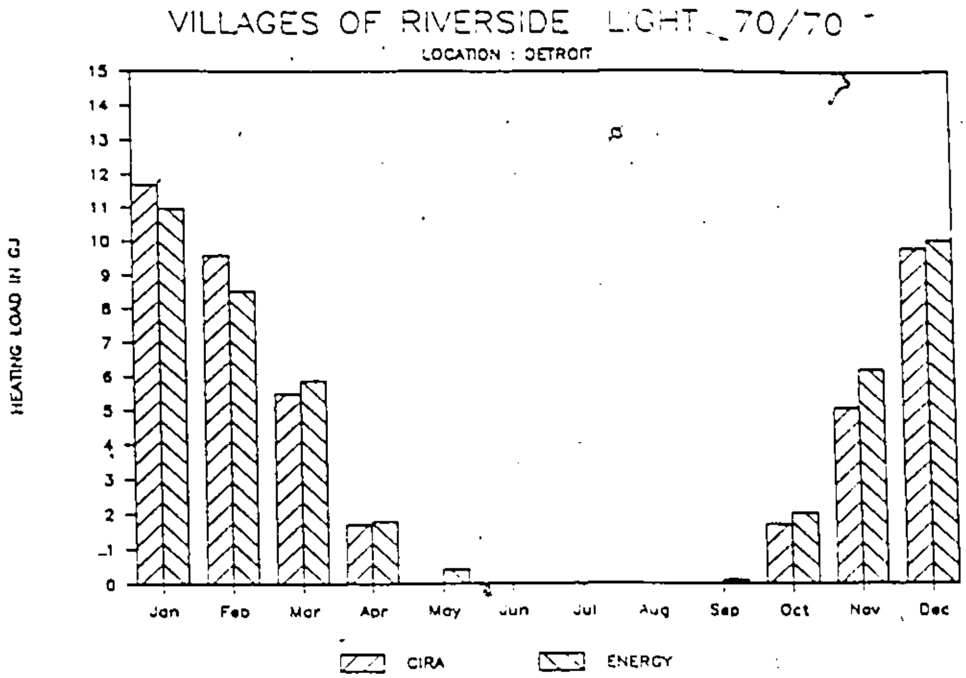


F4.6a

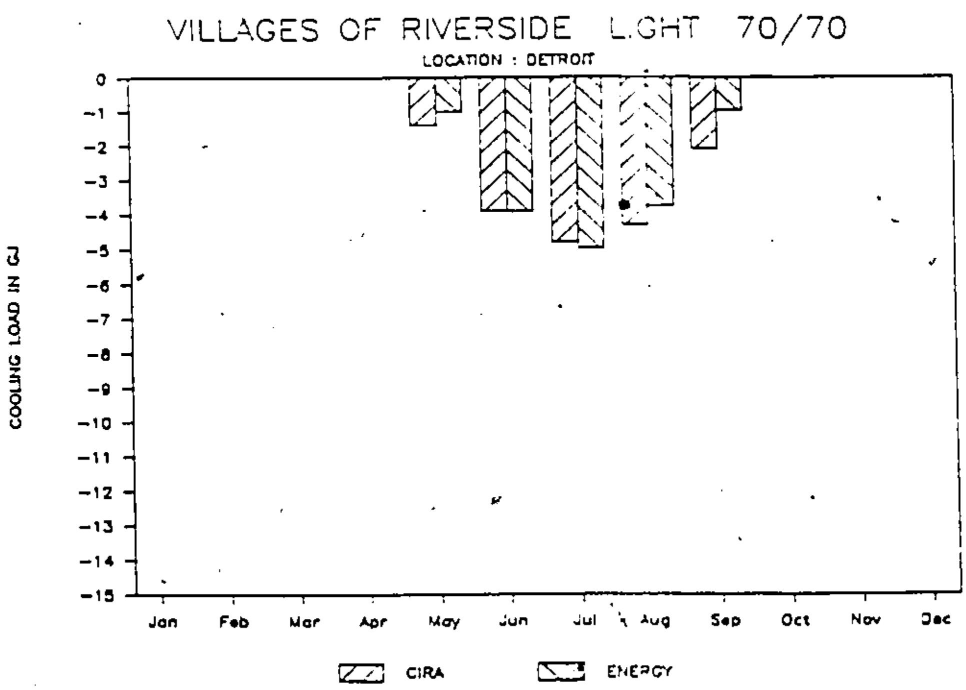


F4.6b

F4.6 ENERGY/CIRA Comparison: House A, Detroit, Heating and Cooling Loads.



F4.7a



F4.7b

F4.7 ENERGY/CIRA Comparison: Villages of Riverside, Detroit, Heating and Cooling Loads

10% of CIRA predicted values. The cooling energy consumption shows a wide scatter. The high percent scatter is partly due to the low cooling load values and that the latent internal gain is assumed to be constant at 25 % of the sensible internal gain.

The heating load values for the months of October and November are significantly higher than CIRA predicted loads, see figures F4.6a & F4.7a. This trend was expected and is due to the difference in the outside temperature data as discussed earlier in Weather File Analysis section.

It can also be seen from figures F4.6a, F4.7a and F4.10a that ENERGY, on the average, predicts higher heating loads. This is due to the use of solar utilizaton factor in ENERGY. CIRA uses a 100% utilization of solar gains through the glazing and the opaque surfaces. This is not correct, since some portion of solar gain is not useful in reducing the heating requirements if the space temperature is to remain in tolerable limits. In ENERGY, use of solar utilization factor reduces the useful solar gain which in turn reduces the total free heat. As a result, the heating loads predicted by ENERGY are generally greater than those predicted by CIRA.

In the month of January however the heat load predicted by ENERGY is lower than that predicted by CIRA, see figures F4.6a and F4.7a. It was expected that ENERGY would predict a higher load than CIRA as the average outside temperature for January is the same in both the programs and ENERGY is using a solar utilization factor. This anomaly in the result can be explained by comparison of the useful solar gains. The useful solar gain calculated by ENERGY is 84% higher than that calculated by CIRA (CIRA useful solar gain is the difference of solar gain and sky radiation loss). This discrepancy in useful solar gains is due to the assumption in ENERGY that the sky radiation loss from a building is cancelled by the opaque solar gain, see appendix A.

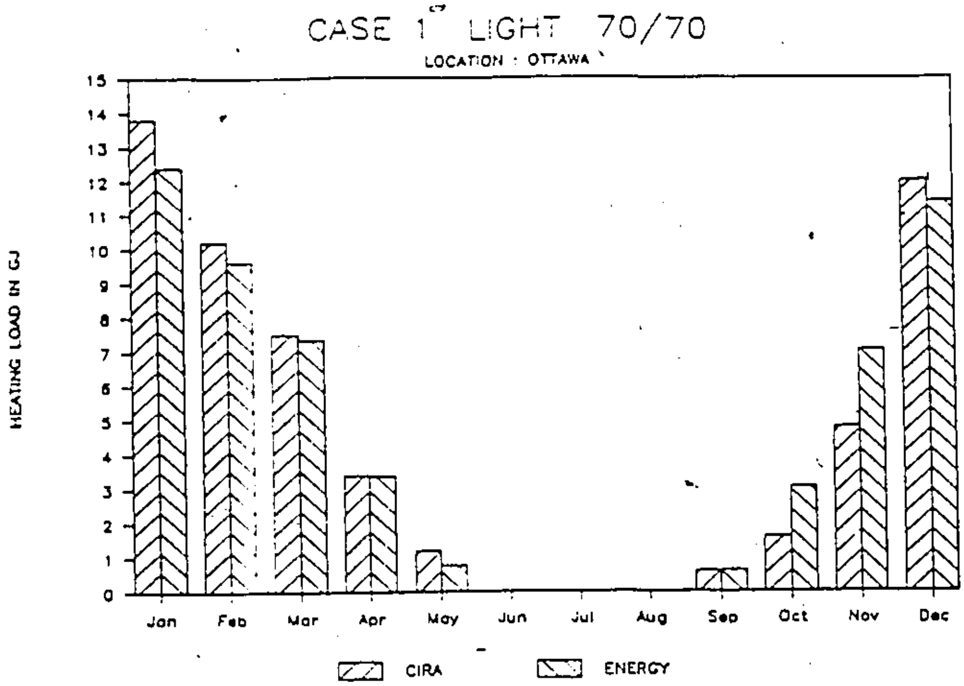
From figure F4.6a we can see that in the swing months of May and September ENERGY predicts both, a heating and a cooling energy requirement. CIRA on the other hand takes swing months to be either heating or cooling. This is not true in most cases, since both, heating and cooling, would be required.

The seasonal comparison of heating and cooling loads for the houses is shown in figure F4.11a & b. It can be seen that the seasonal heating loads are in good agreement within 5 to 10% of CIRA results. In the case of cooling loads the scatter is greater. This is due to the simplified cooling load model used in ENERGY.

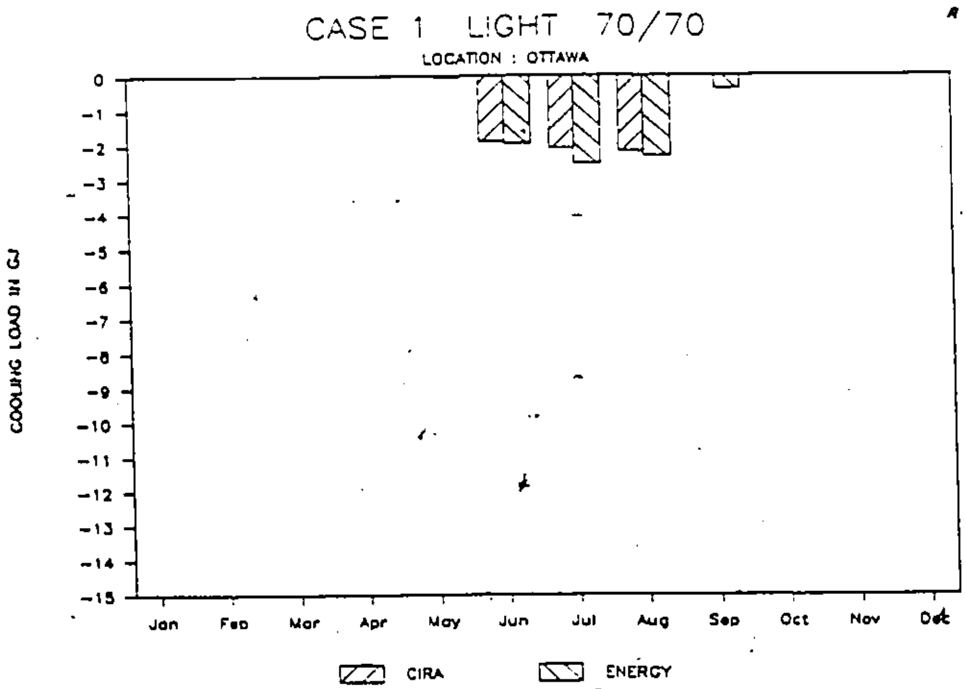
4.3.2 <u>Validation Study on the Passive Solar Ranch House</u>:

Monthly comparisons of CIRA and ENERGY predicted heating and cooling loads for PSRH case 1 and case 2 are shown in figures F4.8 to F4.10. It can be seen that the results are in good agreement. The results for the heating loads are generally within a 10% range. The cooling load agreement is not as good, particularly at the lower values of cooling load.

A comparison between case 1 and case 2 enables us to understand the importance of solar utilization factor. It was expected that a tight, well insulated house would have lower solar utilization factors since most of the solar gain go toward overheating the conditioned

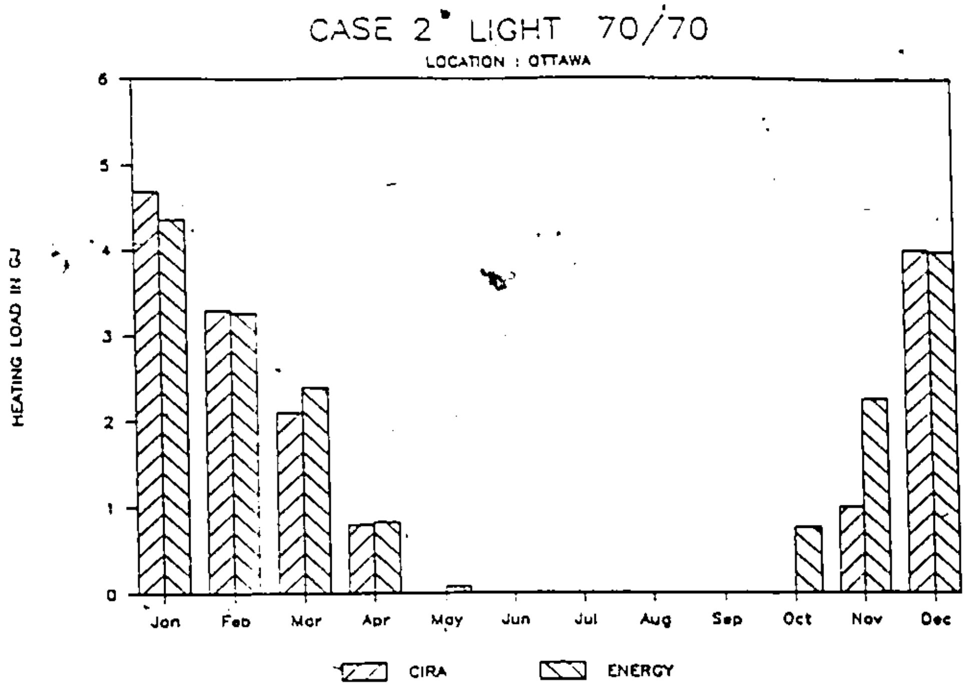


F4.8a

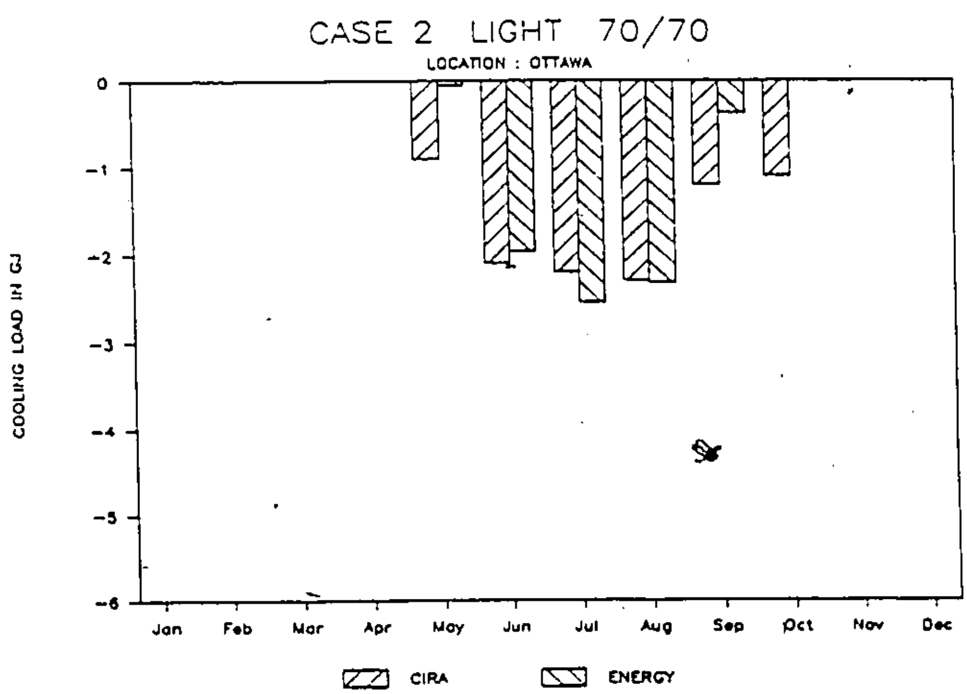


F4.8b

F4.8 ENERGY/CIRA Comparison: Passive Solar Ranch House, Ottawa, Heating and Cooling Loads.

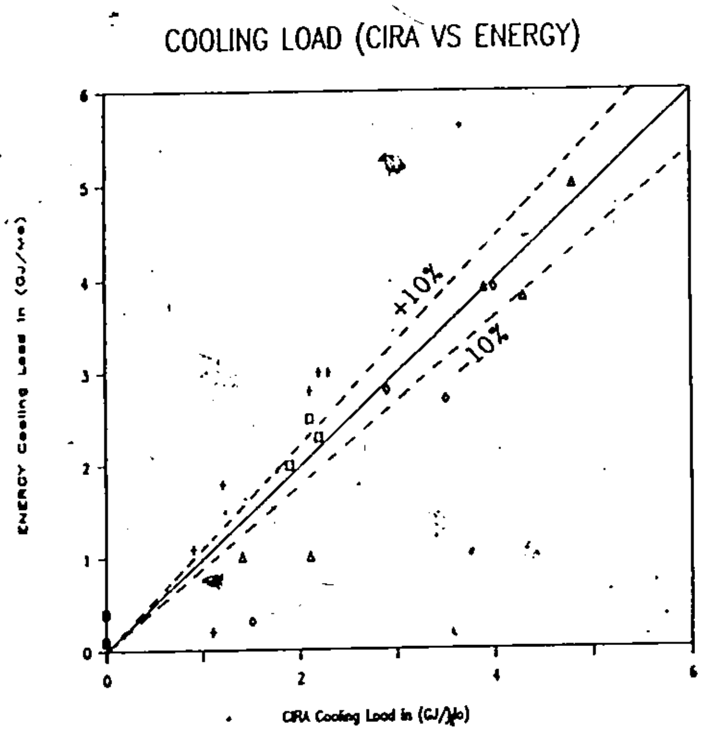


F4.9a



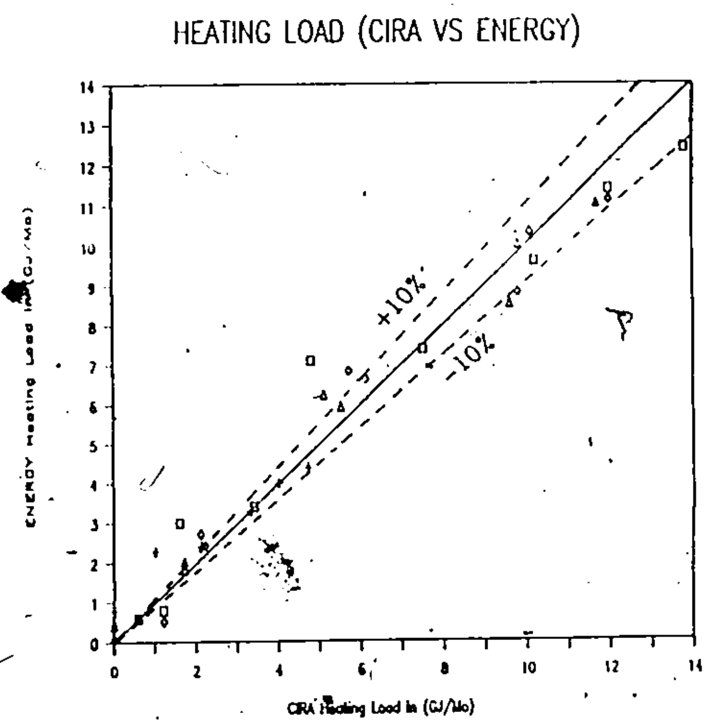
F4.9b

F4.9 ENERGY/CIRA Comparison: Passive Solar Ranch House, Ottawa, Heating and Cooling Loads.



