National Research Council Canada
Conseil national de recherches Canada

A STUDY OF THE USE OF NATURAL GAS AND ELECTRICITY IN SASKATCHEWAN HOMES

by C.P. Hedlin and H.W. Orr

Reprinted, with permission, from
SHELTER, Proceedings of the Technical Program
of the 91st Annual EIC Meeting
held at Jasper, Alberta, 15-21 May 1977
p. 123 - 131

DBR Paper No. 794
Division of Building Research

Price 25 cents OTTAWA NRCC 16898

NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

A STUDY OF THE USE OF NATURAL GAS AND ELECTRICITY IN SASKATCHEWAN HOMES

by

C.P. Hedlin and H.W. Orr

DBR Paper No. 794

of the

Division of Building Research

OTTAWA, July 1978

A STUDY OF THE USE OF NATURAL GAS AND ELECTRICITY IN SASKATCHEWAN HOMES

by C.P. Hedlin and H.W. Orr

ABSTRACT

A study was carried out on energy consumption in a number of Saskatchewan homes where natural gas and electricity are used for cooling, lighting, water and space heating and other domestic needs. Particular attention was given to energy use for space heating.

In some parts of Saskatchewan, the Saskatchewan Power Corporation provides both natural gas and electricity to homes. Their records of consumption in about 1000 Regina homes in five districts within the city were used in this study. Annual average consumptions per house were found for each district. These ranged from 200 GJ (55 MW·h) to 235 GJ (65 MW·h).

The rate at which purchased energy (natural gas plus electricity in these houses) is used varies with the season of the year, primarily owing to space heating requirements. When purchased energy consumption is plotted against heating degree-days, the relationship is usually nearly linear. The slope of this line and its ordinate intercept constitute an energy consumption characteristic for the house. This characteristic is affected by a variety of factors, including the heat loss characteristics of the house, the furnace efficiency and solar heat gain.

UNE ÉTUDE DE L'USAGE DU GAZ NATUREL ET DE L'ÉLECTRICITÉ DANS CERTAINES MAISONS DE LA SASKATCHEWAN

par C.P. Hedlin and H.W. Orr

RÉSUMÉ

Une étude sur la consommation d'énergie a été effectuée en Saskatchewan dans certaines maisons qui emploient le gaz naturel et l'électricité pour la climatisation, l'éclairage, le chauffage de l'eau et des locaux et d'autres applications domestiques. On a prêté une attention particulière à la consommation d'énergie pour le chauffage des locaux.

La Saskatchewan Power Corporation fournit à la fois du gaz naturel et de l'électricité aux maisons de certaines régions de la Saskatchewan. Les dossiers de consommation d'environ 1 000 maisons dans cinq quartiers de la ville de Régina ont été utilisés aux fins de cette étude. La consommation annuelle moyenne par maison a été établie pour chaque quartier: elle varie entre 200 GJ (55 MW·h) et 235 GJ (65 MW·h).

Le taux de consommation d'énergie (gaz naturel et électricité dans ce cas) varie selon la saison, surtout à cause du chauffage des locaux. Lorsque l'on trace sur un diagramme la relation entre l'énergie consommée et les degrés-jours de chauffage, on remarque qu'elle est généralement presque directement proportionnelle. La pente de cette ligne et de son ordonné à l'origine constitue une caractéristique de consommation d'énergie applicable à la maison. Cette caractéristique est influencée par plusieurs facteurs, dont les pertes thermiques de la maison, l'efficacité de la chaudière et les gains d'énergie solaire.

A STUDY OF THE USE OF NATURAL GAS AND ELECTRICITY IN SASKATCHEWAN HOMES

by

C.P. Hedlin and H.W. Orr

It has been estimated that twenty per cent of all the energy used in Canada is consumed in residences. Because we are faced with the need to conserve energy, it is important to investigate this usage and to determine how it can be reduced.

As part of a larger energy study by the Division of Building Research, an investigation is being carried out at the Prairie Regional Station on energy consumption in houses in Regina and Saskatoon. This report contains some statistics on total consumption and a discussion of heat losses.

In many urban homes on the Prairies, natural gas and electricity supply all the energy used for domestic purposes. Natural gas is generally used for house heating and to heat water. Electricity is often used for cooking, lights, clothes drying, for miscellaneous household needs and for car block-heaters and car warmers. In Regina and in parts of Saskatoon, natural gas and electricity are sold to householders by the Saskatchewan Power Corporation, which records the amount consumed in each home. Through the courtesy of the Saskatchewan Power Corporation, the staff of the Prairie Regional Station was given access to some of these statistics.

