SPACE HEATING ENERGY BUDGETS FOR CANADIAN HOUSING

A study for

Policy Development Directorate

Canada Mortgage and Housing Corporation

by

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ENERGY BUDGETS FOR HOUSING

BACKGROUND

CMHC Policy Evaluation Division asked Scanada to carry out a very rapid, first-cut estimation of reasonable energy budgets for Canadian housing. An assumption is implied that current requirements (Measures for Energy Conservation in New Buildings, 1978) are out of date and that the kind of figures which EMR are using (eg. in their Super Energy Efficient Housing Demonstration Program [SEEHDP]) represent a sort of far-term future target not necessarily based on near-term economic realities. Without disputing this assumption, we feel it is important that the issues be clearly understood.

The 1978 "Measures" (actually struck in 1977) are indeed out of date and work is now in progress, albeit slow progress, on the next edition, which we do not expect to be issued before 1983. To some extent this present estimation must anticipate the contents of that next edition of the "Measures". This is done with full consideration of the Measures Committee deliberations to date.

We anticipate that CMHC would want to approach the setting of energy criteria from essentially the same viewpoint as the "Measures" Committee i.e. the criteria are intended to reflect the apparently best economic interests of the home owner or purchaser rather than the economic interests of the country as a whole. This discrepancy between the individual and national perspectives arises from the difference between domestic and world prices for energy.

On the other hand, EMR necessarily approaches the problem from a national perspective and this tends to favour somewhat more stringent criteria. As domestic prices approach world prices this divergence should decrease.

In one regard the "Measures" and the budget figures presented below do not exactly reflect the homeowner's or homebuyer's perspective in that, although they reflect the actual energy prices he must pay now and is likely to pay in the future, they are based on life cycle costing which requires a somewhat longer term outlook than many people would be willing to adopt when considering an investment in energy conservation.

We should also point out that the "Measures" Committee in addition to working on a new edition of its prescriptive code is also developing energy budget value for various types of buildings. Low-rise housing has been given a low priority in this aspect of the Committee's work since it is felt that the prescriptive approach is adequate and in some ways preferable in this area.

THE ECONOMIC OPTIMUM - A MOVING TARGET

In Building Research Note No. 105, D.G. Stephenson (DBR/NRC) developed the following formula for optimum R value (as restated in a paper for the Measures Committee prepared by J.K. Latta)

$$Ropt = \sqrt{\frac{24kDZP}{EFB}}$$

where k is a factor which reflects the portion of the heat saved by higher R values made up by purchased heat as opposed to "free" heat,

D is the degree day value

Z is the current unit cost of fuel,

P is the present worth factor, (reflecting the cost of money, the rate at which energy prices are expected to increase, and the economic life of the building)

E is the seasonal furnace efficiency,

F is the energy content of a unit of fuel, and

B is the incremental cost of increasing the R value

While one might debate the quantitative results which this formula yields, it does show adequately, we believe, the qualitative relationship among the various parameters. Of importance here is that Z, the current price of energy, is in the numerator. This means that, other factors remaining unchanged, each increase in the cost of energy (relative to B) results in an increase in the optimum R values and hence a decrease in the target energy consumption of a house. Thus there is no ultimate level beyond which houses will never go. Theoretically an enlightened builder would carry out this calculation before starting each house he builds. In reality, of course, this is unlikely to happen. Usually some government body or its designate (such as the "Measures" Committee) goes through this exercise and, using various regulatory or incentive strategies, tries to have the resulting criteria applied until the next time it goes through the exercise, usually several years later (eg. 1978 to 1983). Such is the nature of this project.

k - correction factor for free heat = 0.83

Z - unit cost of fuel = \$0.03/kWh (electricity)

E - heating efficiency = 100% (as applicable to this cost of fuel)

F - energy value of fuel = 100 Wh/kWh

P - present worth factor = 23

This value of P is based on the assumption that the cost of money is 13% per annum, the cost of energy will increase at 11% per year and the building has an economic life of 30 years. There are of course other combinations of values for these parameters which would result in the same value for P. It is a conservative value (i.e. closer to the HUDAC end of the present value spectrum than the EMR end).