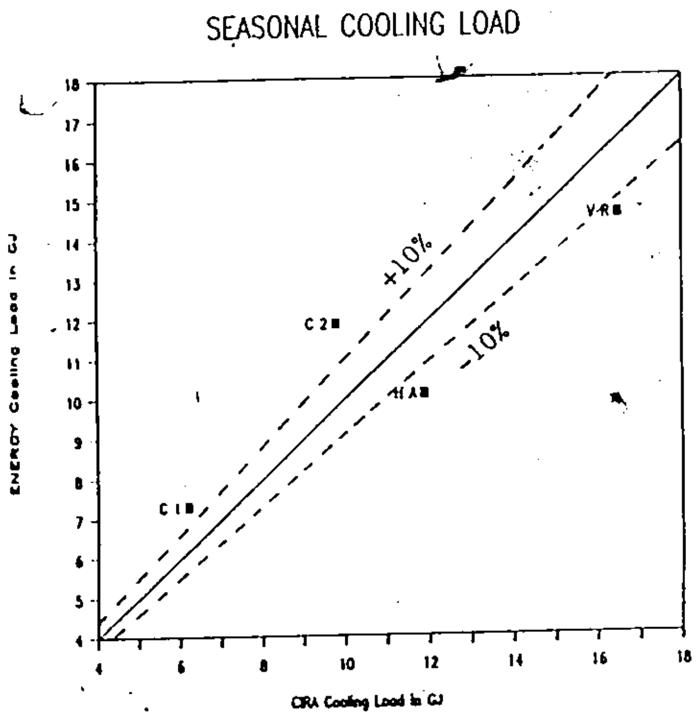
F4.10b

F4.10b ENERGY/CIRA Comparison:
△ House A, Detroit
◊ Villages of Riverside, Detroit
□ PSRH Case 1, Ottawa
+ PSRH Case 2, Ottawa
Monthly Cooling Loads.



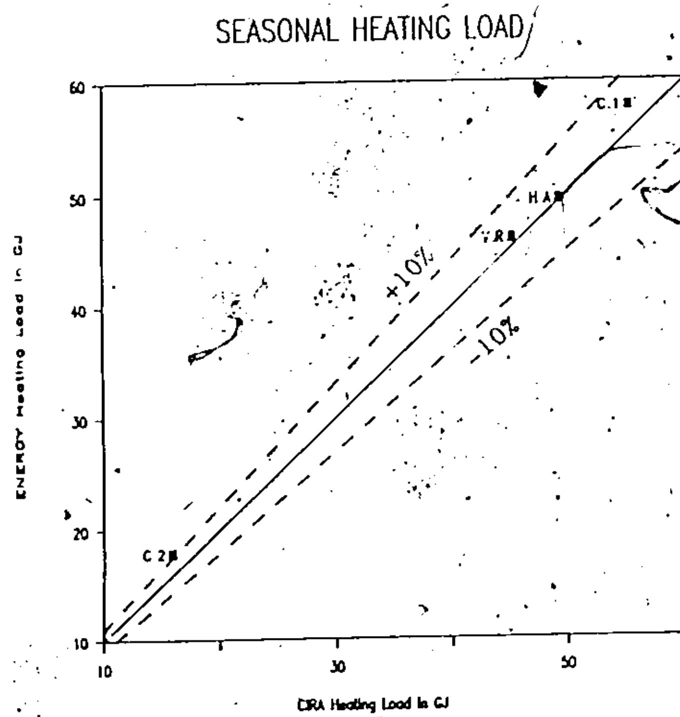
F4.10a

F4.10a ENERGY/CIRA Comparison:
△ House A, Detroit
◊ Villages of Riverside, Detroit
□ PSRH Case 1, Ottawa
+ PSRH Case 2, Ottawa
Monthly Heating Loads.



F4.11b

F4.11b ENERGY/CIRA Comparison:
HA House A, Detroit
VR Villages of Riverside, Detroit
C1 PSRH Case 1, Ottawa
C2 PSRH Case 2, Ottawa
Cooling Load.



F4.11a

F4.11a ENERGY/CIRA Comparison:
HA House A, Detroit
VR Villages of Riverside, Detroit
C1 PSRH Case 1, Ottawa
C2 PSRH Case 2, Ottawa
Heating Load.

space. It can be seen from the house description that case 2 had a higher insulation level and lower air change rate than case 1. This resulted in lower solar utilization factors in case 2, which is in agreement with our expectation, see appendix B.

From figure F4.11 it is seen that the agreement between the seasonal heating load predicted by ENERGY and CIRA is within 5 to 10%. ENERGY-predicted results are higher than those predicted by CIRA due to the use of solar utilization factor.

4.4 VALIDATION AGAINST DOE 2.1a

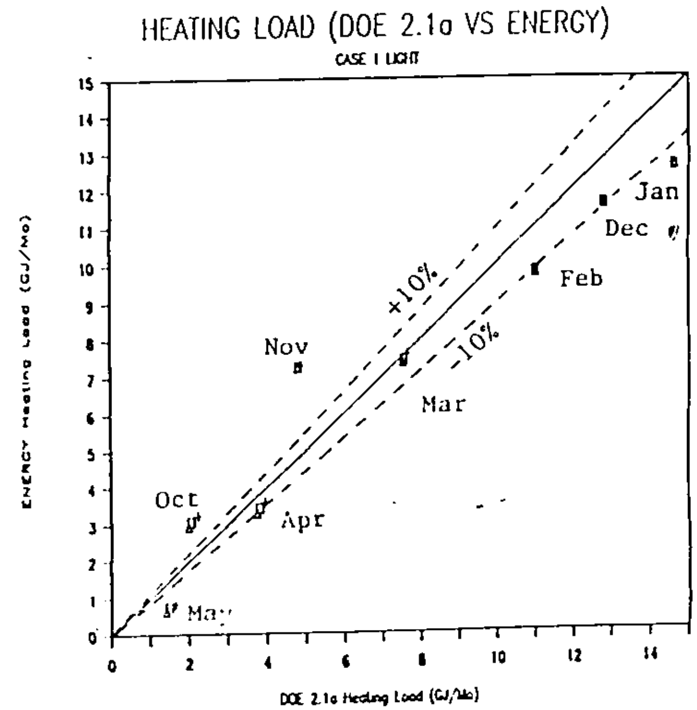
4.4.1 Validation Results and Discussion:

In this validation study ENERGY is compared to DOE 2.1a. The study was carried out on case 1 & 2 of PSRH. The effect of variation of house thermal mass and allowable temperature rise above the set point has also been investigated for three different house thermal masses (Light, Medium and Heavy) and allowable temperature rises (0, 2.75 and 5.5 ^{o}C).

4.4.1a Case 1:

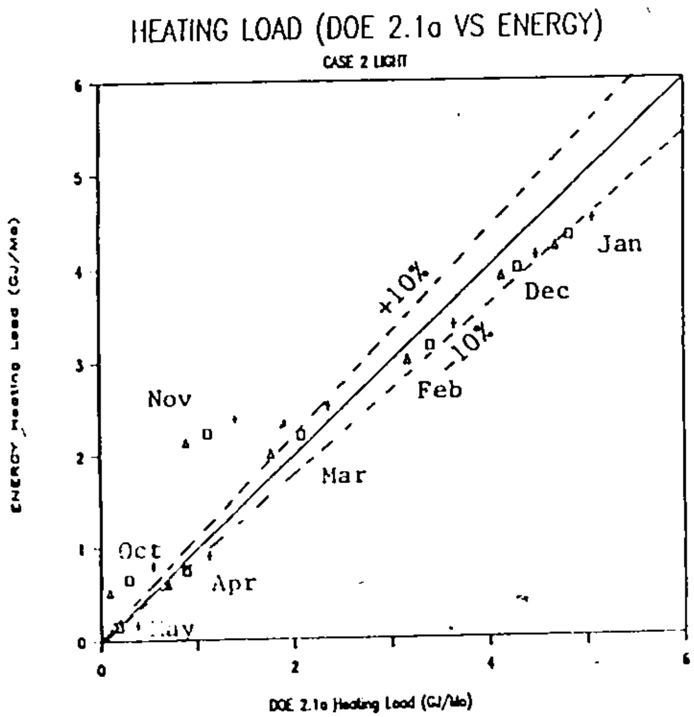
Variation in allowable Temperature Rise:

A monthly and seasonal heating load comparison between ENERGY and DOE 2.1a along with variation in allowable temperature rise can be seen in figures F4.12 to F4.19. The monthly heating loads, except for October and November, are generally within a 10% range. ENERGY-predicted heating loads for October and November were higher as expected and were due to the difference in the outside temperature



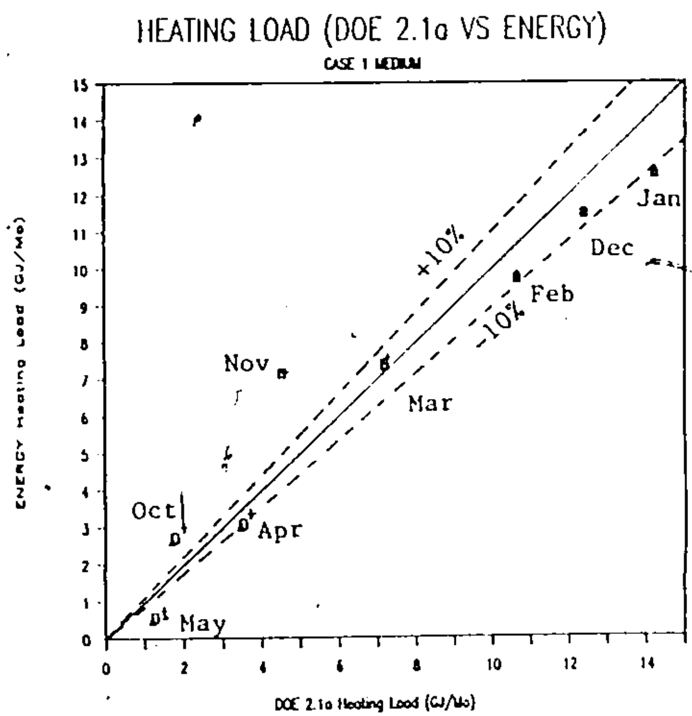
F4.12

F4.12 ENERGY/DOE 2.1a Comparison:
PSRH Case 1, Light, Ottawa
+ 0 Temperature Rise (deg C)
□ 2.75 Temperature Rise (deg C)
△ 5.5 Temperature Rise (deg C)
Monthly Heating Loads.



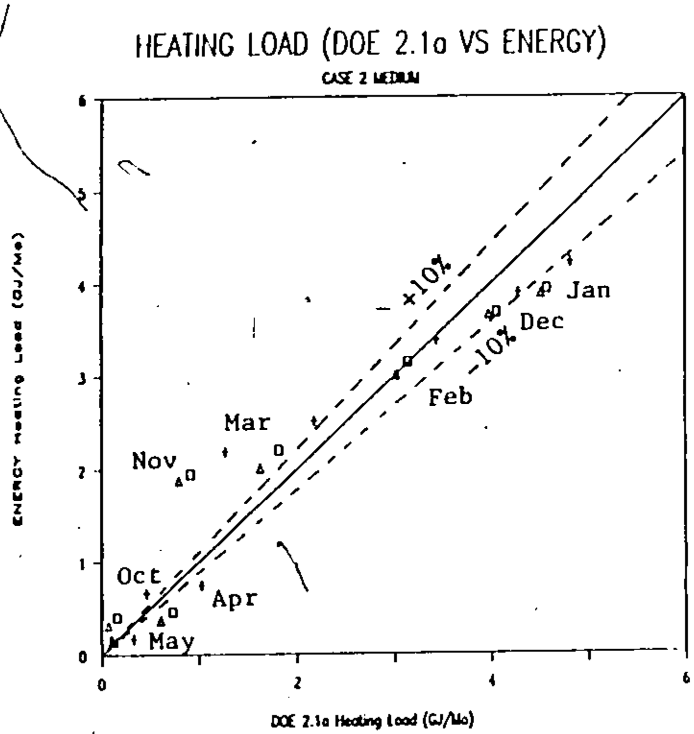
F4.13

F4.13 ENERGY/DOE 2.1a Comparison;
PSRH Case 2, Light, Ottawa
+ 0 Temperature Rise (deg C)
□ 2.75 Temperature Rise (deg C)
△ 5.5 Temperature Rise (deg C)
Monthly Heating Loads.



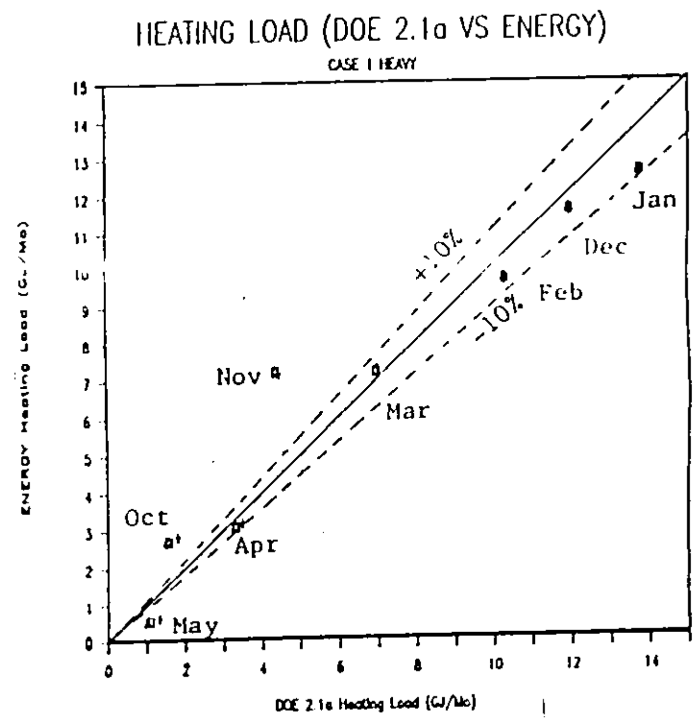
F4.14

F4.14 ENERGY/DOE 2.1a Comparison:
PSRH Case 1, Medium, Ottawa
+ 0 Temperature Rise (deg C)
□ 2.75 Temperature Rise (deg C)
△ 5.5 Temperature Rise (deg C)
Monthly Heating Loads.



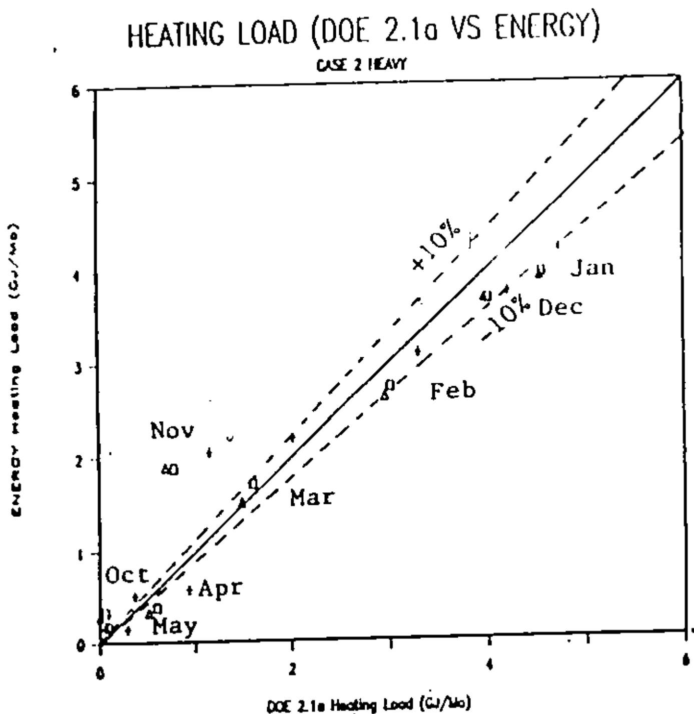
F4.15

F4.15 ENERGY/DOE 2.1a Comparison:
PSRH Case 2, Medium, Ottawa
+ 0 Temperature Rise (deg C)
□ 2.75 Temperature Rise (deg C)
△ 5.5 Temperature Rise (deg C)
Monthly Heating Loads.



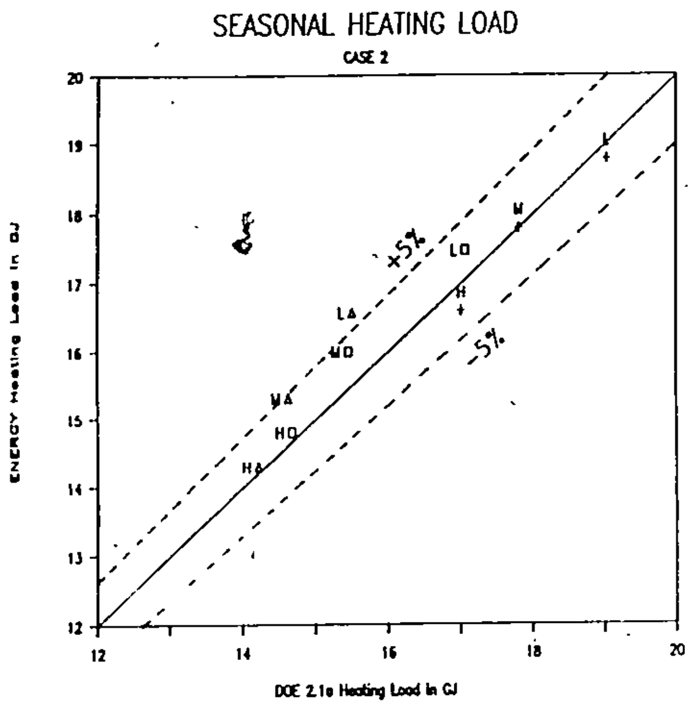
F4.16

F4.16 ENERGY/DOE 2.1a Comparison:
PSRH Case 1, Heavy, Ottawa
+ 0 Temperature Rise (deg C)
□ 2.75 Temperature Rise (deg C)
△ 5.5 Temperature Rise (deg C)
Monthly Heating Loads.