This report is concerned with about one thousand houses in five districts in Regina - City View, Walsh Acres, Glencairn, Lake View, and in an area bounded by Pasqua, North Railway, Empress Drive and 10th Avenue (hereafter called the Empress Drive District).

The energy consumed for house heating will be affected by four main factors:

- structure, i.e., size, shape, insulation, air tightness, color;
- exposure, i.e., temperature, wind, sunshine, building orientation;
- occupancy, i.e., number of occupants, management;
- heating system, i.e., combustion and heat transfer efficiencies.

FACTORS AFFECTING ENERGY CONSUMPTION

Structure

Nearly all of these homes are of wood frame construction, with stucco or lap siding. In a few cases an exterior finish of brick , aluminum siding or Insulbrick has been used. The newer houses (Glencairn

and Walsh Acres) were constructed with a thermal resistance of 1.23 $m^2 \cdot °C/W$ (R7) in the walls and 1.76 $m^2 \cdot °C/W$ (R10) in the ceiling. Because insulation for basements was not specified by the Canadian Code for Residential Construction until 1 July 1975, it is likely that all of these houses were constructed without basement insulation, though some of the owners may have added it subsequently. No data are available on the insulation in the older houses. Some of them would have been constructed with it and others would have been insulated later.

The size and age of house vary from district to district and, in some cases, within districts. City View, Empress Drive and Lake View are heterogeneous areas, containing homes of different age and size. Glencairn and Walsh Acres are new, more homogeneous districts.*

Exposure

The primary exposure variable in determining heat loss is that of outdoor temperature, though wind, solar radiation and orientation also affect the heat balance (Mitalas, 1976).

Occupancy

Most of the homes were originally designed for single-family occupancy. A few of the large, older homes have been divided into suites and roomers are kept in many of the smaller homes. No statistics are available on this at present.

Energy consumption will be affected by the number of occupants and their living habits. These will be reflected in use of hot water, temperature of the home during the day and at night, lighting use, ventilation rates and number of cars using block-heaters and warmers.

Heating Systems

Virtually all of the homes would have central heating systems. Most would use forced warm air, though some gravity warm air and hot water, or radiant heating systems would be included.

ANNUAL ENERGY CONSUMPTION - REGINA HOUSES

Data were obtained from the microfilm records of the Saskatchewan Power Corporation. The utility figures for natural gas consumption were in hundreds of cubic feet. These were converted into joules (watt seconds) or kilowatt hours by using conversion factors of 1.055×10^8 J**

---

* See Appendix for description of districts.

** For convenience, multipliers mega (M) or 10^6, and giga (G) or 10^9 are used.

or 29.3 kW·h/100 ft^3 (9.29 m^3). Kilowatt hours of electricity were converted into joules by multiplying by 3.6×10^6. Energy values are given in both joules and watt hours, the latter in parentheses.

In the first stage of the study, the data were used to find the average consumption per house and the variation in consumption within each district. Annual totals of electricity and natural gas, usually for the period from September to August, were tabulated for each of the approximately two hundred homes in each area. The results were sorted by computer to give frequency-consumption values for electricity and natural gas separately, and for their sums. This is illustrated by the histogram for houses in Glencairn in Figure 1. The summary for all areas is given in Table I for the year 1974-75.

In the City View and Empress Drive districts, where homes averaged about 70 m^2 in area, the mean consumption of electricity plus natural gas, per house, was about 200 GJ (55 MW·h) per year. In Glencairn and Walsh Acres, where the house size was about 90 to 130 m^2, the consumption per house averaged 235 GJ (65 MW·h) per year.† It is not apparent from these limited data that the older homes are thermally much less efficient than the new ones. Further study is needed to clarify this point.

Within districts, the coefficient of variation* for the groups of houses ranged from about 14 per cent in Glencairn to 27 per cent in the Empress Drive District. The greater variation in energy use in the older districts can probably be attributed to the relatively large variation in quality and size of the houses as compared to the new districts.