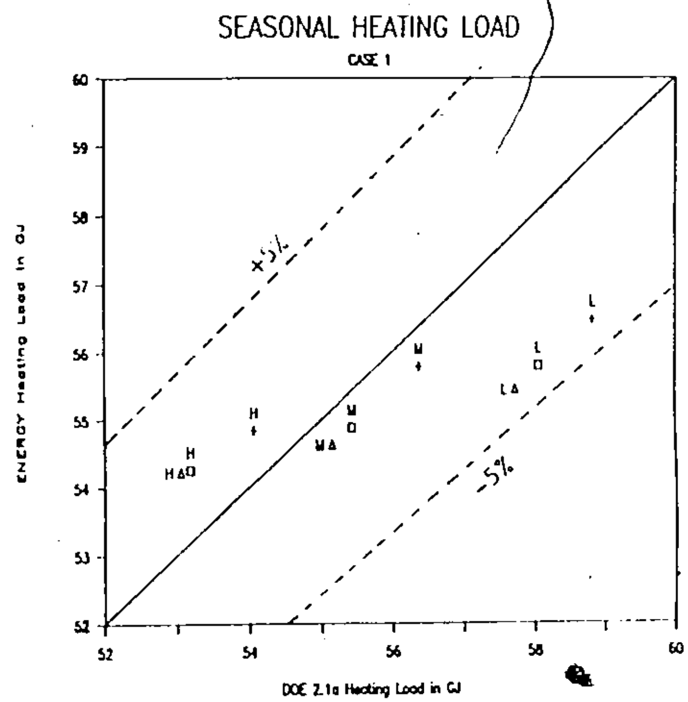
F4.17

F4.17 ENERGY/DOE 2.1a Comparison:
PSRH Case 2, Heavy, Ottawa
+ 0 Temperature Rise (deg C)
□ 2.75 Temperature Rise (deg C)
△ 5.5 Temperature Rise (deg C)
Monthly Heating Loads.



F4.19

F4.19 ENERGY/DOE 2.1a Comparison: PSRH Case 2; L Light, M Medium, H Heavy; Ottawa
+ 0 Temperature Rise (deg C)
□ 2.75 Temperature Rise (deg C)
△ 5.5 Temperature Rise (deg C)
Seasonal Heating Load.



F4.18

F4.18 ENERGY/DOE 2.1a Comparison: PSRH Case 1; L Light, M Medium, H Heavy; Ottawa
+ 0 Temperature Rise (deg C)
□ 2.75 Temperature Rise (deg C)
△ 5.5 Temperature Rise (deg C)
Seasonal Heating Load.

data as discussed in section 4.1 of this chapter. The seasonal heating loads are in very good agreement, generally within a 5% range. When the inside temperature is allowed to rise, thereby utilizing the thermal storage capability of the structure, the agreement with DOE 2.1a remains very good. This indicates that the approach using the concept of solar utilization factor provides results consistent with the much more complex hourly simulation approach used by DOE 2.1a. Only a slight decrease in heating loads is experienced with an increase in allowable temperature rise.

Variation in the thermal mass:

A monthly and seasonal heating load comparison between ENERGY and DOE 2.1a for three different building mass; light, medium and heavy; is shown in the figures F4.12, F4.14, F4.16 and F4.18. It is seen that as the mass of the building is increased the heating load on the building decreases. Both the programs show a decrease in heating loads as the mass is increased from light to heavy. It is found that the heating load predicted by DOE 2.1a is more sensitive to the variation in house mass than that predicted by ENERGY. This trend can be best explained as follows:

For the months of October and November the heating loads predicted by ENERGY are greater than DOE 2.1a-predicted loads, see appendix B. This difference in the heating loads is caused by the difference in the outside temperature weather data as explained earlier. It can also be seen in the appendix B that the monthly solar gains predicted by ENERGY are slightly higher than DOE 2.1a-predicted solar gains. The higher values of monthly heating loads and solar gains result in higher monthly solar utilization factors in ENERGY. As the thermal mass of the house is increased from light to medium the already high solar utilization factors in ENERGY reach the maximum value of '1' for months of November and December, whereas in DOE 2.1a solar utilization factors for these months remain less than '1'. Therefore, when the house thermal mass is changed from medium to heavy the DOE 2.1a-predicted solar utilization factors, unlike those predicted by ENERGY, have room to increase. This in turn causes a decrease in the DOE 2.1a-predicted heating loads. Whereas in ENERGY, both the solar utilization factors and the heating loads remain the same. This explains the high sensitivity of DOE 2.1a-predicted heating loads to the variation in house thermal mass as compared to those predicted by ENERGY.

4.4.1b <u>Case 2</u>:

<u>Variation in the allowable temperature rise</u>:

From the figures F4.13, F4.15, F4.17 and F4.19 we can see the variation in the heating load with an increase in the allowable temperature rise. It is seen that in case 2 the heating load decreases with increase in allowable temperature rise, similar to case 1. The monthly heating load agreement, except for months of October and November, is generally within 5 to 10% range. The agreement between ENERGY and DOE 2.1a for the months with lower values of heating loads is not as good. The seasonal heating load agreement is very good, within 5% range.

<u>Variation in thermal mass</u>:

From the figures F4.13, F4.15, F4.17 and F4.19 it can be seen that the increase in thermal mass causes the heating load to decrease. It is found that the heating load in both, ENERGY and DOE 2.1a, is equally sensitive to the variation of the thermal mass of the building. The ENERGY-predicted solar utilization factors in case 2 are small and do not reach the maximum value of '1' as the thermal mass of the house is changed from light to heavy. Thus the heating load in both the programs decrease by approximately equal amounts with the variation in thermal mass.

The comparative study carried out in this chapter showed that ENERGY is in very good agreement with DOE 2.1a on seasonal basis. The monthly heating load agreement, except for the months of October and November, with DOE 2.1a and CIRA is within a 10% range. The agreement for cooling loads is found to be poor. In general it can be concluded that ENERGY is a reliable heating energy analysis program.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The objective of this study was to develop an easy-to-use yet accurate computer program to carry out a complete energy and retrofit analysis for residential buildings. As a result, a simple computer program, ENERGY, written on LOTUS 1-2-3 spread sheet, was developed. The various physical models used in the program were formulated. The useful solar gains through windows were analysed in detail. ENERGY was examined against other building simulation programs, CIRA and DOE 2.1a. The weather data used in ENERGY was also analysed and compared against the weather data used in CIRA and DOE 2.1a.

This chapter has been divided into two sections.

a) The conclusions drawn from the analysis and development of the ENERGY program have been listed in the first section.

b) The second section includes recommendations.

5.1 CONCLUSIONS:

a) ENERGY is an easy-to-use energy simulation program. It can be used to carry out an energy analysis for residential buildings with low or moderate levels of insulation.

b) ENERGY accounts for passive solar gains through windows by using a solar utilization factor. This passive solar model enables the program to predict heating energy consumption more accurately than programs that do not take into account solar gain utilization.

c) ENERGY uses a sinusoidal temperature curve to represent long-term average daily temperatures over a year. This curve was established as a best fit to daily average temperatures over a 23 year period for the Canadian locations provided in the weather data section. Thus ENERGY-predicted heating results are potentially accurate for analyzing long term performance of residential buildings.

d) The heat load calculations in ENERGY are less accurate for tight, well insulated houses. This is partly due to the simplifying assumption that the effect of solar radiation on opaque surfaces is cancelled by sky radiation losses and that the percent accuracy of the degree-day calculation is worse at very low values of degree days.

e) ENERGY was primarily developed to carry out a heating energy analysis. The cooling load comparison of ENERGY with CIRA was found to be within a 20% range. This high percent difference is due to the low cooling load values. The solar and internal (sensible and latent) gains form the major portion of the cooling load in summer. In ENERGY the latent portion of the internal gains is assumed constant at 25% of the sensible internal gain. This assumption could cause a high percent error in determination of cooling loads.

f) From the comparative study included in chapter IV, it is concluded that ENERGY can be expected to yield very reliable and accurate results for seasonal heating loads. The monthly comparison showed that ENERGY-predicted heating loads were generally within an accuracy of 10%.

g) The infiltration model which was used is generally considered to be the most reliable model available at the present time. This model, however does not take in account the effect of wind direction on infiltration. The weather data used in the program is representative of long term weather. The degree-days to the indoor temperature base make the calculation procedure simple and efficient. The simplified technique of approximating the heating and cooling periods used by ENERGY is reliable.

h) In ENERGY a retrofit and energy analysis can be performed accurately in a short period of time. Further, the program can be easily edited and tailored to the specific needs of the user.

5.2 RECOMMENDATIONS:

a) An accurate and simple model for sky radiation loss and for the effect of solar radiation on opaque surfaces should be included in the program. It is felt that this would improve the monthly heating load calculation for tight, well insulated houses.

b) The ENERGY file should be translated /or converted to pocket computer compatible software. This would enable contractors, engineers, etc. to do energy calculations on site.

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ACCORDING TO LIST OF APPENDICES (PG. XVI).

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APPENDIX A

Comparison of Effect of Solar on Opaque Surfaces with Sky-Radiation Loss based on the simplified models as used by CIRA

TABLE T1.1A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : OTTAWA HOUSE : PSRH (CASE 1)

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.36	0.63	-0.27	-2.03	0.00
FEB	0.44	0.57	-0.13	-1.38	0.00
MAR	0.68	0.64	0.04	0.63	0.00
APR	0.76	0.64	0.12	4.44	0.00
MAY	0.75	0.63	0.12	12.00	0.00
JUN	0.90	0.56	0.34	0.00	14.78
JUL	0.76	0.49	0.27	0.00	10.38
AUG	0.78	0.52	0.26	0.00	8.39
SEP	0.51	0.53	-0.02	0.00	-1.67
OCT	0.42	0.60	-0.18	-12.86	0.00
NOV	0.22	0.60	-0.38	-8.44	0.00
DEC	0.28	0.64	-0.36	-3.08	0.00
TOTAL	6.86	7.05	-0.19	-2.06	9.24

TABLE T1.2A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : TORONTO HOUSE : PERH (CASE 1)

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.35	0.62	-0.27	-2.48	0.00
FEB	0.47	0.57	-0.10	-1.45	0.00
MAR	0.69	0.63	0.06	1.11	0.00
APR	0.81	0.62	0.19	9.05	0.00
MAY	0.74	0.59	0.15	12.50	0.00
JUN	0.94	0.54	0.40	0.00	-15.38
JUL	0.86	0.49	0.37	0.00	-11.94
AUG	0.87	0.51	0.36	0.00	-10.00
SEP	0.55	0.51	0.04	0.00	-2.11
OCT	0.36	0.50	-0.14	-10.00	0.00
NOV	0.23	0.58	-0.35	-9.21	0.00
DEC	0.24	0.63	-0.39	-4.43	0.00
TOTAL	7.11	6.79	0.32	-2.10	-10.45

TABLE T1.3A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : WINNIPEG HOUSE : PSRH (CASE 1)

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.17	0.55	-0.38	-2.22	0.00
FEB	0.25	0.52	-0.27	-2.52	0.00
MAR	0.46	0.58	-0.12	-1.11	0.00
APR	0.72	0.58	0.14	5.60	0.00
MAY	0.90	0.64	0.26	0.00	-11.82
JUN	0.83	0.47	0.36	0.00	-11.25
JUL	0.93	0.51	0.42	0.00	-10.00
AUG	0.78	0.51	0.27	0.00	-6.92
SEP	0.49	0.57	-0.08	-7.27	0.00
OCT	0.30	0.61	-0.31	-6.89	0.00
NOV	0.22	0.59	-0.37	-4.20	0.00
DEC	0.15	0.55	-0.40	-2.31	0.00
TOTAL	6.20	6.68	-0.48	-2.46	-9.70

TABLE T1.4A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : EDMONTON HOUSE : PSRH (CASE 1)

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.27	0.75	-0.48	-3.22	0.00
FEB	0.40	0.64	-0.24	-1.45	0.00
MAR	0.74	0.79	-0.05	-0.91	0.00
APR	0.91	0.76	0.15	3.49	0.00
MAY	1.16	0.80	0.36	20.00	0.00
JUN	1.28	0.70	0.58	0.00	-23.20
JUL	1.27	0.63	0.64	0.00	-20.65
AUG	1.09	0.66	0.43	0.00	-15.93
SEP	0.79	0.69	0.10	0.00	-6.25
OCT	0.47	0.75	-0.28	-9.66	0.00
NOV	0.26	0.76	-0.50	-6.49	0.00
DEC	0.19	0.76	-0.57	-4.79	0.00
TOTAL	8.83	8.69	0.14	-2.46	-17.68

TABLE T1.5A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : DETROIT HOUSE : PSRH (CASE 1)

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.27	0.60	-0.33	-3.51	0.00
FEB	0.39	0.56	-0.17	-2.43	0.00
MAR	0.58	0.62	-0.04	-1.05	0.00
APR	0.77	0.59	0.18	12.86	0.00
MAY	0.85	0.57	0.28	0.00	-17.50
JUN	0.91	0.47	0.44	0.00	-11.89
JUL	0.10	0.47	-0.37	0.00	8.04
AUG	0.86	0.44	0.42	0.00	10.00
SEP	0.64	0.47	0.17	0.00	-5.31
OCT	0.46	0.56	-0.10	-9.09	0.00
NOV	0.27	0.57	-0.30	-8.33	0.00
DEC	0.20	0.60	-0.40	-5.00	0.00
TOTAL	6.30	6.52	-0.22	-3.38	-5.43

TABLE T1.6A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : OTTAWA HOUSE : PSRH (CASE 2)

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.17	0.33	-0.16	-3.64	0.00
FEB	0.21	0.30	-0.09	-3.33	0.00
MAR	0.32	0.34	-0.02	-1.33	0.00
APR	0.36	0.34	0.02	0.00	-2.00
MAY	0.36	0.33	0.03	0.00	-2.31
JUN	0.43	0.29	0.14	0.00	-5.60
JUL	0.37	0.26	0.11	0.00	-4.23
AUG	0.37	0.27	0.10	0.00	-3.12
SEP	0.24	0.28	-0.04	0.00	2.11
OCT	0.20	0.31	-0.11	0.00	6.87
NOV	0.11	0.32	-0.21	-23.33	0.00
DEC	0.13	0.33	-0.20	-5.26	0.00
TOTAL	3.27	3.70	-0.43	-5.11	-1.77

TABLE T1.7A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : TORONTO HOUSE : PSRH (CASE 2)

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.17	0.33	-0.16	-4.85	0.00
FEB	0.22	0.30	-0.08	-4.71	0.00
MAR	0.33	0.33	0.00	0.00	0.00
APR	0.39	0.33	0.06	0.00	-3.75
MAY	0.36	0.31	0.05	0.00	-3.57
JUN	0.45	0.28	0.17	0.00	-6.30
JUL	0.41	0.26	0.15	0.00	-4.84
AUG	0.41	0.27	0.14	0.00	-4.00
SEP	0.26	0.27	-0.01	0.00	0.42
OCT	0.17	0.30	-0.13	0.00	9.29
NOV	0.11	0.31	-0.20	-28.57	0.00
DEC	0.11	0.33	-0.22	-8.46	0.00
TOTAL	3.39	3.62	-0.23	-6.88	-2.67

TABLE T1.8A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : WINNIPEG HOUSE : PSRH (CASE 2)

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.08	0.29	-0.21	-3.04	0.00
FEB	0.12	0.27	-0.15	-4.17	0.00
MAR	0.22	0.30	-0.08	-2.29	0.00
APR	0.34	0.31	0.03	0.00	-1.76
MAY	0.43	0.34	0.09	0.00	-3.10
JUN	0.39	0.25	0.14	0.00	-4.12
JUL	0.44	0.27	0.17	0.00	-4.36
AUG	0.37	0.27	0.10	0.00	-2.56
SEP	0.23	0.30	-0.07	0.00	3.04
OCT	0.14	0.32	-0.18	-16.36	0.00
NOV	0.10	0.31	-0.21	-7.50	0.00
DEC	0.07	0.29	-0.22	-3.19	0.00
TOTAL	2.93	3.52	-0.59	-4.23	-2.54

TABLE T1.9A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : EDMONTON HOUSE : PSRH (CASE 2)

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.13	0.40	-0.27	-4.74	0.00
FEB	0.19	0.34	-0.15	-2.38	0.00
MAR	0.35	0.42	-0.07	-5.38	0.00
APR	0.43	0.40	0.03	3.00	0.00
MAY	0.55	0.42	0.13	0.00	-6.84
JUN	0.60	0.37	0.23	0.00	-7.93
JUL	0.60	0.33	0.27	0.00	-8.44
AUG	0.52	0.34	0.18	0.00	-6.00
SEP	0.38	0.36	0.02	0.00	-0.80
OCT	0.22	0.40	-0.18	-25.71	0.00
NOV	0.12	0.40	-0.28	-12.17	0.00
DEC	0.09	0.40	-0.31	-6.89	0.00
TOTAL	4.18	4.58	-0.40	-5.64	-6.15

TABLE T1.10A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : DETROIT HOUSE : PSRH (CASE 2)

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.13	0.31	-0.18	-6.21	0.00
FEB	0.18	0.30	-0.12	-6.00	0.00
MAR	0.26	0.33	-0.07	-7.78	0.00
APR	0.36	0.31	0.05	0.00	-2.38
MAY	0.40	0.30	0.10	0.00	-4.17
JUN	0.43	0.25	0.18	0.00	-5.00
JUL	0.48	0.25	0.23	0.00	-5.61
AUG	0.41	0.23	0.18	0.00	-4.29
SEP	0.30	0.25	0.05	0.00	-1.47
OCT	0.22	0.30	-0.08	0.00	3.81
NOV	0.13	0.30	-0.17	-24.29	0.00
DEC	0.10	0.31	-0.21	-8.40	0.00
TOTAL	3.40	3.44	-0.04	-8.33	-3.24

TABLE T1.11A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : OTTAWA HOUSE : HOUSE A

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.39	0.49	-0.10	-0.62	0.00
FEB	0.45	0.45	0.00	0.00	0.00
MAR	0.66	0.50	0.16	1.80	0.00
APR	0.69	0.50	0.19	4.87	0.00
MAY	0.64	0.49	0.1[illegible]	10.00	0.00
JUN	0.76	0.44	0.32	0.00	-14.55
JUL	0.64	0.39	0.25	0.00	-9.26
AUG	0.69	0.41	0.28	0.00	-11.20
SEP	0.47	0.41	0.06	6.00	0.00
OCT	0.42	0.47	-0.05	-1.79	0.00
NOV	0.24	0.47	-0.23	-3.48	0.00
DEC	0.31	0.50	-0.19	-1.35	0.00
TOTAL	6.36	5.52	0.84	-0.01	-11.49

TABLE T1.12A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : TORONTO HOUSE : HOUSE A

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.38	0.49	-0.11	-0.81	0.00
FEB	0.48	0.45	0.03	0.30	0.00
MAR	0.64	0.49	0.15	1.85	0.00
APR	0.73	0.48	0.25	9.26	0.00
MAY	0.63	0.46	0.17	10.62	0.00
JUN	0.81	0.42	0.39	0.00	-16.25
JUL	0.73	0.38	0.35	0.00	-11.67
AUG	0.77	0.40	0.37	0.00	-12.33
SEP	0.51	0.40	0.11	15.71	0.00
OCT	0.36	0.44	-0.08	-2.96	0.00
NOV	0.25	0.46	-0.21	-3.56	0.00
DEC	0.26	0.49	-0.23	-2.04	0.00
TOTAL	6.55	5.36	1.19	0.14	-13.21

TABLE T1.13A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : WINNIPEG HOUSE : HOUSE A

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.19	0.43	-0.24	-1.28	0.00
FEB	0.26	0.40	-0.14	-1.09	0.00
MAR	0.46	0.45	0.01	0.08	0.00
APR	0.68	0.45	0.23	6.22	0.00
MAY	0.84	0.50	0.34	18.89	0.00
JUN	0.78	0.37	0.41	0.00	-14.64
JUL	0.85	0.40	0.45	0.00	-12.16
AUG	0.73	0.40	0.33	0.00	-10.65
SEP	0.48	0.44	0.04	2.22	0.00
OCT	0.31	0.48	-0.17	-2.70	0.00
NOV	0.24	0.46	-0.22	-1.96	0.00
DEC	0.17	0.43	-0.26	-1.38	0.00
TOTAL	5.99	5.21	0.78	-0.46	-12.40

TABLE T1,14A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : EDMONTON HOUSE : HOUSE A

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.29	0.59	-0.30	-1.83	0.00
FEB	0.40	0.50	-0.10	-0.56	0.00
MAR	0.73	0.62	0.11	1.47	0.00
APR	0.87	0.59	0.28	5.09	0.00
MAY	1.11	0.62	0.49	22.27	0.00
JUN	1.20	0.54	0.66	0.00	-26.40
JUL	1.18	0.50	0.68	0.00	-21.25
AUG	1.02	0.52	0.50	0.00	-22.73
SEP	0.77	0.54	0.23	12.78	0.00
OCT	0.47	0.59	-0.12	-2.55	0.00
NOV	0.27	0.59	-0.32	-3.37	0.00
DEC	0.20	0.59	-0.39	-2.87	0.00
TOTAL	8.51	6.79	1.72	-0.15	-23.29

TABLE T1.15A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : DETROIT HOUSE : HOUSE A

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.28	0.47	-0.19	-1.64	0.00
FEB	0.39	0.44	-0.05	-0.53	0.00
MAR	0.56	0.48	0.08	1.40	0.00
APR	0.71	0.46	0.25	12.50	0.00
MAY	0.79	0.44	0.35	31.82	0.00
JUN	0.83	0.37	0.46	0.00	-13.53
JUL	0.91	0.37	0.54	0.00	-11.74
AUG	0.80	0.34	0.46	0.00	-10.70
SEP	0.61	0.37	0.24	0.00	-11.43
OCT	0.46	0.44	0.02	1.05	0.00
NOV	0.28	0.45	-0.17	-3.21	0.00
DEC	0.21	0.47	-0.26	-2.65	0.00
TOTAL	6.83	5.10	1.73	0.06	-11.81

TABLE T1.16A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : OTTAWA HOUSE : V OF R

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.33	0.44	-0.11	-0.68	0.00
FEB	0.37	0.40	-0.03	-0.25	0.00
MAR	0.53	0.45	0.08	0.95	0.00
APR	0.54	0.45	0.09	2.73	0.00
MAY	0.50	0.44	0.06	5.00	0.00
JUN	0.59	0.39	0.20	0.00	-6.90
JUL	0.50	0.34	0.16	0.00	-4.85
AUG	0.54	0.36	0.18	0.00	-5.63
SEP	0.38	0.37	0.01	0.00	-1.43
OCT	0.35	0.42	-0.07	-3.18	0.00
NOV	0.21	0.42	-0.21	-3.39	0.00
DEC	0.26	0.44	-0.18	-1.27	0.00
TOTAL	5.10	4.92	0.18	-0.58	-5.45

TABLE T1.17A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : TORONTO HOUSE : V OF R

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.32	0.44	-0.12	-0.88	0.00
FEB	0.40	0.40	0.00	0.00	0.00
MAR	0.54	0.44	0.10	1.33	0.00
APR	0.58	0.43	0.15	5.36	0.00
MAY	0.49	0.41	0.08	6.67	0.00
JUN	0.63	0.37	0.26	0.00	-8.39
JUL	0.57	0.34	0.23	0.00	-6.22
AUG	0.60	0.36	0.24	0.00	-6.67
SEP	0.41	0.35	0.06	0.00	-6.00
OCT	0.30	0.39	-0.09	-4.09	0.00
NOV	0.21	0.41	-0.20	-3.64	0.00
DEC	0.22	0.44	-0.22	-2.00	0.00
TOTAL	5.27	4.78	0.49	-0.56	-6.93

TABLE T1.18A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : WINNIPEG HOUSE : V OF R

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.16	0.38	-0.22	-1.14	0.00
FEB	0.22	0.36	-0.14	-1.10	0.00
MAR	0.36	0.40	-0.04	-0.31	0.00
APR	0.53	0.40	0.13	4.19	0.00
MAY	0.64	0.45	0.19	0.00	-8.26
JUN	0.60	0.33	0.27	0.00	-7.50
JUL	0.66	0.35	0.31	0.00	-6.60
AUG	0.57	0.36	0.21	0.00	-5.53
SEP	0.38	0.39	-0.01	-0.71	0.00
OCT	0.25	0.44	-0.19	-3.28	0.00
NOV	0.20	0.41	-0.21	-1.91	0.00
DEC	0.14	0.39	-0.25	-1.29	0.00
TOTAL	4.71	4.66	0.05	-1.09	-6.81

TABLE T1419A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : EDMONTON HOUSE : V OF R

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.25	0.53	-0.28	-1.69	0.00
FEB	0.33	0.46	-0.13	-0.72	0.00
MAR	0.58	0.56	0.02	0.29	0.00
APR	0.68	0.54	0.14	2.98	0.00
MAY	0.85	0.57	0.28	0.00	-20.00
JUN	0.92	0.49	0.43	0.00	-11.94
JUL	0.91	0.45	0.46	0.00	-10.95
AUG	0.79	0.47	0.32	0.00	-10.32
SEP	0.61	0.49	0.12	0.00	-10.91
OCT	0.39	0.53	-0.14	-3.59	0.00
NOV	0.23	0.54	-0.31	-3.44	0.00
DEC	0.17	0.54	-0.37	-2.76	0.00
TOTAL	6.71	6.17	0.54	-1.48	-12.01

TABLE T1.20A : COMPARISON OF EFFECT OF SOLAR ON OPAQUE SURFACES WITH SKY-RADIATION LOSS

CITY : DETROIT HOUSE : V OF R

MONTH	OPAQUE SOLAR OS (GJ)	SKY-RAD. LOSS RL (GJ)	DIFF. OS-RL (GJ)	OS-RL %'AGE OF HTG LOAD	OS-RL %'AGE OF CLG LOAD
JAN	0.23	0.42	-0.19	-1.67	0.00
FEB	0.32	0.39	-0.07	-0.77	0.00
MAR	0.44	0.43	0.01	0.20	0.00
APR	0.55	0.41	0.14	9.33	0.00
MAY	0.61	0.39	0.22	0.00	-11.58
JUN	0.64	0.33	0.31	0.00	-7.05
JUL	0.70	0.33	0.37	0.00	-6.61
AUG	0.62	0.31	0.31	0.00	-6.20
SEP	0.48	0.33	0.15	0.00	-5.56
OCT	0.37	0.39	-0.02	-1.33	0.00
NOV	0.23	0.40	-0.17	-3.54	0.00
DEC	0.17	0.42	-0.25	-2.63	0.00
TOTAL	5.36	4.55	0.81	-1.29	-6.94

APPENDIX B
Comparison of ENERGY with DOE 2.1a

TABLE T1.1B : COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 1 (Light), 70/70

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.476	1.000	0.972	14.615	12.624
FEB	2.997	3.366	0.982	0.948	11.006	9.825
MAR	3.181	3.605	0.898	0.891	7.643	7.550
APR	2.258	2.539	0.659	0.790	3.957	3.567
MAY	1.530	1.183	0.341	0.459	1.652	0.823
OCT	2.245	2.470	0.489	0.769	2.252	3.224
NOV	2.107	2.272	0.853	0.959	4.895	7.275
DEC	2.529	2.907	0.983	0.979	12.809	11.592
TOTAL	19.927	21.818	0.816	0.839	58.830	56.480

TABLE T1.2B : COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 1 (Medium), 70/70

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.476	1.000	0.972	14.201	12.624
FEB	2.997	3.366	0.989	0.948	10.650	9.825
MAR	3.181	3.605	0.929	0.891	7.270	7.555
APR	2.258	2.539	0.693	0.881	3.701	3.336
MAY	1.530	1.183	0.359	0.534	1.488	0.736
OCT	2.245	2.470	0.524	0.862	2.015	2.994
NOV	2.107	2.272	0.880	1.000	4.627	7.182
DEC	2.529	2.907	0.988	1.000	12.412	11.531
TOTAL	19.927	21.818	0.835	0.878	56.364	55.783

TABLE T1.3B : COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 1 (Light), 70/75

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.476	1.000	0.982	14.615	12.588
FEB	2.997	3.366	0.989	0.967	10.984	9.758
MAR	3.181	3.605	0.929	0.929	7.544	7.419
APR	2.258	2.539	0.728	0.853	3.801	3.407
MAY	1.530	1.183	0.458	0.535	1.473	0.735
OCT	2.245	2.470	0.579	0.837	2.[illegible]50	3.056
NOV	2.107	2.272	0.897	0.975	4.803	7.240
DEC	2.529	2.907	0.990	0.986	12.792	11.571
TOTAL	19.927	21.818	0.855	0.881	58.062	55.774

TABLE T1.4B : COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 1 (Medium), 70/75

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.476	1.000	0.982	14.201	12.588
FEB	2.997	3.366	0.995	0.967	10.633	9.758
MAR	3.181	3.605	0.961	0.929	7.173	7.419
APR	2.258	2.539	0.782	0.978	3.500	3.090
MAY	1.530	1.183	0.515	0.700	1.247	0.563
OCT	2.245	2.470	0.639	0.969	1.757	2.731
NOV	2.107	2.272	0.932	1.000	4.516	7.182
DEC	2.529	2.907	0.995	1.000	12.393	11.531
TOTAL	19.927	21.818	0.882	0.932	55.420	54.862

TABLE T1.5B : COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 1 (Light), 70/80

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.476	1.000	0.983	14.615	12.586
FEB	2.997	3.366	0.991	0.970	10.978	9.751
MAR	3.181	3.605	0.939	0.942	7.512	7.372
APR	2.258	2.539	0.762	0.890	3.724	3.314
MAY	1.530	1.183	0.509	0.619	1.395	0.644
OCT	2.245	2.470	0.619	0.878	1.959	2.955
NOV	2.107	2.272	0.912	0.976	4.770	7.237
DEC	2.529	2.907	0.991	0.987	12.788	11.567
TOTAL	19.927	21.818	0.871	0.903	57.740	55.426

TABLE T1.6B : COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 1 (Medium), 70/80

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.476	1.000	0.983	14.201	12.586
FEB	2.997	3.366	0.996	0.970	10.630	9.751
MAR	3.181	3.605	0.967	0.942	7.154	7.372
APR	2.258	2.539	0.813	1.000	3.429	3.035
MAY	1.530	1.183	0.566	0.767	1.169	0.500
OCT	2.245	2.470	0.674	1.000	1.679	2.655
NOV	2.107	2.272	0.942	1.000	4.495	7.182
DEC	2.529	2.907	0.995	1.000	12.393	11.531
TOTAL	19.927	21.818	0.896	0.947	55.150	54.612

TABLE T1.7B : COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 1 (Heavy), 70/70

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.476	1.000	1.000	13.748	12.526
FEB	2.997	3.366	0.996	0.999	10.303	9.652
MAR	3.181	3.605	0.967	0.963	6.987	7.295
APR	2.258	2.539	0.758	0.942	3.466	3.182
MAY	1.530	1.183	0.402	0.623	1.324	0.641
OCT	2.245	2.470	0.594	0.927	1.802	2.834
NOV	2.107	2.272	0.921	1.000	4.442	7.182
DEC	2.529	2.907	0.994	1.000	11.983	11.531
TOTAL	19.927	21.818	0.866	0.929	54.055	54.843

TABLE T1.8B : COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 2 (Light), 70/70

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.445	0.829	0.802	5.065	4.500
FEB	2.983	3.243	0.752	0.727	3.648	3.387
MAR	3.196	3.233	0.628	0.618	2.360	2.515
APR	2.115	2.198	0.416	0.475	1.127	0.906
MAY	1.546	1.434	0.159	0.036	0.381	0.165
OCT	1.936	2.380	0.219	0.444	0.545	0.804
NOV	2.014	2.373	0.523	0.740	1.406	2.386
DEC	2.577	2.845	0.798	0.826	4.496	4.115
TOTAL	19.448	21.150	0.591	0.640	19.028	18.778

TABLE T1.9B : COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 1 (Heavy), 70/75

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.476	1.000	1.000	13.748	12.526
FEB	2.997	3.366	0.999	1.000	10.296	9.649
MAR	3.181	3.605	0.987	1.000	6.928	7.161
APR	2.258	2.539	0.844	1.000	3.281	3.035
MAY	1.530	1.183	0.581	0.763	1.062	0.504
OCT	2.245	2.470	0.712	0.990	1.549	2.657
NOV	2.107	2.272	0.969	1.000	4.347	7.182
DEC	2.529	2.907	0.998	1.000	11.974	11.531
TOTAL	19.927	21.818	0.912	0.964	53.185	54.245

TABLE T1.10B: COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 2 (Light), 70/75

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.445	0.898	0.862	4.830	4.314
FEB	2.983	3.243	0.828	0.803	3.402	3.158
MAR	3.196	3.233	0.718	0.713	2.069	2.212
APR	2.115	2.198	0.526	0.552	0.885	0.752
MAY	1.546	1.434	0.296	0.062	0.185	0.149
OCT	1.936	2.380	0.328	0.524	0.286	0.657
NOV	2.014	2.373	0.647	0.814	1.112	2.237
DEC	2.577	2.845	0.867	0.881	4.300	3.974
TOTAL	19.448	21.150	0.684	0.717	17.069	17.453

TABLE T1.11B: COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 1 (Heavy), 70/80

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.476	1.000	1.000	13.748	12.526
FEB	2.997	3.366	0.999	1.000	10.296	9.649
MAR	3.181	3.605	0.987	1.000	6.927	7.161
APR	2.258	2.539	0.849	1.000	3.270	3.036
MAY	1.530	1.183	0.624	0.808	0.999	0.464
OCT	2.245	2.470	0.733	0.997	1.506	2.660
NOV	2.107	2.272	0.971	1.000	4.343	7.182
DEC	2.529	2.907	0.998	1.000	11.974	11.531
TOTAL	19.927	21.818	0.918	0.967	53.063	54.209

TABLE T1.12B: COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 2 (Light), 70/80

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.445	0.930	0.896	4.680	4.210
FEB	2.983	3.243	0.872	0.853	3.164	3.011
MAR	3.196	3.233	0.770	0.776	1.757	2.010
APR	2.115	2.198	0.581	0.634	0.685	0.602
MAY	1.546	1.434	0.327	0.048	0.130	0.158
OCT	1.936	2.380	0.379	0.607	0.084	0.518
NOV	2.014	2.373	0.702	0.861	0.887	2.142
DEC	2.577	2.845	0.905	0.909	4.131	3.901
TOTAL	19.448	21.150	0.729	0.769	15.518	16.552

TABLE T1.13B: COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 2 (Medium), 70/70

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.445	0.869	0.891	4.816	4.225
FEB	2.983	3.243	0.791	0.727	3.433	3.387
MAR	3.196	3.233	0.663	0.618	2.173	2.515
APR	2.115	2.198	0.435	0.553	1.029	0.750
MAY	1.546	1.434	0.152	0.036	0.333	0.165
OCT	1.936	2.380	0.228	0.518	0.467	0.666
NOV	2.014	2.373	0.553	0.836	1.270	2.193
DEC	2.577	2.845	0.835	0.912	4.281	3.894
TOTAL	19.448	21.150	0.620	0.698	17.802	17.795

TABLE T1.14B: COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 2 (Heavy), 70/70

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.445	0.926	0.891	4.737	4.225
FEB	2.983	3.243	0.859	0.824	3.302	3.098
MAR	3.196	3.233	0.739	0.717	2.011	2.197
APR	2.115	2.198	0.495	0.642	0.927	0.588
MAY	1.546	1.434	0.166	0.051	0.292	0.156
OCT	1.936	2.380	0.271	0.605	0.368	0.522
NOV	2.014	2.373	0.624	0.905	1.153	2.053
DEC	2.577	2.845	0.891	0.964	4.216	3.758
TOTAL	19.448	21.150	0.678	0.771	17.006	16.597

TABLE T1.15B: COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 2 (Medium), 70/75

Month	Solar Gain GJ DOE	Solar Gain GJ ENERGY	Solar U Factor DOE	Solar U Factor ENERGY	Heating Load GJ DOE	Heating Load GJ ENERGY
JAN	3.081	3.445	0.942	0.983	4.565	3.941
FEB	2.983	3.243	0.884	0.803	3.130	3.158
MAR	3.196	3.233	0.779	0.713	1.800	2.212
APR	2.115	2.198	0.575	0.716	0.722	0.469
MAY	1.546	1.434	0.298	0.062	0.122	0.149
OCT	1.936	2.380	0.360	0.686	0.152	0.403
NOV	2.014	2.373	0.706	0.954	0.908	1.955
DEC	2.577	2.845	0.916	0.993	4.050	3.686
TOTAL	19.448	21.150	0.731	0.812	15.449	15.973

TABLE T1.16B: COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 2 (Heavy), 70/75

Month	Solar Gain GJ DOE	Solar Gain GJ ENERGY	Solar U Factor DOE	Solar U Factor ENERGY	Heating Load GJ DOE	Heating Load GJ ENERGY
JAN	3.081	3.445	0.978	0.983	4.558	3.941
FEB	2.983	3.243	0.948	0.947	3.011	2.731
MAR	3.196	3.233	0.869	0.870	1.593	1.710
APR	2.115	2.198	0.648	0.783	0.589	0.373
MAY	1.546	1.434	0.309	0.037	0.087	0.165
OCT	1.936	2.380	0.402	0.748	0.057	0.323
NOV	2.014	2.373	0.785	0.991	0.772	1.880
DEC	2.577	2.845	0.964	1.000	4.010	3.667
TOTAL	19.448	21.150	0.789	0.876	14.677	14.790

TABLE T1.17B: COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 2 (Medium), 70/80