BUILDING HEAT LOSS

The preceding totals represent energy used for all domestic purposes. The largest fraction is used for house heating but when the weather is warm, little or no energy is needed for this purpose. The calculation of heating degree-days is based on the assumption that heat from household activities, the sun, etc., is sufficient to maintain comfortable temperatures when the mean outdoor temperature exceeds 18°C. Under cooler conditions, furnace heat is required and consumption of purchased energy rises.**

---

† This would correspond to approximately 190,000 to 250,000 Btu/ft^2/year; basement space is not taken into account.

* Coefficient of variation $= \frac{\text{standard deviation}}{\text{arithmetic mean}} \times 100$

** Heating degree-days are accumulated when the mean temperature for a day is below 18°C, e.g., if the mean temperature for a day were 0°C, there would be 18 heating degree-days in it. The values used in this report are based on airport observations, given in meteorological summaries published by Environment Canada.

In Figure 2a, the line E_T represents the rate of combined consumption of electricity and natural gas plotted against the number of heating degree-days. Even when there are no heating degree-days, energy is used for other purposes, consequently the line E_T intercepts the ordinate at a positive value. The consumption of electricity is shown by the lower line, E_{El}, and natural gas accounts for the rest of the energy.

Figure 2b illustrates ways in which energy is consumed in a house.

If one is concerned mainly with house heating, energy derived from electricity and natural gas for domestic purposes can be classified either as useful or waste heat, depending on whether it helps to keep the house warm.

Waste heat includes furnace stack loss, latent heat in water vapor produced in the house and removed by ventilation or exfiltration, sensible and latent heat exhausted to the outside by vented clothes dryers, hot water going to drains, and energy used in equipment outside the house. Some of these items will change with the season, e.g., in cold weather more electricity may be used in block-heaters, car warmers, Christmas lights and for clothes drying.

The region between the line E_S and the abscissa (Figure 2b) represents the purchased energy used to offset structural heat loss, e.g., through walls, windows, floors, and that due to air exfiltration. This heat comes from furnace output, interior electrical devices and miscellaneous sources, e.g., hot-water pipes, pilot lights. In addition to purchased energy, useful heat is obtained gratuitously from solar radiation which enters through windows (and by reversal of heat flow through walls at certain times in the heating season) and by heat from occupants of the house. This is represented by the region between the abscissa and the line E_G below it. This gratuitous heat eventually becomes structural heat loss.

Actual values of electricity and total energy consumption (electricity plus natural gas) were plotted against the heating degree-days accumulated in the same period (Figure 3). For billing purposes, meters are read or consumptions are estimated each month. Thus twelve data points were provided per year by each house. In practice, to avoid estimation errors, a data point was calculated only when the meter was actually read, i.e., the period represented by a data point would be two months if a single estimate was made, or three months if two estimates were made in sequence. When applying least squares analysis to find equations to fit the results, such data points were entered two or three times, depending on the number of months spanned, to give them proper weighting.

Figure 3 shows the annual energy consumption for a single-family bungalow with an insulated basement. The energy consumption was 181 GJ (50.2 MW·h) in the form of natural gas and 23 GJ (6.3 MW·h) in the form of electricity for a total of 204 GJ (56.5 MW·h). On the basis of

main floor area, consumption amounted to 2.19 GJ (607 kW·h)/m^2 (0.193 MBtu/ft^2); including the basement it was 1.10 GJ (303 kW·h)/m^2 (0.096 MBtu/ft^2).

The lower line, E_{El}, representing total electricity consumption, rises in colder weather. Besides the items already mentioned, this increase could be caused by extra lighting loads and seasonal changes in cooking habits; the consumption increased by 0.62 MJ (0.17 kW·h) per degree day. On average, the daily consumption in the coldest weather (40 degree days/day) was about 85 MJ (23 kW·h), compared to 58 MJ (16 kW·h) in midsummer.

The upper line, E_T, representing the combined consumption of electricity and natural gas, is nearly linear, and has a slope of 21.0 MJ (5.9 kW·h) per degree day. On the basis of main floor area, this amounts to 0.226 MJ (0.063 kW·h)/m^2·degree day (20 Btu/ft^2·degree day) or, including the basement, 0.113 MJ (0.031 kW·h)/m^2·degree day 10 Btu/ft^2·degree day). The coefficient of determination for this set of data is 0.981.*

This slope constitutes a useful energy consumption characteristic for the dwelling. As indicated in Figure 2b, it is different than that of the line E_S since structural heat loss does not include waste heat but does include heat obtained gratuitously; however, structural heat loss is the main factor in determining the slope of the total energy line.