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.445	0.960	1.000	4.502	3.889
FEB	2.983	3.243	0.923	0.853	3.005	3.011
MAR	3.196	3.233	0.837	0.776	1.612	2.010
APR	2.115	2.198	0.629	0.787	0.601	0.368
MAY	1.546	1.434	0.315	0.048	0.098	0.158
OCT	1.936	2.380	0.399	0.752	0.061	0.318
NOV	2.014	2.373	0.756	0.992	0.789	1.878
DEC	2.577	2.845	0.945	1.000	3.968	3.667
TOTAL	19.448	21.150	0.769	0.850	14.636	15.299

TABLE T1.18B: COMPARISON OF ENERGY WITH DOE 2.1a
SINGLE FAMILY RESIDENCE, OTTAWA
(NRC) WEATHER 1970, Case 2 (Heavy), 70/80

Month	Solar Gain GJ		Solar U Factor		Heating Load GJ	
	DOE	ENERGY	DOE	ENERGY	DOE	ENERGY
JAN	3.081	3.445	0.983	1.000	4.542	3.889
FEB	2.983	3.243	0.964	0.988	2.960	2.607
MAR	3.196	3.233	0.903	0.939	1.483	1.488
APR	2.115	2.198	0.685	0.929	0.509	0.313
MAY	1.546	1.434	0.322	0.021	0.066	0.175
OCT	1.936	2.380	0.426	0.791	0.001	0.273
NOV	2.014	2.373	0.819	0.993	0.692	1.876
DEC	2.577	2.845	0.976	1.000	3.976	3.667
TOTAL	19.448	21.150	0.810	0.901	14.229	14.288

APPENDIX C

Comparison of Building Loads Predicted by CIRA and ENERGY

TABLE T1.1C : A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Ottawa, Case 1, Light, 70/70

MONTH	HEATING LOAD CIRA GJ	HEATING LOAD ENERGY GJ	COOLING LOAD CIRA GJ	COOLING LOAD ENERGY GJ
Jan	13.8	12.4	0.0	0.0
Feb	10.2	9.6	0.0	0.0
Mar	7.5	7.4	0.0	0.0
Apr	3.4	3.4	0.0	0.0
May	1.2	0.8	0.0	-0.1
Jun	0.0	0.0	-1.9	-2.0
Jul	0.0	0.0	-2.1	-2.5
Aug	0.0	0.0	-2.2	-2.3
Sep	0.6	0.6	0.0	-0.4
Oct	1.6	3.0	0.0	0.0
Nov	4.8	7.1	0.0	0.0
Dec	12.0	11.4	0.0	0.0
Total	55.1	57.7	-6.2	-7.3

TABLE T1.2C : A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Ottawa, Case 2, Light, 70/70

MONTH	HEATING CIRA GJ	LOAD ENERGY GJ	COOLING CIRA GJ	LOAD ENERGY GJ
Jan	4.7	4.4	0.0	0.0
Feb	3.3	3.3	0.0	0.0
Mar	2.1	2.4	0.0	0.0
Apr	0.8	0.8	0.0	-0.1
May	0.0	0.1	-0.9	-1.1
Jun	0.0	0.0	-2.1	-2.8
Jul	0.0	0.0	-2.2	-3.0
Aug	0.0	0.0	-2.3	-3.0
Sep	0.0	0.0	-1.2	-1.8
Oct	0.0	0.8	-1.1	-0.2
Nov	1.0	2.3	0.0	0.0
Dec	4.0	4.0	0.0	0.0
Total	15.9	17.9	-9.8	-11.9

TABLE T1.3C : A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Detroit, House A, Light, 70/70

MONTH	HEATING CIRA GJ	LOAD ENERGY GJ	COOLING CIRA GJ	LOAD ENERGY GJ
Jan	12.0	11.1	0.0	0.0
Feb	9.8	8.8	0.0	0.0
Mar	6.1	6.6	0.0	0.0
Apr	2.2	2.4	0.0	0.0
May	1.2	0.5	0.0	-0.4
Jun	0.0	0.0	-2.9	-2.8
Jul	0.0	0.0	-4.0	-3.9
Aug	0.0	0.0	-3.5	-2.7
Sep	0.0	0.4	-1.5	-0.3
Oct	2.1	2.7	0.0	0.0
Nov	5.7	6.8	0.0	0.0
Dec	10.1	10.3	0.0	0.0
Total	49.2	49.5	-11.9	-10.1

TABLE T1.4C : A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Detroit, V of R, Light, 70/70

MONTH	HEATING CIRA GJ	LOAD ENERGY GJ	COOLING CIRA GJ	LOAD ENERGY GJ
Jan	11.7	11.0	0.0	0.0
Feb	9.6	8.5	0.0	0.0
Mar	5.5	5.9	0.0	0.0
Apr	1.7	1.8	0.0	0.0
May	0.0	0.4	-1.4	-1.0
Jun	0.0	0.0	-3.9	-3.9
Jul	0.0	0.0	-4.8	-5.0
Aug	0.0	0.0	-4.3	-3.8
Sep	0.0	0.1	-2.1	-1.0
Oct	1.7	2.0	0.0	0.0
Nov	5.1	6.2	0.0	0.0
Dec	9.8	10.0	0.0	0.0
Total	45.1	46.0	-16.5	-14.6

TABLE T1.5C : A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Ottawa, Case 1, Medium, 70/70

MONTH	HEATING CIRA GJ	LOAD ENERGY GJ	COOLING CIRA GJ	LOAD ENERGY GJ
Jan	13.8	12.3	0.0	0.0
Feb	10.3	9.4	0.0	0.0
Mar	7.5	7.1	0.0	0.0
Apr	3.3	3.1	0.0	0.0
May	1.1	0.8	0.0	-0.1
Jun	0.0	0.0	-1.6	-2.0
Jul	0.0	0.0	-2.0	-2.5
Aug	0.0	0.0	-1.9	-2.3
Sep	0.6	0.5	0.0	-0.4
Oct	1.4	2.8	0.0	0.0
Nov	4.7	7.0	0.0	0.0
Dec	12.0	11.3	0.0	0.0
Total	54.7	54.3	-5.5	-7.3

TABLE T1.6C : A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Ottawa, Case 2, Medium, 70/70

MONTH	HEATING CIRA GJ	LOAD ENERGY GJ	COOLING CIRA GJ	LOAD ENERGY GJ
Jan	4.8	4.1	0.0	0.0
Feb	3.2	3.0	0.0	0.0
Mar	2.0	2.1	0.0	0.0
Apr	0.7	0.7	0.0	-0.2
May	0.0	0.1	-0.7	-1.1
Jun	0.0	0.0	-1.9	-2.8
Jul	0.0	0.0	-2.1	-3.0
Aug	0.0	0.0	-2.2	-3.0
Sep	0.0	0.0	-1.1	-1.9
Oct	0.0	0.6	-0.8	-0.2
Nov	0.9	2.1	0.0	0.0
Dec	4.1	3.8	0.0	0.0
Total	15.7	16.3	-8.8	-12.1

TABLE T1.7C : A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Detroit, House A, Medium, 70/70

MONTH	HEATING CIRA GJ	LOAD ENERGY GJ	COOLING CIRA GJ	LOAD ENERGY GJ
Jan	11.9	11.1	0.0	0.0
Feb	9.9	8.8	0.0	0.0
Mar	6.2	6.6	0.0	0.0
Apr	2.1	2.3	0.0	0.0
May	1.1	0.4	0.0	-0.4
Jun	0.0	0.0	-2.7	-2.8
Jul	0.0	0.0	-3.7	-3.9
Aug	0.0	0.0	-3.4	-2.7
Sep	0.0	0.4	-1.4	-0.3
Oct	2.1	2.7	0.0	0.0
Nov	5.7	6.8	0.0	0.0
Dec	10.0	10.3	0.0	0.0
Total	49.0	49.3	-11.2	-10.1

TABLE T1.8C : A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Detroit, V of R, Medium, 70/70

MONTH	HEATING LOAD CIRA GJ	HEATING LOAD ENERGY GJ	COOLING LOAD CIRA GJ	COOLING LOAD ENERGY GJ
Jan	11.8	11.0	0.0	0.0
Feb	9.7	8.5	0.0	0.0
Mar	5.4	5.9	0.0	0.0
Apr	1.5	1.8	0.0	0.0
May	0.0	0.4	-1.1	-1.0
Jun	0.0	0.0	-3.6	-3.9
Jul	0.0	0.0	-4.7	-5.0
Aug	0.0	0.0	-4.2	-3.8
Sep	0.0	0.1	-1.9	-1.0
Oct	1.6	2.0	0.0	0.0
Nov	5.2	6.2	0.0	0.0
Dec	9.7	10.0	0.0	0.0
Total	44.9	45.9	-15.5	-14.6

TABLE T1.9C : A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Ottawa, Case 1, Heavy, 70/70

MONTH	HEATING LOAD CIRA GJ	HEATING LOAD ENERGY GJ	COOLING LOAD CIRA GJ	COOLING LOAD ENERGY GJ
Jan	13.8	12.3	0.0	0.0
Feb	10.3	9.4	0.0	0.0
Mar	7.5	7.1	0.0	0.0
Apr	3.2	3.1	0.0	0.0
May	1.0	0.6	0.0	0.0
Jun	0.0	0.0	-1.9	-2.0
Jul	0.0	0.0	-2.1	-2.5
Aug	0.0	0.0	-2.2	-2.3
Sep	0.4	0.5	0.0	-0.4
Oct	1.3	2.8	0.0	0.0
Nov	4.7	7.0	0.0	0.0
Dec	12.0	11.3	0.0	0.0
Total	54.2	54.2	-6.2	-7.3

TABLE T1.10C: A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Ottawa, Case 2, Heavy, 70/70

MONTH	HEATING LOAD CIRA GJ	HEATING LOAD ENERGY GJ	COOLING LOAD CIRA GJ	COOLING LOAD ENERGY GJ
Jan	4.7	4.1	0.0	0.0
Feb	3.3	3.0	0.0	0.0
Mar	1.9	2.1	0.0	0.0
Apr	0.5	0.7	0.0	-0.2
May	0.0	0.1	-0.5	-1.1
Jun	0.0	0.0	-1.9	-2.8
Jul	0.0	0.0	-2.2	-3.0
Aug	0.0	0.0	-2.2	-3.0
Sep	0.0	0.0	-1.0	-1.9
Oct	0.0	0.6	-0.6	-0.2
Nov	1.0	2.1	0.0	0.0
Dec	4.0	3.8	0.0	0.0
Total	15.4	16.3	-8.4	-12.1

TABLE T1.11C: A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Detroit, House A, Heavy, 70/70

MONTH	HEATING CIRA GJ	LOAD ENERGY GJ	COOLING CIRA GJ	LOAD ENERGY GJ
Jan	11.9	11.1	0.0	0.0
Feb	9.9	8.8	0.0	0.0
Mar	6.2	6.6	0.0	0.0
Apr	1.9	2.3	0.0	0.0
May	0.9	0.4	0.0	-0.4
Jun	0.0	0.0	-2.5	-2.8
Jul	0.0	0.0	-3.6	-3.9
Aug	0.0	0.0	-3.2	-2.7
Sep	0.0	0.4	-1.2	-0.3
Oct	2.1	2.7	0.0	0.0
Nov	5.7	6.8	0.0	0.0
Dec	10.1	10.3	0.0	0.0
Total	48.7	49.3	-10.5	-10.1

TABLE T1.12C: A COMPARISON OF BUILDING LOADS PREDICTED BY CIRA AND ENERGY
Detroit, V of R, Heavy, 70/70

MONTH	HEATING CIRA GJ	LOAD ENERGY GJ	COOLING CIRA GJ	LOAD ENERGY GJ
Jan	11.8	10.9	0.0	0.0
Feb	9.6	8.5	0.0	0.0
Mar	5.4	5.9	0.0	0.0
Apr	1.4	1.6	0.0	0.0
May	0.0	0.4	-1.7	-1.0
Jun	0.0	0.0	-3.5	-3.9
Jul	0.0	0.0	-4.6	-5.0
Aug	0.0	0.0	-4.1	-3.8
Sep	0.0	0.1	-1.7	-1.0
Oct	1.5	2.0	0.0	0.0
Nov	5.1	6.2	0.0	0.0
Dec	9.8	10.0	0.0	0.0
Total	44.6	45.6	-15.6	-14.6

APPENDIX D

Solar Utilization Correction Factor (C_f)

TABLE T1.1D : SOLAR UTILIZATION CORRECTION FACTOR (Cf)
(SUF(Barkat)/SUF(Doe))

House Mass, Light, MGR = 1.105 hr/C

GLR	ACTUAL			CALCULATED		
	TEMPERATURE RISE IN F					
	70/70	70/75	70/80	70/70	70/75	70/80
0.174	0.917	0.935	0.943	0.924	0.937	0.943
0.215	0.893	0.901	0.917	0.894	0.902	0.919
0.303	0.877	0.877	0.901	0.852	0.856	0.881
0.165	0.943	0.952	0.952	0.932	0.946	0.948
0.232	0.862	0.877	0.901	0.884	0.891	0.911
0.287	0.840	0.847	0.877	0.858	0.862	0.887
0.405	0.826	0.840	0.862	0.829	0.831	0.853
0.221	0.901	0.901	0.917	0.890	0.898	0.916
0.435	0.813	0.806	0.826	0.826	0.828	0.847
0.533	0.806	0.813	0.826	0.821	0.820	0.833
0.736	0.794	0.806	0.833	0.812	0.812	0.820
0.421	0.855	0.847	0.862	0.827	0.829	0.849
0.754	0.813	0.813	0.813	0.810	0.811	0.820
0.953	0.781	0.806	0.813	0.783	0.807	0.814
1.349	0.787	0.800	0.813	0.787	0.800	0.813
0.735	0.833	0.820	0.820	0.812	0.812	0.820

BMDP5R - POLYNOMIAL REGRESSION (D1.1)

GOODNESS OF FIT TEST RESULTS:
House Mass: Light

Temperature Rise in ^{o}F	70/70	70/75	70/80
F Statistic	0.00	0.49	0.76
Tail Probability	0.9574	0.4986	0.4025

TABLE T1.2D : SOLAR UTILIZATION CORRECTION FACTOR (Cf)
(SUF(Barkat)/SUF(Doe))

House Mass, Medium, MGR = 1.99 hr/C

GLR	ACTUAL			CALCULATED		
	TEMPERATURE RISE IN F					
	70/70	70/75	70/80	70/70	70/75	70/80
0.179	0.935	0.952	0.962	0.938	0.953	0.962
0.221	0.901	0.926	0.943	0.905	0.931	0.946
0.312	0.877	0.901	0.926	0.862	0.892	0.917
0.170	0.952	0.962	0.971	0.946	0.959	0.965
0.237	0.885	0.917	0.935	0.895	0.923	0.941
0.293	0.855	0.893	0.917	0.868	0.899	0.923
0.413	0.840	0.870	0.901	0.842	0.865	0.892
0.225	0.909	0.935	0.943	0.902	0.929	0.945
0.442	0.820	0.840	0.877	0.839	0.860	0.887
0.541	0.826	0.847	0.870	0.837	0.848	0.870
0.749	0.826	0.847	0.870	0.834	0.842	0.851
0.428	0.870	0.877	0.893	0.840	0.862	0.889
0.764	0.826	0.840	0.840	0.834	0.842	0.850
0.966	0.820	0.840	0.847	0.821	0.840	0.846
1.371	0.840	0.847	0.847	0.840	0.847	0.847
0.746	0.855	0.840	0.840	0.834	0.842	0.851

BMDP5R - POLYNOMIAL REGRESSION (D1.1)

GOODNESS OF FIT TEST RESULTS:
House Mass: Medium

Temperature Rise in ^{o}F	70/70	70/75	70/80
F Statistic	0.10	0.05	0.00
Tail Probability	0.7537	0.8354	0.975

TABLE T1.3D : SOLAR UTILIZATION CORRECTION FACTOR (Cf)
(SUF(Barkat)/SUF(Doe))

House Mass, Heavy, MGR = 5.45 hr/C

GLR	ACTUAL 70/70	ACTUAL 70/75	ACTUAL 70/80	CALCULATED 70/70	CALCULATED 70/75	CALCULATED 70/80
	TEMPERATURE RISE IN F					
0.175	0.971	0.980	0.980	0.973	0.985	0.984
0.217	0.952	0.971	0.980	0.950	0.976	0.981
0.304	0.926	0.962	0.971	0.918	0.959	0.972
0.167	0.980	0.990	0.990	0.978	0.987	0.985
0.233	0.935	0.971	0.980	0.942	0.972	0.979
0.293	0.909	0.962	0.971	0.921	0.961	0.973
0.405	0.901	0.943	0.962	0.902	0.943	0.960
0.222	0.952	0.980	0.980	0.947	0.974	0.980
0.434	0.885	0.926	0.952	0.900	0.939	0.956
0.533	0.893	0.926	0.943	0.902	0.929	0.943
0.734	0.909	0.926	0.935	0.914	0.919	0.921
0.421	0.926	0.952	0.962	0.901	0.941	0.957
0.751	0.901	0.909	0.909	0.914	0.919	0.920
0.950	0.909	0.917	0.893	0.909	0.918	0.908
1.340	0.943	0.917	0.909	0.943	0.917	0.909
0.734	0.935	0.926	0.917	0.914	0.919	0.921

BMDP5R – POLYNOMIAL REGRESSION (D1.1)

GOODNESS OF FIT TEST RESULTS:

House Mass: Heavy Temperature Rise in °F	70/70	70/75	70/80
F Statistic	0.05	0.03	0.29
Tail Probability	0.8233	0.8594	0.6015

APPENDIX E
ENERGY Weather Files

CITY : DETROIT   LATITUDE in degrees : 42.33

LOCATED IN CELL RANGE OF I141 TO N158

VALUE OF "d" IS 1.00115

Minimum Temperature °C = -4.8 *

Maximum Temperature °C = 22.3 *

Average Temperature °C = 9.2 *

Month = 1 - Day = 15 $(T_{max} - T_{min}).d = 27.41165$

SOLAR RADIATION ON HORIZONTAL AND VERTICAL SURFACES in MJ/(sqm.day) *   SPECIFIC INFILTRATION * in Cu.m/(Hr.sqcm)

Month	Horiz	East & West	North	South	Wind Effect
Jan	5.247	3.666	1.850	8.834	0.229
Feb	8.756	6.255	2.505	12.717	0.260
Mar	12.424	8.632	4.172	13.028	0.234
Apr	17.841	11.882	6.073	13.930	0.241
May	18.875	13.115	8.190	12.774	0.222
Jun	21.430	14.155	8.839	12.543	0.190
Jul	23.156	15.011	8.592	13.189	0.180
Aug	19.352	13.092	6.988	13.840	0.183
Sep	14.434	9.747	4.916	13.447	0.168
Oct	9.710	6.691	2.854	12.273	0.199
Nov	5.497	3.955	2.143	8.185	0.229
Dec	3.929	2.790	1.706	6.119	0.248

* TRY 1968

CITY : TORONTO LATITUDE in degrees : 43.683

LOCATED IN CELL RANGE OF O141 TO S158

VALUE OF "d" IS 1

Minimum Temperature ^{o}C = -6.7

Maximum Temperature ^{o}C = 20.7

Average Temperature ^{o}C = 7.4

Month = 1 Day = 23 $(T_{max} - T_{min}).d$ = 27.4

SOLAR RADIATION ON HORIZONTAL AND VERTICAL SURFACES in MJ/(sqm.day) * | SPECIFIC INFILTRATION * in Cu.m/(Hr.sqcm)

Month	Horiz	East & West	North	South	Wind Effect
Jan	6.348	4.489	1.680	12.609	0.193
Feb	9.914	6.859	2.354	15.516	0.237
Mar	14.207	9.393	3.421	15.493	0.224
Apr	18.750	11.125	3.747	13.570	0.230
May	17.671	9.398	3.096	8.372	0.184
Jun	22.815	12.605	5.678	9.987	0.179
Jul	20.226	10.894	4.415	9.206	0.155
Aug	19.817	11.453	3.817	11.921	0.148
Sep	12.310	7.411	1.970	11.380	0.157
Oct	7.143	4.686	0.986	10.434	0.165
Nov	4.315	3.044	0.485	9.350	0.221
Dec	4.134	2.990	0.781	9.823	0.209

* TRY

CITY : OTTAWA LATITUDE in degrees : 45.3167

LOCATED IN CELL RANGE OF T141 TO X158

VALUE OF "d" IS 1.00115

Minimum Temperature °C = -14.42 *

Maximum Temperature °C = 21.06 *

Average Temperature °C = 5.47 *

Month = 1 Day = 15 $(T_{max} - T_{min}).d = 35.888$

SOLAR RADIATION ON HORIZONTAL AND VERTICAL SURFACES in MJ/(sqm.day) * | SPECIFIC INFILTRATION * in Cu.m/(Hr.sqcm)

Month	Horiz	East & West	North	South	Wind
Jan	6.314	4.635	1.647	13.396	0.199
Feb	9.187	6.525	2.277	15.012	0.244
Mar	13.832	9.430	3.729	15.717	0.231
Apr	17.500	10.617	3.557	13.308	0.236
May	17.512	9.683	3.539	9.122	0.215
Jun	21.918	11.914	5.008	9.758	0.197
Jul	18.182	9.714	3.491	8.152	0.157
Aug	17.943	10.356	3.384	11.391	0.145
Sep	11.379	6.982	1.845	11.042	0.165
Oct	8.177	6.883	0.215	10.822	0.170
Nov	4.077	2.973	0.468	9.412	0.187
Dec	4.849	3.583	1.267	11.100	0.220

* NRC 1970

CITY : WINNIPEG LATITUDE in degrees : 49.9

LOCATED IN CELL RANGE OF Y141 TO AC158

VALUE OF "d" IS 1

Minimum Temperature °C = -18.2

Maximum Temperature °C = 19.9

Average Temperature °C = 2.6

Month = 1 Day = 19 $(T_{max} - T_{min}).d$ = 38.1

SOLAR RADIATION ON HORIZONTAL AND VERTICAL SURFACES in MJ/(sqm.day) * | SPECIFIC INFILTRATION * in Cu.m/(Hr.sqcm)

Month	Horiz	East & West	North	South	Wind Effect
Jan	3.157	2.335	1.107	6.965	0.258
Feb	5.485	4.079	1.775	9.677	0.245
Mar	9.721	6.992	2.946	12.474	0.223
Apr	16.796	11.491	4.961	15.295	0.222
May	20.828	14.128	7.213	14.583	0.198
Jun	19.215	13.662	8.756	13.526	0.252
Jul	21.714	14.371	7.568	14.159	0.222
Aug	17.705	12.191	5.939	14.332	0.200
Sep	11.107	7.831	3.451	12.280	0.246
Oct	6.053	4.505	2.371	8.501	0.243
Nov	4.213	3.173	1.332	8.957	0.268
Dec	2.760	2.094	0.988	6.430	0.250

* TRY

CITY : EDMONTON LATITUDE in degrees : 53.567

LOCATED IN CELL RANGE OF AD141 TO AH158

VALUE OF "d" IS 1

Minimum Temperature °C = -14.2

Maximum Temperature °C = 16.0

Average Temperature °C = 2.1

Month = 1 Day = 15 $(T_{max} - T_{min}).d = 30.2$

SOLAR RADIATION ON HORIZONTAL AND VERTICAL SURFACES in MJ/(sqm.day) * | SPECIFIC INFILTRATION * in Cu.m/(Hr.sqcm)

Month	Horiz	East & West	North	South	Wind Effect
Jan	4.145	2.868	1.320	7.768	0.140
Feb	7.155	4.823	2.659	9.777	0.152
Mar	12.435	9.040	3.776	13.549	0.160
Apr	16.376	11.863	5.791	12.716	0.157
May	19.511	15.685	9.182	11.571	0.187
Jun	22.724	17.130	10.651	11.857	0.159
Jul	22.100	16.408	9.316	11.480	0.143
Aug	19.306	13.961	6.129	12.734	0.112
Sep	14.048	10.271	3.732	13.562	0.149
Oct	7.654	5.197	2.287	10.219	0.173
Nov	4.179	2.805	1.183	7.570	0.142
Dec	2.896	1.822	0.884	5.612	0.185

* TRY

APPENDIX F
CIRA Listing of House A

APPENDIX F

CIRA LISTING OF HOUSE A

GENERAL

Current answers for GENERAL named HOUSE-A:

```
A ) NAME of this house....................? 'HOUSE-A'
B ) What CITY.............................? 'Detroit'
C ) AZIMUTH of north face (degrees).......? '0' degrees
D ) What type of THERMOSTAT...............? 'Dual heating & cooling'
E ) Heating THERMOSTAT setting (degC).....? '21.11111' degC
F ) Heating NIGHT setting (degC)..........? '21.11111' degC
G ) Cooling THERMOSTAT setting (degC).....? '25.55556' degC
H ) Cooling NIGHT setting (degC)..........? '25.55556' degC
I ) Total house FLOOR AREA (sqm)..........? '171.8708' degC
J ) House MASS............................? 'Light'
K ) Solar STORAGE factor (unitless).......? '0.22' unitless
L ) SPECIFIC THERMAL MASS (kJ/K-sqm)......? '38.8132' kJ/K-sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

WALLS

Current answers for WALLS named FRONT:

```
A ) NAME for the following walls..........? 'Front'
B ) Which wall ORIENTATION................? 'East walls'
C ) Wall TYPE.............................? '50 by 100 mm Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm).............? '76.2' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)................? '1.409816' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '21.81479' sqm
J ) No. of WINDOWS (No.)..................? '4' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '233.2873' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

Current answers for WALLS named LEFT:

```
A ) NAME for the following walls..........? 'LEFT'
B ) Which wall ORIENTATION................? 'South walls'
C ) Wall TYPE.............................? '50 by 100 mm Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm).............? '76.2' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)................? '1.409816' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '18.69109' sqm
J ) No. of WINDOWS (No.).................? '2' No.
K ) No. of VENTS in wall (No.)...........? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '187.3179' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

Current answers for WALLS named BACK:

```
A ) NAME for the following walls..........? 'BACK'
B ) Which wall ORIENTATION................? 'West walls'
C ) Wall TYPE.............................? '50 by 100 mm Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm).............? '76.2' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)................? '1.409816' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '24.04056' sqm
J ) No. of WINDOWS (No.).................? '4' No.
K ) No. of VENTS in wall (No.)...........? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '212.5033' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

```
Current answers for WALLS named RIGHT:

A ) NAME for the following walls..........? 'RIGHT'
B ) Which wall ORIENTATION................? 'North walls'
C ) Wall TYPE.............................? '50 by 100 mm Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm).............? '76.2' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)................? '1.409816' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '18.12838' sqm
J ) No. of WINDOWS (No.)..................? '2' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '192.3991' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

WINDOWS

```
Current answers for WINDOWS named SOUTH:

A ) NAME of the following windows.........? 'SOUTH'
B ) Which window ORIENTATION..............? 'South'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Single pane w/ OUTSIDE
                                             storm'
E ) DRAPES & SHUTTERS.....................? 'Shades or Blinds'
F ) Are window covers USED at DAYtime.....? 'No'
G ) U-value (W/sqm-K).....................? '2.947581' W/sqm-K
H ) Average sash FIT......................? 'Average'
I ) Specific LEAKAGE AREA (sqmm/sqm)......? '548.9589' sqmm/sqm
J ) Summer SOLAR GAIN factor (%)..........? '77' %
K ) Winter SOLAR GAIN factor (%)..........? '77' %
L ) Window AREA (sqm).....................? '0.9949926' sqm
M ) Overhang PROTRUSION (mm)..............? '457.2' mm
N ) HEIGHT above top of window (mm).......? '304.8' mm
O ) Average window HEIGHT (m).............? '1.648968' m
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

```
Current answers for WINDOWS named WEST:

A ) NAME of the following windows.........? 'WEST'
B ) Which window ORIENTATION..............? 'West'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Single pane w/OUTSIDE
                                            storm'
E ) DRAPES & SHUTTERS.....................? 'Shades or Blinds'
F ) Are window covers USED at DAYtime.....? 'No'
G ) U-value (W/sqm-K).....................? '2.947581' W/sqm-K
H ) Average sash FIT......................? 'Average'
I ) Specific LEAKAGE AREA (sqmm/sqm)......? '548.9589' sqmm/sqm
J ) Summer SOLAR GAIN factor (%)..........? '77' %
K ) Winter SOLAR GAIN factor (%)..........? '77' %
L ) Window AREA (sqm)....................? '2.331869' sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...


Current answers for WINDOWS named NORTH:

A ) NAME of the following windows.........? 'NORTH'
B ) Which window ORIENTATION..............? 'North'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Single pane w/OUTSIDE
                                            storm'
E ) DRAPES & SHUTTERS.....................? 'Shades or Blinds'
F ) Are window covers USED at DAYtime.....? 'No'
G ) U-value (W/sqm-K).....................? '2.947581' W/sqm-K
H ) Average sash FIT......................? 'Average'
I ) Specific LEAKAGE AREA (sqmm/sqm)......? '548.9589' sqmm/sqm
J ) Summer SOLAR GAIN factor (%)..........? '77' %
K ) Winter SOLAR GAIN factor (%)..........? '77' %
L ) Window AREA (sqm)....................? '1.557986' sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

```
Current answers for WINDOWS named EAST:

A ) NAME of the following windows.........? 'EAST'
B ) Which window ORIENTATION..............? 'East'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Single pane w/OUTSIDE
                                             storm'
E ) DRAPES & SHUTTERS.....................? 'Shades or Blinds'
F ) Are window covers USED at DAYtime.....? 'No'
G ) U-value (W/sqm-K).....................? '2.947581' W/sqm-K
H ) Average sash FIT......................? 'Average'
I ) Specific LEAKAGE AREA (sqmm/sqm)......? '548.9589' sqmm/sqm
J ) Summer SOLAR GAIN factor (%)..........? '77' %
K ) Winter SOLAR GAIN factor (%)..........? '77' %
L ) Window AREA (sqm).....................? '4.557828' sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

<u>SUBFLOOR</u>

```
Current answers for SUBFLOOR named BASEMENT:

A ) Subfloor NAME ........................? 'BASEMENT'
B ) Subfloor TYPE.........................? 'Basement'
C ) Joist INSULATION......................? 'Heated Basement'
D ) Total joist R-VALUE (K-sqm/W).........? '0.528681' K-sqm/W
E ) Floor AREA (Joists) (sqm).............? '85.93539' sqm
F ) No. of floor PENETRATIONS (No.).......? ' ' No.
G ) Floor sp. LEAKAGE AREA (sqmm/sqm).....? '267.643' K-sqm/W
H ) Subfloor WALL INSULATION material.....? 'None'
I ) Above-grade wall R-VALUE (K-sqm/W)....? '1.409816' K-sqm/W
J ) ABOVE-Grade HEIGHT (m)................? '0.0304803' m
K ) Exposed PERIMETER (m).................? '39.0144' m
L ) Soil CONDUCTIVITY (W/m-K).............? '2.162' W/m-K
M ) No. of WINDOWS (No.)..................? ' ' No.
N ) No. of wall VENTS (No.) ..............? ' ' No.
O ) No. of wall PENETRATIONS (No.)........? ' ' No.
P ) Wall specific LEAKAGE AREA (sqmm/sqm).? '1023.346' sqmm/sqm
Q ) Below-grade R-VALUE (K-sqm/W).........? '1.05736' K-sqm/W
R ) Floor R-VALUE (K-sqm/W)...............? '0.352454' K-sqm/W
S ) Eqv Floor RESIST' outs'd (K-sqm/W)....? '6.344171' K-sqm/W
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

INFILTRATION

Current answers for INFILTRA named Ventilation:

```
A ) Is there MECHANICAL Ventilation.......? 'None'
B ) NATURAL Cooling Ventilation...........? 'No'
C ) TERRAIN class.........................? 'Class 3'
D ) SHEILDING class.......................? 'Class 3'
E ) HEIGHT of living space (m)............? '2.438281' m
F ) Approximate house VOLUME (m3).........? '209.5427' m3
G ) HOW was leakage area MEASURED.........? 'Total only'
H ) TOTAL leakage area (sqcm).............? '387.096' sqcm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

DOOR

Current answers for DOORS named EAST:

```
A ) NAME of following doors...............? 'EAST'
B ) Door TYPE.............................? 'Plain (Hinged)'
C ) Door MATERIAL.........................? 'Wood Solid Core'
D ) Approximate Glass AREA (%)............? '0' %
E ) Any STORM doors.......................? 'Outside Storm'
F ) U-value (W/sqm-K).....................? '1.407959' W/sqm-K
G ) Door FIT..............................? 'Average'
H ) Specific leakage AREA (sqmm/sqm)......? '204.5141' sqmm/sqm
I ) Door AREA (sqm)......................? '1.858992'
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

Current answers for DOORS named WEST:

```
A ) NAME of following doors...............? 'WEST'
B ) Door TYPE.............................? 'Plain (Hinged)'
C ) Door MATERIAL.........................? 'Wood Solid Core'
D ) Approximate Glass AREA (%)............? '0' %
E ) Any STORM doors.......................? 'Outside Storm'
F ) U-value (W/sqm-K).....................? '1.407959' W/sqm-K
G ) Door FIT..............................? 'Average'
H ) Specific leakage AREA (sqmm/sqm)......? '204.5141' sqmm/sqm
I ) Door AREA (sqm)......................? '1.858992'
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

ROOF-CEILING

```
Current answers for ROOF-CEI named ATTIC:

A ) NAME for attic/roof or ceiling........? 'ATTIC'
B ) Roof/Ceiling TYPE.....................? 'Unfinished attic'
C ) Insulation TYPE.......................? 'Fiberglass batts'
D ) Insulation THICKNESS (mm).............? '330.2' mm
E ) Insulatable AIR SPACE (mm)............? '0' mm
F ) Ceiling R-value (K-sqm/W).............? '7.577762' K-sqm/W
G ) Ceiling AREA (sqm)....................? '85.93539' sqm
H ) No. of ceiling VENTS (no.)............? '5' no.
I ) No. of ceiling PENETRATIONS (no.).....? '10' no.
J ) Ceiling sp. LEAKAGE area (sqmm/sqm)...? '302.5529' sqmm/sqm
K ) Roof PITCH (%)........................? '30' %
L ) Roof top MATERIAL.....................? 'Asphalt Shingles'
M ) Roof ABSORPTIVITY (%).................? '95' %
N ) Attic VENTILATION (m3/hr-sqm).........? '9.11' m3/hr-sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

HVAC-SYSTEM

```
Current answers for HVAC-SYS named Heat-Cool:

A ) What HEATING EQUIPMENT................? 'Gas Furnace'
B ) Rated INPUT capacity (kW).............? '29.29115' kW
C ) Steady-state EFFICIENCY (%)...........? '70' %
D ) FLUE gas temperature (degC)...........? '121.1111' degC
E ) What DISTRIBUTION system..............? 'Forced Air'
F ) WHERE are pipes or ducts..............? 'Basement'
G ) INSULATION on pipes  or ducts.........? 'None'
H ) Insulatable duct/pipe LENGTH (m)......? '30.47851' m
I ) Distribution LOSSES to outside (%)....? '25' %
J ) What COOLING EQUIPMENT................? 'Central Air Conditioning'
K ) Rated TOTAL capacity (kW).............? '7.029877' kW
L ) Rated SENSIBLE capacity (kW)..........? '4.920914' kW
M ) Rated COP (unitless)..................? '2' unitless
N ) Actual Fan Flow (m3/hr)...............? '1247.027' m3/hr
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

APPLIANCES

Current answers for APPLIANC named OCCUPANTS:

```
A ) NAME of occupants.....................? 'OCCUPANTS'
B ) How many DAYTIME OCCUPANTS (people)...? '1' people
C ) How many NIGHT OCCUPANTS (people).....? '0' people
D ) DAILY hot water USE (L/day)...........? '166.5404' L/day
E ) WATER HEATER type.....................? 'Gas'
F ) Input RATING (kW).....................? '11.71646' kW
G ) Hot water THERMOSTAT setting (degC)...? '60' degC
H ) WHERE is water heater.................? 'Basement'
I ) Stdby/plumb. LOSSES (kW)..............? '0.3280609' kW
J ) REFRIGERATOR type.....................? 'Man. defrost & sep.
                                              freezer'
K ) Average MONTHLY CONSUMPTION (kWh/mo)..? '65' kWh/mo
L ) DRYER and RANGE type..................? 'Both Electric'
M ) Internal MOISTURE generation (kg/day).? '1.215424' kg/day
N ) LIGHTS & OTHER HEAT GAINS (kW)........? '0.4253076' kW
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

LANDSCAPE

Current answers for LANDSCAP named Yard & Trees:

```
A ) Ground SURFACE TYPE...................? 'Green grass'
B ) Ground REFLECTANCE (%)................? '24' %
C ) SOUTH solar EXPOSURE - DECEMBER (%)...? '60' %
D ) SOUTH solar EXPOSURE - JUNE (%).......? '80' %
E ) EAST solar EXPOSURE - DECEMBER (%)....? '60' %
F ) EAST solar EXPOSURE - JUNE (%)........? '80' %
G ) WEST solar EXPOSURE - DECEMBER (%)....? '60' %
H ) WEST solar EXPOSURE - JUNE (%)........? '80' %
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

ECONOMIC

```
Current answers for ECONOMIC named Price & Use:

A ) Economic HORIZON (years)..................? '20' years
B ) REAL DISCOUNT rate (%)....................? '3' %
C ) REPLACEMENT-RETROFIT esc. rate (%)....? '4' %
D ) Maximum INVESTMENT ($).................? '2000' $
E ) ADJUST results to ACTUAL use..........? 'No'
F ) NON-ELECTRIC fuel.....................? 'Gas'
G ) GAS price ($/GJ)......................? '5.298761' $/GJ
H ) GAS escalation rate (%)...............? '2.8' %
I ) ELECTRICITY price ($/kWh).............? '0.0711' $/kWh
J ) ELECTRICITY escalation rate (%).......? '1.5' %
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

APPENDIX G
CIRA Listing of Villages of Riverside

APPENDIX G

CIRA LISTING OF VILLAGES OF RIVERSIDE

GENERAL

Current answers for GENERAL named V of R :

```
A ) NAME of this house...................? 'V of R '
B ) What CITY............................? 'Detroit'
C ) AZIMUTH of north face (degrees).......? '0' degrees
D ) What type of THERMOSTAT...............? 'Heating only'
E ) Heating THERMOSTAT setting (degC).....? '21.11111' degC
F ) Heating NIGHT setting (degC)..........? '21.11111' degC
G ) Avg Indoor SUMMER temperature (degC)..? '25.55556' degC
H ) Total house FLOOR AREA (sqm)..........? '134.0592' sqm
I ) House MASS...........................? 'Light'
J ) Solar STORAGE factor (unitless).......? '0.22' unitless
K ) SPECIFIC THERMAL MASS (kJ/K-sqm)......? '38.8132' kJ/K-sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

WALLS

Current answers for WALLS named Front:

```
A ) NAME for the following walls..........? 'Front'
B ) Which wall ORIENTATION................? 'South walls'
C ) Wall TYPE............................? '50 by 100 mm Frame'
D ) Wall INSULATION......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm)............? '88.9' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)...............? '1.938497' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '30.03538' sqm
J ) No. of WINDOWS (No.).................? '1' No.
K ) No. of VENTS in wall (No.)...........? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '110.1547' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

```
Current answers for WALLS named Rear:

A ) NAME for the following walls..........? 'Rear'
B ) Which wall ORIENTATION................? 'North walls'
C ) Wall TYPE.............................? '50 by 100 mm Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm).............? '88.9' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)................? '1.938497' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '25.62841' sqm
J ) No. of WINDOWS (No.)..................? '1' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '120.9048' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...