Based on the degree day concept, the ordinate intercept of the line E_T represents energy used for purposes other than house heating. From it one can make an estimate of energy used for water heating. In this case the intercept value is 207 MJ (57.5 kW·h) per day. Subtracting an electricity consumption of 58 MJ (16 kW·h) per day, based on the intercept of the line E_{El}, and an estimated 25 MJ (7 kW·h) per day for the furnace pilot light (1 cfh), leaves 124 MJ (34 kW·h) per day for water heating. The validity of using intercept values to estimate hot water consumption

---

* The coefficient of determination (r^2) measures the proportion of variance in the energy consumption (y) that is explained by heating degree-days.

$$r^2 = 1 - \frac{S_y^2}{\sigma_y^2}$$

where S_y = the standard error of estimate

σ_y = the standard deviation

is uncertain. More detailed field measurements are needed to determine the accuracy limits or to show whether this method of estimating hot water use can be improved with suitable adjustments.

Slope intercept values were found for groups of houses by totalling monthly energy usages and calculating average monthly values. Figure 4 gives the results for 25 houses in the Glencairn district. The slope of the line is 31.0 MJ (8.6 kW·h) per degree day, and the ordinate intercept is 144 MJ (40.0 kW·h) per day. Values for 25 houses for each of the five districts are given in Table II.

A similar analysis can be done, though with less accurate results because the ranges are smaller, by using annual totals. Figure 5 shows plots for the Lakeview and Glencairn districts for four- and three-year periods, respectively, based on the mean energy consumption per house for each group. These give slopes of 18.9 MJ (5.25 kW·h) and 19.8 MJ (5.5 kW·h) per degree day. The ordinate intercepts of the plots, based on long extrapolations, are 332 MJ (92.3 kW·h) and 323 MJ (89.8 kW·h) per day. These values are substantially different from those given in Table II. If one arbitrarily assigns an intercept value of 144 MJ (40 kW·h) per day, the slopes, based on grand averages of energy consumption and degree days, are 29.9 MJ (8.3 kW·h) per degree day for both districts.

The reliability of slope values for the line E_T as a measure of variation in energy consumption with heating degree-days increases with increasing index of determination. However, there seems to be some variation from year to year. As shown in Figure 2b, its slope is affected by seasonal variations in all of the items listed. If the seasonal effect on such factors as the use of hot water or exterior lights varies from year to year, if annual differences in weather affect the relationship between structural heat loss and degree days, if the seasonal rate of solar heat gained affects the slope of the line E_G, or if the management of the house varies from year to year, there will be corresponding changes in the slope of the line E_T. Further work is needed to determine the extent of annual slope variation and, if possible, to explain it.

Energy use for house heating varies with four main factors - structure, exposure, occupancy and the heating system. Of these, only the exposure effect has been treated quantitatively in this report, and only that part of exposure represented by temperature. It is proposed that studies also be made concerning structure and occupancy. Data on the effect of structure on energy consumption could be used in estimating the effectiveness of minor or major retrofitting. Statistical analyses of records for individual houses with changed ownership, or on groups of nominally identical houses, might reveal the effect of occupancy on variations in consumption.

CONCLUSION

Data on the consumption of natural gas and electricity in about one thousand homes in five districts in Regina were obtained from records of the Saskatchewan Power Corporation. Average total annual energy consumption per home varied somewhat between districts. For the period from September 1974 to August 1975, when there were 5764 heating degree-days, the mean consumption per house ranged from about 200 to 235 GJ (55 to 65 MW·h) per year for the five districts.

The relationship between total energy used and heating degree-days was illustrated using data for a single house and average slope-intercept values were found for one group of 25 houses in each of the five Regina districts. Ratios of energy consumption to heating degree-days for the 25 house groups ranged from about 25 MJ (6.8 kW·h) per degree day in the Empress Drive and City View districts to 36.4 MJ (10.1 kW·h) per degree day in Lakeview. These analyses gave estimates of energy required for purposes other than heating, ranging from 99 MJ (27.5 kW·h) to 197 MJ (54.8 kW·h) per degree day.

ACKNOWLEDGEMENTS

The authors wish to thank the Saskatchewan Power Corporation for providing the energy statistics and other data upon which this report is based. They also wish to thank T. Remple, R.G. Nicholson and J.T. Makohon, who have helped to secure and process the data used in the preparation of the report. This paper is a contribution from the Division of Building Research of the National Research Council of Canada and is published with the approval of the Director of the Division.