Current answers for WALLS named Right:

A ) NAME for the following walls..........? 'Right'
B ) Which wall ORIENTATION................? 'East walls'
C ) Wall TYPE.............................? '50 by 100 mm Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm).............? '88.9' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)................? '1.938497' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '24.22906' sqm
J ) No. of WINDOWS (No.)..................? '0' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '104.4402' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

Current answers for WALLS named Left:

```
A ) NAME for the following walls..........? 'Left'
B ) Which wall ORIENTATION................? 'West walls'
C ) Wall TYPE.............................? '50 by 100 mm Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm).............? '88.9' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)................? '1.938497' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '15.52747' sqm
J ) No. of WINDOWS (No.)..................? '1' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '182.5943' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

WINDOWS

Current answers for WINDOWS named Front:

```
A ) NAME of the following windows.........? 'Front'
B ) Which window ORIENTATION..............? 'South'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Double pane'
E ) DRAPES & SHUTTERS.....................? 'Shades or Blinds'
F ) Are window covers USED at DAYtime.....? 'No'
G ) U-value (W/sqm-K).....................? '2.947579' W/sqm-K
H ) Average sash FIT......................? 'Average'
I ) Specific LEAKAGE AREA (sqmm/sqm)......? '548.9592' sqmm/sqm
J ) Summer SOLAR GAIN factor (%)..........? '77' %
K ) Winter SOLAR GAIN factor (%)..........? '77' %
L ) Window AREA (sqm).....................? '0.8779346' sqm
M ) Overhang PROTRUSION (mm)..............? '0' mm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

```
Current answers for WINDOWS named Left:

A ) NAME of the following windows.........? 'Left'
B ) Which window ORIENTATION..............? 'West'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Double pane'
E ) DRAPES & SHUTTERS.....................? 'Shades or Blinds'
F ) Are window covers USED at DAYtime.....? 'No'
G ) U-value (W/sqm-K)....................? '2.947579' W/sqm-K
H ) Average sash FIT......................? 'Average'
I ) Specific LEAKAGE AREA (sqmm/sqm)......? '548.9592' sqmm/sqm
J ) Summer SOLAR GAIN factor (%)..........? '77' %
K ) Winter SOLAR GAIN factor (%)..........? '77' %
L ) Window AREA (sqm)....................? '8.705953' sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...


Current answers for WINDOWS named Rear:

A ) NAME of the following windows.........? 'Rear'
B ) Which window ORIENTATION..............? 'North'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Double pane'
E ) DRAPES & SHUTTERS.....................? 'Shades or Blinds'
F ) Are window covers USED at DAYtime.....? 'No'
G ) U-value (W/sqm-K)....................? '2.947579' W/sqm-K
H ) Average sash FIT......................? 'Average'
I ) Specific LEAKAGE AREA (sqmm/sqm)......? '548.9592' sqmm/sqm
J ) Summer SOLAR GAIN factor (%)..........? '77' %
K ) Winter SOLAR GAIN factor (%)..........? '77' %
L ) Window AREA (sqm)....................? '3.25161' sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

SUBFLOOR

Current answers for SUBFLOOR named Basement:

```
A ) Subfloor NAME .......................? 'Basement'
B ) Subfloor TYPE........................? 'Basement'
C ) Joist INSULATION.....................? 'Heated Basement'
D ) Total joist R-VALUE (K-sqm/W).........? '0.9251935' K-sqm/W
E ) Floor AREA (Joists) (sqm).............? '44.68641' sqm
F ) No. of floor PENETRATIONS (No.).......? ' ' No.
G ) Floor sp. LEAKAGE AREA (sqmm/sqm).....? '315.9796' K-sqm/W
H ) Subfloor WALL INSULATION material.....? 'None'
I ) Above-grade wall R-VALUE (K-sqm/W)....? '1.938497' K-sqm/W
J ) ABOVE-Grade HEIGHT (m)................? '0.0304803' m
K ) Exposed PERIMETER (m).................? '28.28544' m
L ) Soil CONDUCTIVITY (W/m-K).............? '1.2972' W/m-K
M ) No. of WINDOWS (No.)..................? ' ' No.
N ) No. of wall VENTS (No.) ..............? ' ' No.
O ) No. of wall PENETRATIONS (No.)........? ' ' No.
P ) Wall specific LEAKAGE AREA (sqmm/sqm).? '1159.576' sqmm/sqm
Q ) Below-grade R-VALUE (K-sqm/W).........? '0.8247423' K-sqm/W
R ) Floor R-VALUE (K-sqm/W)...............? '0.352454' K-sqm/W
S ) Eqv Floor RESIST' outs'd (K-sqm/W)....? '6.247263' K-sqm/W
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

INFILTRATION

Current answers for INFILTRA named Ventilation:

```
A ) Is there MECHANICAL Ventilation.......? 'None'
B ) NATURAL Cooling Ventilation...........? 'No'
C ) TERRAIN class.........................? 'Class 3'
D ) SHEILDING class.......................? 'Class 3'
E ) HEIGHT of living space (m)............? '5.556233' m
F ) Approximate house VOLUME (m3)..........? '322.3843' m3
G ) HOW was leakage area MEASURED.........? 'All three measured'
H ) TOTAL leakage area (sqcm).............? '483.87' sqcm
H ) CEILING leakage area (sqcm)...........? '179.1958' sqcm
H ) FLOOR leakage area (sqcm).............? '104.045' sqcm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

DOOR

```
Current answers for DOORS named Front:

A ) NAME of following doors...............? 'Front'
B ) Door TYPE.............................? 'Plain (Hinged)'
C ) Door MATERIAL.........................? 'Wood Solid Core'
D ) Approximate Glass AREA (%)............? '0' %
E ) Any STORM doors.......................? 'None'
F ) U-value (W/sqm-K).....................? '1.872585' W/sqm-K
G ) Door FIT..............................? 'Average'
H ) Specific leakage AREA (sqmm/sqm)......? '204.5144' sqmm/sqm
I ) Door AREA (sqm).......................? '1.680618'
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

ROOF-CEILING

```
Current answers for ROOF-CEI named TOP:

A ) NAME for attic/roof or ceiling........? 'TOP'
B ) Roof/Ceiling TYPE.....................? 'Unfinished attic'
C ) Insulation TYPE.......................? 'Fiberglass batts'
D ) Insulation THICKNESS (mm).............? '152.4' mm
E ) Insulatable AIR SPACE (mm)............? '152.4' mm
F ) Ceiling R-value (K-sqm/W).............? '3.876993' K-sqm/W
G ) Ceiling AREA (sqm)....................? '44.68641' sqm
H ) No. of ceiling VENTS (no.)............? '5' no.
I ) No. of ceiling PENETRATIONS (no.).....? '10' no.
J ) Ceiling sp. LEAKAGE area (sqmm/sqm)...? '383.1142' sqmm/sqm
K ) Roof PITCH (%)........................? '30' %
L ) Roof top MATERIAL.....................? 'Asphalt Shingles'
M ) Roof ABSORPTIVITY (%).................? '95' %
N ) Attic VENTILATION (m3/hr-sqm).........? '9.11' m3/hr-sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

HVAC-SYSTEM

```
Current answers for HVAC-SYS named Heat-Cool:

A ) What HEATING EQUIPMENT................? 'Electric Baseboard'
B ) Rated INPUT capacity (kW).............? '8.787346' kW
C ) Steady-state EFFICIENCY (%)...........? '100' %
D ) What DISTRIBUTION system..............? 'In Room'
E ) Distribution LOSSES to outside (%)....? '0' %
F ) What COOLING EQUIPMENT................? 'None'
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

APPLIANCES

Current answers for APPLIANC named RESIDENT:

```
A ) NAME of occupants......................? 'RESIDENTS'
B ) How many DAYTIME OCCUPANTS (people)...? '2' people
C ) How many NIGHT OCCUPANTS (people).....? '4' people
D ) DAILY hot water USE (L/day)...........? '283.875' L/day
E ) WATER HEATER type.....................? 'Electric'
F ) Input RATING (kW).....................? '4' kW
G ) Hot water THERMOSTAT setting (degC)...? '60' degC
H ) WHERE is water heater.................? 'Living space'
I ) Stdby/plumb. LOSSES (kW)..............? '0.124' kW
J ) REFRIGERATOR type.....................? 'Man. defrost & sep. freezer'
K ) Average MONTHLY CONSUMPTION (kWh/mo)..? '65' kWh/mo
L ) DRYER and RANGE type..................? 'Both Electric'
M ) Internal MOISTURE generation (kg/day).? '1.977329' kg/day
N ) LIGHTS & OTHER HEAT GAINS (kW)........? '0.3632103' kW
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

LANDSCAPE

Current answers for LANDSCAP named Yard & Trees:

```
A ) Ground SURFACE TYPE...................? 'Green grass'
B ) Ground REFLECTANCE (%)................? '24' %
C ) SOUTH solar EXPOSURE - DECEMBER (%)...? '60' %
D ) SOUTH solar EXPOSURE - JUNE (%).......? '80' %
E ) EAST solar EXPOSURE - DECEMBER (%)....? '60' %
F ) EAST solar EXPOSURE - JUNE (%)........? '80' %
G ) WEST solar EXPOSURE - DECEMBER (%)....? '60' %
H ) WEST solar EXPOSURE - JUNE (%)........? '80' %
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

ECONOMIC

Current answers for ECONOMIC named Price & Use:

```
A ) Economic HORIZON (years)..............? '20' years
B ) REAL DISCOUNT rate (%)................? '3' %
C ) REPLACEMENT-RETROFIT esc. rate (%)....? '4' %
D ) Maximum INVESTMENT ($)................? '2000' $
E ) ADJUST results to ACTUAL use..........? 'No'
F ) NON-ELECTRIC fuel.....................? 'Gas'
G ) GAS price ($/GJ)......................? '5.298761' $/GJ
H ) GAS escalation rate (%)...............? '2.8' %
I ) ELECTRICITY price ($/kWh).............? '0.0449999' $/kWh
J ) ELECTRICITY escalation rate (%).......? '1.5' %
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

APPENDIX H

CIRA Listing of Passive Solar Ranch House (Case 1 & 2)

CIRA LISTING OF PASSIVE SOLAR RANCH HOUSE (CASE 1 & 2)

GENERAL

Current answers for GENERAL named Case1 (Case2):

```
A ) NAME of this house....................? 'Case1' (Case2)
B ) What CITY.............................? 'Ottawa'
C ) AZIMUTH of north face (degrees).......? '0' degrees
D ) What type of THERMOSTAT...............? 'Dual heating & cooling'
E ) Heating THERMOSTAT setting (degC).....? '21.11111' degC
F ) Heating NIGHT setting (degC)..........? '21.11111' degC
G ) Cooling THERMOSTAT setting (degC).....? '26.66667' degC
H ) Cooling NIGHT setting (degC)..........? '26.66667' degC
I ) Total house FLOOR AREA (sqm)..........? '109.2541' sqm
J ) House MASS............................? 'Light'
K ) Solar STORAGE factor (unitless).......? '0.22' unitless
L ) SPECIFIC THERMAL MASS (kJ/K-sqm)......? '38.8' kJ/K-sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

WALLS

Current answers for WALLS named Front:

```
A ) NAME for the following walls..........? 'Front'
B ) Which wall ORIENTATION................? 'South walls'
C ) Wall TYPE.............................? '50 by 100 mm Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm).............? '101.6' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)................? '2.290951' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '16.07718' sqm
J ) No. of WINDOWS (No.)..................? '7' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '336.6872' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

```
Current answers for WALLS named Rear:

A ) NAME for the following walls..........? 'Rear'
B ) Which wall ORIENTATION................? 'North walls'
C ) Wall TYPE.............................? '50 by 100 mm Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm).............? '101.6' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)................? '2.290951' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '27.23297' sqm
J ) No. of WINDOWS (No.).................? '4' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '170.4526' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

```
Current answers for WALLS named Right:

A ) NAME for the following walls..........? 'Right'
B ) Which wall ORIENTATION................? 'East walls'
C ) Wall TYPE.............................? '50 by 100 mm Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm).............? '101.6' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)................? '2.290951' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '20.79987' sqm
J ) No. of WINDOWS (No.).................? '0' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '107.2068' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

Current answers for WALLS named Left:

```
A ) NAME for the following walls..........? 'Left'
B ) Which wall ORIENTATION................? 'West walls'
C ) Wall TYPE.............................? '50 by 100 mm Frame'
D ) Wall INSULATION.......................? 'Fiberglass batts'
E ) Insulation THICKNESS (mm).............? '101.6' mm
F ) INSULATABLE wall THICKNESS (mm).......? '0' mm
G ) Exterior INSULATING SHEATHING.........? 'None'
H ) Wall R-VALUE (K-sqm/W)................? '2.290951' K-sqm/W
I ) Wall AREA wo/ windows & doors (sqm)...? '20.79987' sqm
J ) No. of WINDOWS (No.)..................? '0' No.
K ) No. of VENTS in wall (No.)............? '1' No.
L ) No. of other PENETRATIONS (No.).......? '1' No.
M ) Specific LEAKAGE AREA (sqmm/sqm)......? '107.2068' sqmm/sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

WINDOWS

Current answers for WINDOWS named Front:

```
A ) NAME of the following windows.........? 'Front'
B ) Which window ORIENTATION..............? 'South'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Double pane'
E ) DRAPES & SHUTTERS.....................? 'None'
F ) U-value (W/sqm-K).....................? '2.72376' W/sqm-K
G ) Average sash FIT......................? 'Average'
H ) Specific LEAKAGE AREA (sqmm/sqm)......? '548.9592' sqmm/sqm
I ) Summer SOLAR GAIN factor (%)..........? '71' %
J ) Winter SOLAR GAIN factor (%)..........? '71' %
K ) Window AREA (sqm).....................? '7.694237' sqm
L ) Overhang PROTRUSION (mm)..............? '1066.8' mm
M ) HEIGHT above top of window (mm).......? '70.104' mm
N ) Average window HEIGHT (m).............? '1.575816' m
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

```
Current answers for WINDOWS named Slid:

A ) NAME of the following windows.........? 'Slid'
B ) Which window ORIENTATION..............? 'South'
C ) Window TYPE...........................? 'Horizontal Sliding'
D ) GLAZING...............................? 'Double pane'
E ) DRAPES & SHUTTERS.....................? 'None'
F ) U-value (W/sqm-K).....................? '2.72376' W/sqm-K
G ) Average sash FIT......................? 'Average'
H ) Specific LEAKAGE AREA (sqmm/sqm)......? '322.9171' sqmm/sqm
I ) Summer SOLAR GAIN factor (%)..........? '71' %
J ) Winter SOLAR GAIN factor (%)..........? '71' %
K ) Window AREA (sqm).....................? '5.576975' sqm
L ) Overhang PROTRUSION (mm)..............? '1066.8' mm
M ) HEIGHT above top of window (mm).......? '342.9' mm
N ) Average window HEIGHT (m).............? '2.033016' m
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...