REFERENCE

Mitalas, G.P. 1976. Net annual heat loss factor method for estimating heat requirements in buildings. National Research Council of Canada, Division of Building Research, Building Research Note 117, 22 p.

TABLE I

Electricity and natural gas consumption in Regina homes from September 1974 to August 1975, inclusive (5764 heating degree-days). Mean values and standard deviations (SD) are given in giga joules and megawatt hours (in parenthesis). Coefficients of variation (CV) are given in per cent.

	Electricity			Natural Gas			Electricity and Natural Gas		
District	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
Empress Drive	21.2	8.3	39	177	49.7	28	199	54.0	27
(190 homes)	(5.9)	(2.3)		(49.3)	(13.8)		(55.3)	(15.0)	
City View	25.2	9.0	36	179	46.0	26	205	49.3	24
(220 homes)	(7.0)	(2.5)		(49.6)	(12.8)		(56.8)	(13.7)	
Lakeview	25.2	9.7	39	204	45.4	22	228	48.2	21
(209 homes)	(7.0)	(2.7)		(56.6)	(12.6)		(63.3)	(13.4)	
Glencairn	31.0	8.3	24	201	28.8	14	231	31.3	14
(209 homes)	(8.6)	(2.3)		(55.8)	(8.0)		(64.2)	(8.7)	
Walsh Acres	27.7	6.8	25	207	37.8	18	235	40.0	17
(230 homes)	(7.7)	(1.9)		(57.4)	(10.5)		(65.3)	(11.1)	

TABLE II

Slope-intercept values for a group of 25 homes in each of five Regina districts. Intercept values (I) are given in MJ (kW·h) per day and slope values (S) are given in MJ (kW·h) per degree day.

	Electricity			Electricity and Natural Gas			
District	I	S	CD*	I	S	CD	Year
Empress Drive	36.7	1.11	0.914	99.0	25.2	0.986	1973-4
	(10.2)	(0.307)		(27.5)	(7.0)		
City View	55.4	0.965	0.313	197	24.5	0.952	1974-5
	(15.4)	(0.268)		(54.8)	(6.8)		
Lakeview	56.5	1.05	0.407	174	36.4	0.994	1974-75
	(15.7)	(0.291)		(48.4)	(10.1)		
Glencairn	57.6	1.55	0.795	144	31.0	0.993	1973-4
	(16.0)	(0.430)		(40.0)	(8.6)		
Walsh Acres	57.6	1.55	0.516	127	34.6	0.991	1974-5
	(16.0)	(0.328)		(35.2)	(9.6)		

* CD (Coefficient of Determination)

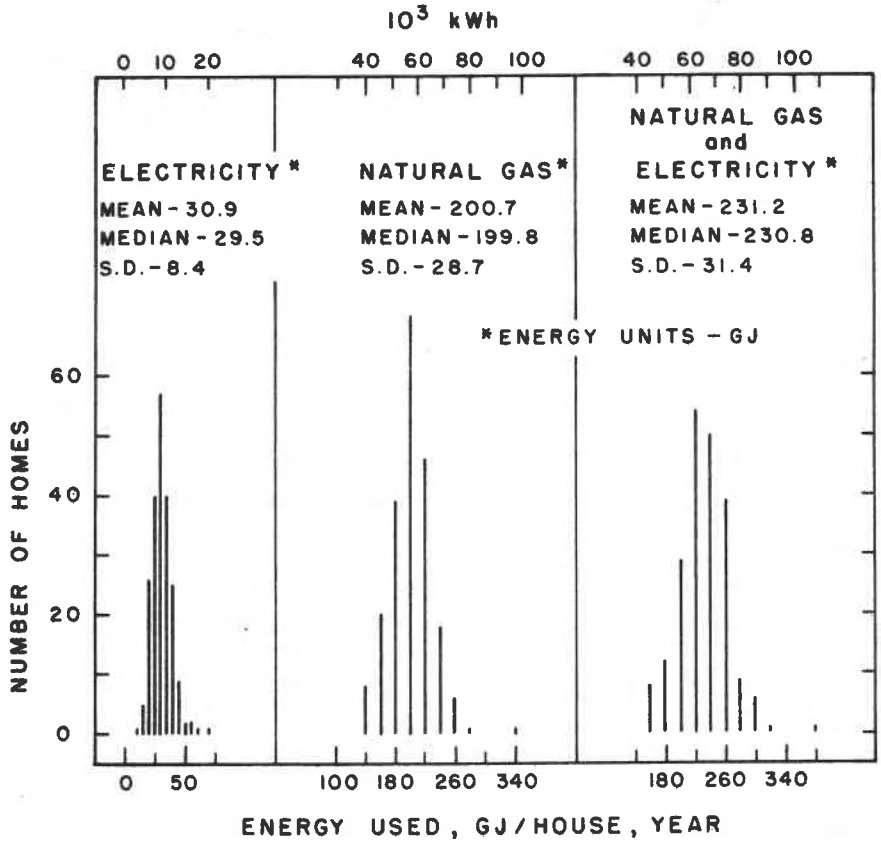

Figure 1

Histograms showing the frequency distribution for use of electricity, natural gas and electricity plus natural gas in 209 homes in the Glencairn district in Regina

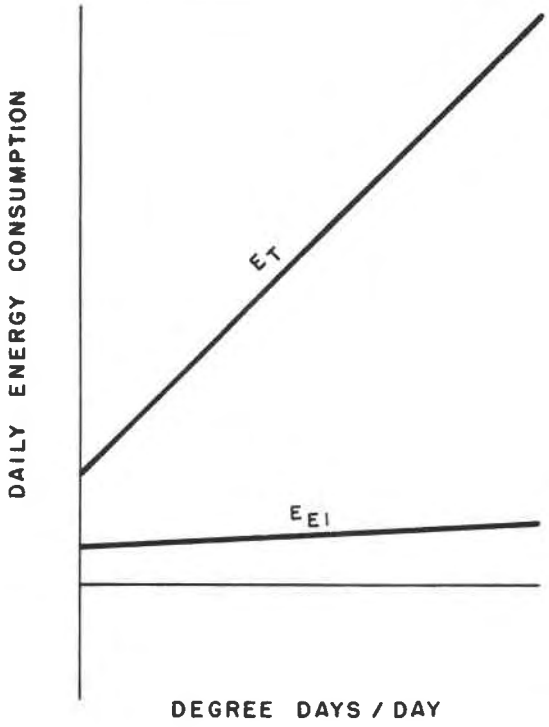

Figure 2(a)

Plot of electricity plus natural gas E_T and electricity E_{E1} in a house as a function of heating degree-days

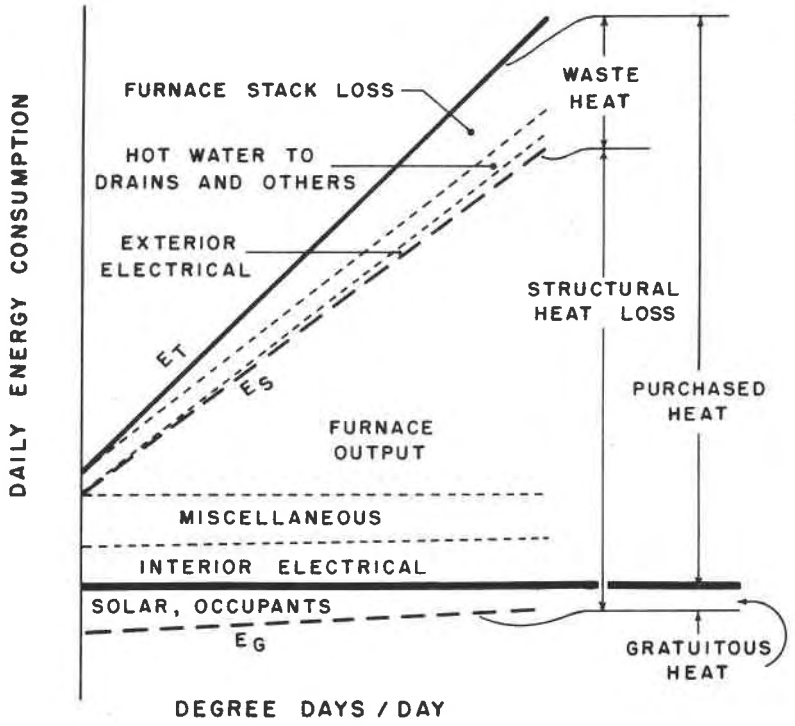

Figure 2(b)