Current answers for WINDOWS named Rear:

A ) NAME of the following windows.........? 'Rear'
B ) Which window ORIENTATION..............? 'North'
C ) Window TYPE...........................? 'Double hung'
D ) GLAZING...............................? 'Double pane'
E ) DRAPES & SHUTTERS.....................? 'None'
F ) U-value (W/sqm-K).....................? '2.72376' W/sqm-K
G ) Average sash FIT......................? 'Average'
H ) Specific LEAKAGE AREA (sqmm/sqm)......? '548.9592' sqmm/sqm
I ) Summer SOLAR GAIN factor (%)..........? '71' %
J ) Winter SOLAR GAIN factor (%)..........? '71' %
K ) Window AREA (sqm).....................? '3.968822' sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

SUBFLOOR

```
Current answers for SUBFLOOR named Slab:

A ) Subfloor NAME .......................? 'Slab'
B ) Subfloor TYPE........................? 'Slab-on-grade'
C ) Floor AREA (Joists) (sqm)............? '1.858063' sqm
D ) Exposed PERIMETER (m)................? '42.672' m
E ) Soil CONDUCTIVITY (W/m-K)............? '0.3603333' W/m-K
F ) Floor R-VALUE (K-sqm/W)..............? '7.049079' K-sqm/W
G ) Eqv Floor RESIST' outs'd (K-sqm/W)....? '17.6227' K-sqm/W
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

INFILTRATION

```
Current answers for INFILTRA named Ventilation:

A ) Is there MECHANICAL Ventilation.......? 'None'
B ) NATURAL Cooling Ventilation...........? 'No'
C ) TERRAIN class.........................? 'Class 3'
D ) SHEILDING class.......................? 'Class 3'
E ) HEIGHT of living space (m)............? '2.438281' m
F ) Approximate house VOLUME (m3).........? '266.4024' m3
G ) HOW was leakage area MEASURED.........? 'All three measured'
H ) TOTAL leakage area (sqcm).............? '754.8372' sqcm
I ) CEILING leakage area (sqcm)...........? '393.5483' sqcm
J ) FLOOR leakage area (sqcm).............? '316.1278' sqcm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

DOOR

```
Current answers for DOORS named Front:

A ) NAME of following doors...............? 'Front'
B ) Door TYPE.............................? 'Plain (Hinged)'
C ) Door MATERIAL.........................? 'Wood Solid Core'
D ) Approximate Glass AREA (%)............? '0' %
E ) Any STORM doors.......................? 'None'
F ) U-value (W/sqm-K).....................? '2.2698' W/sqm-K
G ) Door FIT..............................? 'Average'
H ) Specific leakage AREA (sqmm/sqm)......? '204.5144' sqmm/sqm
I ) Door AREA (sqm)......................? '1.858063' sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

ROOF-CEILING

Current answers for ROOF-CEI named Attic:

```
A ) NAME for attic/roof or ceiling........? 'Attic'
B ) Roof/Ceiling TYPE.....................? 'Unfinished attic'
C ) Insulation TYPE.......................? 'Fiberglass batts'
D ) Insulation THICKNESS (mm).............? '152.4' mm
E ) Insulatable AIR SPACE (mm)............? '0' mm
F ) Ceiling R-value (K-sqm/W).............? '4.405675' K-sqm/W
G ) Ceiling AREA (sqm)....................? '109.2541' sqm
H ) No. of ceiling VENTS (no.)............? '5' no.
I ) No. of ceiling PENETRATIONS (no.).....? '10' no.
J ) Ceiling sp. LEAKAGE area (sqmm/sqm)...? '283.9261' sqmm/sqm
K ) Roof PITCH (%)........................? '22.62' %
L ) Roof top MATERIAL.....................? 'Asphalt Shingles'
M ) Roof ABSORPTIVITY (%).................? '95' %
N ) Attic VENTILATION (m3/hr-sqm).........? '9.11' m3/hr-sqm
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

HVAC-SYSTEM

Current answers for HVAC-SYS named Heat-Cool:-

```
A ) What HEATING EQUIPMENT................? 'Gas Furnace'
B ) Rated INPUT capacity (kW).............? '14.64558' kW
C ) Steady-state EFFICIENCY (%)...........? '75' %
D ) FLUE gas temperature (degC)...........? '121.1111' degC
E ) What DISTRIBUTION system.............? 'Forced Air'
F ) WHERE are pipes or ducts..............? 'Living space'
G ) INSULATION on pipes  or ducts.........? 'None'
H ) Insulatable duct/pipe LENGTH (m)......? '15.23926" m
I ) Distribution LOSSES to outside (%)....? '5' %
J ) What COOLING EQUIPMENT................? 'Central Air Conditioning'
K ) Rated TOTAL capacity (kW).............? '7.029877' kW
L ) Rated SENSIBLE capacity (kW)..........? '4.686585' kW
M ) Rated COP (unitless)..................? '2' unitless
N ) Actual Fan Flow (m3/hr)...............? '1189.263' m3/hr
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

APPLIANCES

Current answers for APPLIANC named Life:

```
A ) NAME of occupants.......................? 'Life'
B ) How many DAYTIME OCCUPANTS (people)...? '1' people
C ) How many NIGHT OCCUPANTS (people).....? '2' people
D ) DAILY hot water USE (L/day)...........? '283.875' L/day
E ) WATER HEATER type.....................? 'Gas'
F ) Input RATING (kW).....................? '11.71646' kW
G ) Hot water THERMOSTAT setting (degC)...? '60' degC
H ) WHERE is water heater.................? 'Living space'
I ) Stdby/plumb. LOSSES (kW)..............? '0.3632103' kW
J ) REFRIGERATOR type.....................? 'Man. defrost & sep. freezer'
K ) Average MONTHLY CONSUMPTION (kWh/mo)..? '65' kWh/mo
L ) DRYER and RANGE type..................? 'Both Electric'
M ) Internal MOISTURE generation (kg/day).? '1.977329' kg/day
N ) LIGHTS & OTHER HEAT GAINS (kW)........? '2.929115E-02' kW
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

LANDSCAPE

Current answers for LANDSCAP named Yard & Trees:

```
A ) Ground SURFACE TYPE...................? 'Green grass'
B ) Ground REFLECTANCE (%)................? '24' %
C ) SOUTH solar EXPOSURE - DECEMBER (%)...? '100' %
D ) SOUTH solar EXPOSURE - JUNE (%).......? '100' %
E ) EAST solar EXPOSURE - DECEMBER (%)....? '100' %
F ) EAST solar EXPOSURE - JUNE (%)........? '100' %
G ) WEST solar EXPOSURE - DECEMBER (%)....? '100' %
H ) WEST solar EXPOSURE - JUNE (%)........? '100' %
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

ECONOMIC

```
Current answers for ECONOMIC named Price & Use:

A ) Economic HORIZON (years)..............? '20' years
B ) REAL DISCOUNT rate (%)................? '3' %
C ) REPLACEMENT-RETROFIT esc. rate (%)....? '4' %
D ) Maximum INVESTMENT ($)................? '2000' $
E ) ADJUST results to ACTUAL use..........? 'No'
F ) NON-ELECTRIC fuel.....................? 'Gas'
G ) GAS price ($/GJ)......................? '5.298761' $/GJ
H ) GAS escalation rate (%)...............? '2.8' %
I ) ELECTRICITY price ($/kWh).............? '0.0449999' $/kWh
J ) ELECTRICITY escalation rate (%).......? '1.5' %
Y) < DELETE this Component >...
Z) < Changes COMPLETED >...
```

APPENDIX I
Sample Run

APPENDIX I

SAMPLE RUN

1) From the Command Menu, shown below, choose the House Data Input Section by pressing 'Alt' and letter 'A' key simultaneously.

COMMAND MENU	Display	Print
House Data Input Section ------------------------	A	B
Command and Report Menu ------------------------	Z	R
Load Previously Entered House Data --------------	P	
Calculate Energy --------------------------------	C	
Save & Quit ------------------------------------	Q	
Quit Without Saving ----------------------------	W	

REPORT MENU		Display	Print
Pre-Retrofit	Heating Report # 1 --------------	D	J
	Heating Report # 2 --------------	E	K
	Cooling Report ------------------	F	L
Post-Retrofit	Heating Report # 1 --------------	G	M
	Heating Report # 2 --------------	H	N
	Cooling Report ------------------	I	O

(Press 'Alt' & corresponding letter Key simultaneously)

2) Input the following data in the House Data Input Section

RESIDENTIAL BUILDING ENERGY CONSUMPTION CALCULATION

1) Location (enter a number from 1 - 5) 2
1-Detroit,2-Toronto,3-Ottawa,4-Winnipeg,5-Edmonton

HOUSE NAME : SAMPLE HOUSE VARIABLE	HOUSE DATA	RETROFIT (DELTA)
2) Conduction Coefficient in W/C	60	0
3) Indoor Temperature in C		
Heating Season	21	-2
Cooling Season	26	0
4) Window Data		
Area Horizontal	0	0

(in sq.m)	East	0	0
	West	0	4
	South	13	0
	North	4	0
Shading Coefficient (0 to 1)	Horizontal	0	0
	East	0	0
	West	0	0.78
	South	0.78	0
	North	0.78	0
Solar Exposure (0 to 1)	East	1	0
	West	1	0
	South	0.83	0
South Window (all in m)	Overhang Protrusion	1.7	0
	Height above top of Window.	0.2	0
	Average Window Height	1.8	0

5) Average monthly Internal Gains in MJ/Month ...	1600	0
6) Thermal Capacity of the house in MJ/(K.sq.m) .	0.175	0
7) Temperature Rise in C (Enter 0, 2.75 or 5.5)..	2.75	0
8) Leakage areas		
Ceiling Leakage Area in sq.cm	161	0
Floor Leakage Area in sq.cm	129	0
Total Leakage Area in sq.cm	323	0
9) Terrain Class (enter 1 to 5 only)	3	0
10) Shielding Class (enter 1 to 5 only)	3	0
11) Living Space Height in m	2.44	0
12) Mechanical Ventilation in Cu.m/Hr	0	0
13) House Floor area in sqm	109	0

Have you fed in all the data? If yes then :
Press the 'Alt' key and letter 'C' simultaneously

3) After energy calculations select the desired Heating or Cooling Season Report from the Report Menu by pressing 'Alt' and the corresponding letter key simultaneously. All the output reports for the above sample input data have been listed in this appendix.

Note: The above data for house named SAMPLE is also the default house data for the program. The SAMPLE house data (default) is automatically recalled each time ENERGY is loaded onto LOTUS 1-2-3 spread sheet.

SAMPLE HEATING SEASON REPORT # 1 (PRE-RETROFIT) Toronto

MONTH	MON. #	HEATING START	HEATING END	THETA BALANCE	DD(@Ti) (C-DAY)	HEAT LOSS (MJ)	HEATING FRACTION
JANUARY	1	1	31	-0.142	838	6793	1
FEBRUARY	2	1	28	-0.188	734	5913	1
MARCH	3	1	31	-0.122	687	5387	1
APRIL	4	1	18	-0.050	314	2314	0.612881
MAY	5	1	16	0.180	163	1123	0.504254
JUNE	6	0	0	0.000	0	0	0
JULY	7	0	0	0.000	0	0	0
AUGUST	8	0	0	0.000	0	0	0
SEPTEMBER	9	0	0	0.000	-0	0	0
OCTOBER	10	15	31	0.071	209	1455	0.500677
NOVEMBER	11	1	30	-0.056	560	4202	1
DECEMBER	12	1	31	-0.068	752	5945	1
					4258	33132	

SAMPLE HEATING SEASON REPORT # 1 (POST-RETROFIT) Toronto

MONTH	MON. #	HEATING START	HEATING END	THETA BALANCE	DD(@Ti) (C-DAY)	HEAT LOSS (MJ)	HEATING FRACTION
JANUARY	1	1	31	-0.221	838	6793	1
FEBRUARY	2	1	28	-0.285	734	5913	1
MARCH	3	1	28	-0.224	633	4963	0.910301
APRIL	4	1	18	-0.053	309	2276	0.601200
MAY	5	1	9	0.128	104	716	0.300830
JUNE	6	0	0	0.000	0	0	0
JULY	7	0	-0	0.000	0	0	0
AUGUST	8	0	0	0.000	0	0	0
SEPTEMBER	9	0	0	0.000	0	0	0
OCTOBER	10	15	31	0.076	215	1498	0.518132
NOVEMBER	11	8	30	-0.131	428	3215	0.730217
DECEMBER	12	1	31	-0.166	752	5945	1
					4014	31319	

SAMPLE HEATING SEASON REPORT # 2 (PRE-RETROFIT) Toronto

MONTH	MON. #	SGAIN (MJ)	HTG SGAIN (MJ)	SUF	USE SGAIN (MJ)	FRHEAT (MJ)	HTG LOAD (MJ)
JANUARY	1	2841	2841	0.985	2798	4398	2395
FEBRUARY	2	2997	2997	0.877	2629	4229	1684
MARCH	3	3021	3021	0.833	2517	4117	1270
APRIL	4	2227	1365	0.767	1047	2028	286
MAY	5	1387	699	0.180	126	933	190
JUNE	6	1794	0	0.000	0	0	0
JULY	7	1618	0	0.000	0	0	0
AUGUST	8	1976	0	0.000	0	0	0
SEPTEMBER	9	1969	0	0.000	0	0	0
OCTOBER	10	2107	1055	0.433	457	1258	197
NOVEMBER	11	1950	1950	0.926	1806	3406	796
DECEMBER	12	2199	2199	0.994	2185	3785	2159
		26085	16126	0.841	13567	24155	8977

SAMPLE HEATING SEASON REPORT # 2 (POST-RETROFIT)-Toronto

MONTH	MON. #	SGAIN (MJ)	HTG SGAIN (MJ)	SUF	USE SGAIN (MJ)	FRHEAT (MJ)	HTG LOAD (MJ)
JANUARY	1	3218	3218	0.881	2836	4436	2357
FEBRUARY	2	3518	3518	0.789	2777	4377	1537
MARCH	3	3811	3469	0.712	2471	3928	1035
APRIL	4	3133	1884	0.410	773	1735	541
MAY	5	2177	655	0.057	38	519	197
JUNE	6	2921	0	0.000	0	0	0
JULY	7	2535	0	0.000	0	0	0
AUGUST	8	2940	0	0.000	0	0	0
SEPTEMBER	9	2572	0	0.000	0	0	0
OCTOBER	10	2501	1296	0.182	235	1064	434
NOVEMBER	11	2198	1605	0.827	1327	2495	720
DECEMBER	12	2450	2450	0.962	2357	3957	1987
		33875	18096	0.708	12814	22511	8809

SAMPLE COOLING SEASON REPORT (PRE-RETROFIT) Toronto

MONTH	MON. #	COOLING START	COOLING END	COOLING FRACTION	DD(@Ti) (C-DAY)	SOL & INT LOAD (MJ)	CLG LOAD (MJ)
JANUARY	1	0	0	0	0	0	0
FEBRUARY	2	0	0	0	0	0	0
MARCH	3	0	0	0	0	0	0
APRIL	4	18	30	0.387118	216	-1636	-223
MAY	5	16	31	0.495745	185	-1679	-518
JUNE	6	1	30	1	242	-3794	-2285
JULY	7	1	31	1	162	-3618	-2631
AUGUST	8	1	31	1	187	-3976	-2845
SEPTEMBER	9	1	30	1	307	-3969	-2096
OCTOBER	10	1	15	0.499322	230	-2051	-633
NOVEMBER	11	0	0	0	0	0	0
DECEMBER	12	0	0	0	0	0	0
					1529	-20723	-11231

SAMPLE COOLING SEASON REPORT (POST-RETROFIT) Toronto

MONTH	MON. #	COOLING START	COOLING END	COOLING FRACTION	DD(@Ti) (C-DAY)	SOL & INT LOAD (MJ)	CLG LOAD (MJ)
JANUARY	1	0	0	0	0	0	0
FEBRUARY	2	0	0	0	0	0	0
MARCH	3	28	31	0.089698	68	-521	-79
APRIL	4	18	30	0.398799	223	-2047	-588
MAY	5	9	31	0.699169	276	-2921	-1192
JUNE	6	1	30	1	242	-4821	-3311
JULY	7	1	31	1	162	-4535	-3548
AUGUST	8	1	31	1	187	-4940	-3809
SEPTEMBER	9	1	30	1	307	-4572	-2700
OCTOBER	10	1	15	0.481867	221	-2169	-806
NOVEMBER	11	1	8	0.269782	172	-1133	-17
DECEMBER	12	0	0	0	0	0	0
					1857	-27658	-16050

REFERENCES

1.1 Hall, J.D. A Retrofit Strategy for two Canadian Residential Dwellings using the Building Energy Simulation Program DOE 2.1a. M.A.Sc thesis in Department of Mechanical Engineering, University of Windsor, 1983.

1.2 ASHRAE Handbook, 1985 Fundamental. Energy Estimating Methods Chapter 28, p. 28.2.

1.3 Patwardhan, A.G. A Critical Evaluation of the Computerised, Instrumented Residential Audit (CIRA) program M.A.Sc thesis in Department of Mechanical Engineering, University of Windsor, Windsor, 1984.

1.4 Mitalas, G.P., Calculation of Basement Heat Loss. ASHRAE Journal, 1983, Part 1A.

1.5 Sander, D.M. and Barakat, S.A. A Method of Estimating the Utilization of Solar Gains through Windows. ASHRAE Journal, 1983, Part 1A.

1.6 Sander, D.M. and Barakat, S.A., A Method of Estimating the Utilization of Internal heat Gains. ASHRAE Journal, 1986, Part 1A.

2.1 ASHRAE Handbook, 1985 Fundamentals. Air-Conditioning Cooling Load. Chapter 26, p. 26.13.

2.2 Dumont, R.S., M.E. Lux, and Orr, H.W. HOTCAN : A computer program for estimating the space heating requirements of residences. Computer program No. 49 of the DBR, Ottawa, September, 1982.

2.3 Energy Performance of Buildings Group. Engineering Methods CIRA (Version 1.0), Reference Mannual, Lawrence Berkeley Laboratory (LBL), University of California, December 1982.

2.4 Barakat, S.A. and Sander, D.M. Utilization of Solar Gain through Windows for Heating Houses. BR Note 184, DBR, National Research Council of Canada, Ottawa, March 1982.

2.5 Carroll, W.L. Internal Loads For Multi-Zone Residential Modeling (BEPS Compatible). LBL Passive Solar Group, Technical Note # 9, March 1980.

2.6 Colborne, W.G., Wilson, N.W and Hall, J.D. Confirmation of Solar Utilization Factors using DOE-2 Simulation. University of Windsor, Windsor, June 1982.

2.7 ASHRAE Handbook, 1985 Fundamentals. Air-Conditioning Cooling Load. Chapter 26, p. 26.18, 26.23 and 26.38.

2.8 Al-Jubouri, A., Colborne, W.G. and Kierkus, W.T. Generalized Weather Data for Canadian Cities. University of Windsor, Windsor, 1987.

2.9 Holt, D. A Microcomputer Algorithm for Degree-days to any arbitrary base. P.E. 40, U.S. Department of Energy, April 2, 1986.

2.10 Grimsrud, D.T., Modera, M.P. and Sherman, M.H. A Predictive Air Infiltration Model; Long-Term Field Test Validation. HO-82-16 No. 1, Energy Performance of Buildings Group, LBL, University of California, Berkeley

2.11 ASHRAE Handbook, 1985 Fundamentals. Natural Ventilation and Infiltration. Chapter 22, p. 22.16.

3.1 ASHRAE Handbook, 1985 Fundamentals. Fenestration. Chapter 27, p. 27.35.

3.2 Energy Performance of Buildings Group. Landscape CIRA (Version 1.0), Reference Mannual, Lawrence Berkeley Laboratory (LBL), University of California, December 1982.

3.3 ASHRAE Handbook, 1985 Fundamentals. Air-Conditioning Cooling Load. Chapter 26, p. 26.21.

3.4 Goldstein, D.B., Levine, M.D. and Mass, J. Methodology and Assumptions for the Evaluation of Building Energy Performance Standards for Residences. LBL Report 9110, University of California, Berkeley

3.5 ASHRAE Handbook, 1985 Fundamentals. Natural Ventilation and Infiltration. Chapter 22, p. 22.14.

3.6 ASHRAE Handbook, 1985 Fundamentals. Natural Ventilation and Infiltration. Chapter 22, p. 22.7.

4.1 ASHRAE Handbook, 1985 Fundamentals. Weather Data and Design Conditions. Chapter 24, p. 24.3.

4.2 Siurna, D.L., D'Andrea, L.J. and Hollands, K.G.T. A Canadian Representative Meteorological Year for Solar System Simulation. University of Waterloo, Ontario.

4.3 Crow, L.W. Weather Year for Energy Calculations. ASHRAE Journal, June 1984.

D1.1 BMDP Statistical Software.. University of California Press, 1983.

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