Energy budget for a house - consumption vs heating degree-days

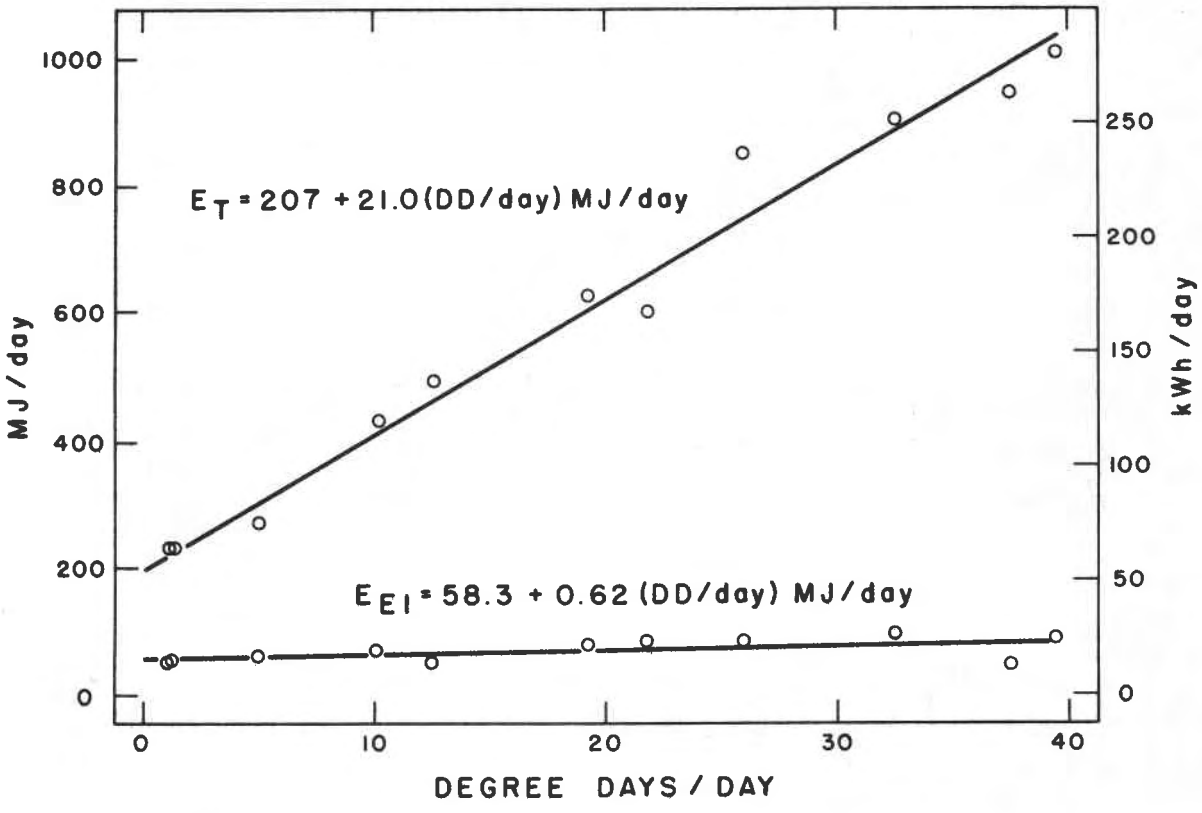

Figure 3

Electricity, E_{El}, and natural gas plus electricity consumption, E_T, for one year vs degree days, DD, in a single-family bungalow in Saskatoon (main floor area - 93 m^2; basement insulated)

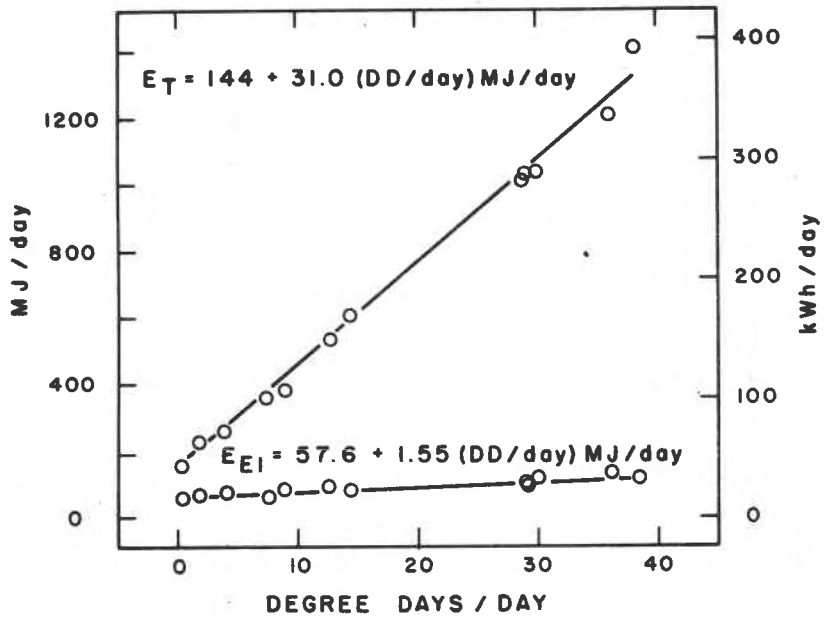

Figure 4

Consumption of electricity, E_{El}, and electricity plus natural gas, E_T, per house - average for 25 houses in the Glencairn district in Regina (Sept. 1974 to Aug. 1975)

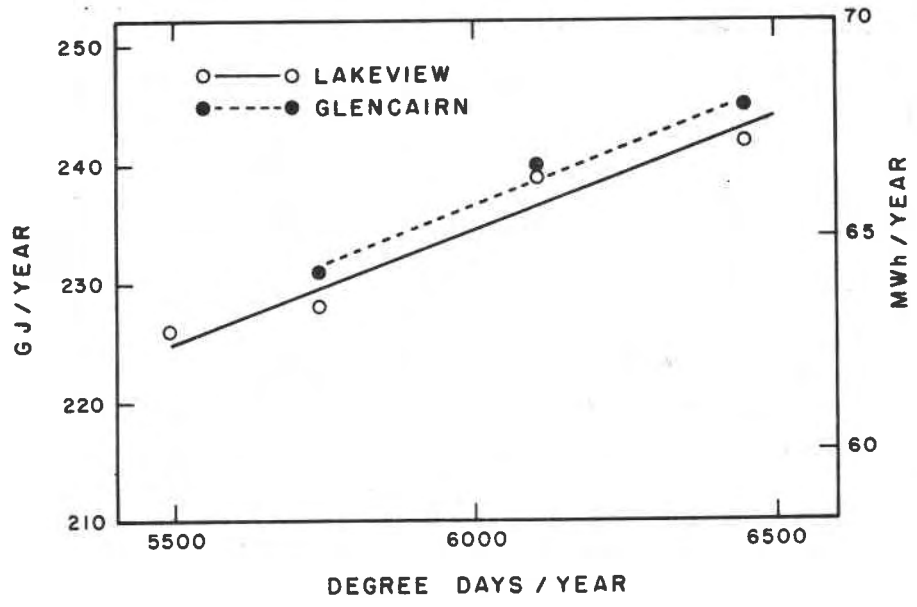

Figure 5

Plot of average annual energy consumption/house (electricity plus natural gas) vs annual degree-days for two Regina districts. The figures represent approximately 200 houses in each district

APPENDIX A

City View

This district is located in the northeast part of Regina. Approximately 60 per cent of the homes are of prewar construction and 40 per cent postwar. They are mainly single-storey dwellings with areas ranging from 45 to 85 m^2, averaging around 70 m^2. Some homes have been re-sided, most painted and some are covered with Insulbrick.

Empress Drive

This area contains both prewar and postwar houses and some 1 1/2 storey "wartime" houses. The prewar homes range from 45 to 85 m^2 averaging about 70 m^2. The area also contains a substantial fraction of good postwar homes ranging from 93 to 102 m^2. It contains a large fraction of homes of modest size.

Lakeview

This district is just west of Albert Street. There are a number of large, well built two-storey homes, originally designed for wealthy people and still well kept. These probably date from around the World War I period. Farther west the size of homes decreases, some being only 45 m^2. Generally these homes would not have been built later than the 1950's. They are well kept and the majority range from 75 to 98 m^2.

Glencairn

This is a new area (post 1970) on the east side of Regina. It is fairly homogeneous in nature. There are a few duplexes but most of the homes are single storey and range from 85 to 100 m^2; the average size is about 97 m^2.

Walsh Acres

This is also a new area, similar to Glencairn but the homes are somewhat larger. The majority are single-storey dwellings, but there is a fair representation (20 per cent) of split-level homes.