The values of B, the incremental cost of adding insulation, used for walls, roofs and basements were taken from a study done by Scanada for the "Measures" Committee in August 1980.

It was necessary to derive an expression for Ropt for foundation walls since the Stephenson formula is not applicable. It was derived in a manner similar to that used by Stephenson and was based on a Scanada paper recently presented at ASHRAE entitled "Engineering Method for Estimating Annual Basement Heat Loss and Insulation Performance". The basement wall was assumed to be insulated over its full height.

The degree day values for these three particular cities were chosen because they give a wide enough range of climate and detailed weather data in a form suitable for use with the Dumont program are available for these cities.

As large apartment buildings are likely to have a much higher proportion of free heat and as time did not permit the derivation of a revised value of k, the Stephenson formula could not be used for apartments. It was therefore decided to simply assume that the R values prescribed for small buildings in the 1978 "Measures" would now apply to large buildings. This is equivalent to a 1500 shift in the degree day value.

The resulting R values used are as follows:

	Rwall	Rroof	Rbsmt. wall
Low Rise			
Toronto	3.95 (22.4)	5.05 (28.6)*	1.81 (10.3)
Fredericton	4.24 (24.1)	5.41 (30.7)*	2.06 (11.7)
Saskatoon	4.82 (27.4)	6.18 (35.1)*	2.54 (14.4)
Apartments			
Toronto	2.7 (15.3)	2.7 (15.3)	
Fredericton	2.9 (16.5)	2.9 (16.5)	
Saskatoon	3.3 (18.7)	3.3 (18.7)	

Step 2

Double glazed windows were assumed for Toronto and Fredericton and triple glazed for Saskatoon.

The low-rise dwellings were assumed to experience an annual average air change rate of 0.2 air changes per hour. This assumes the dwelling has a reasonably tight envelope (but not as tight as the Saskatoon demonstration houses, for example) and a ventilation system with controls which modulate the ventilation according to need.

Apartments were assumed to experience 0.3 air changes per hour.

Low-rise dwellings were assumed to have an average occupancy of 3.5 people and apartments 1.5 people.

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* As these Ropt calculations resulted in R values slightly lower than in the 1978 "Measures" the 1978 "Measures" values were used.

Relatively low energy use for appliances was assumed (i.e. efficient appliances) resulting in a relatively low free heat contribution from this source.

25% of domestic hot water energy consumption during the heating season was assumed to be available for space heating (40% in apartments).

All units were assumed to be randomly oriented relative to the sun; i.e. not specifically designed for passive solar.

Step 5

The 1979 typical practice values are based on a survey conducted by Brian Grey of CMHC to determine insulation levels and other energy related features in NHA and non-NHA housing across the country.

Results

The budgets should be expressed in terms of GJ per m^2 of floor area per year. The recommended values are as follows:

detached low rise - 3.6×10^{-5} D + 0.12
attached low rise - 2.1×10^{-5} D + 0.04
apartments - 1.2×10^{-5} D

ENERGY BUDGETS FOR EXISTING HOUSING

Energy budgets for existing housing are necessarily less stringent than those for new housing since -

- the remaining economic life of the building is likely to be lower (lower P value in Ropt formula),

- the cost of retrofitting energy conserving features is higher than the cost of incorporating them in new construction (higher B value in Ropt formula), and

- the means of safeguarding against interstitial condensation problems are different, more difficult and, to some extent, unknown at this point in time

The energy budgets for existing housing were developed using the CMHC-Scanada model of the existing housing stock (Canada II). Rather than carrying out Ropt calculations, the following upgrading measures were assumed:

- low-rise	- ceiling - to R 5.3 (30) - basement walls - to R 1.8 (10) full depth - walls - fill
- apartments	- insulate basement walls of walk-ups to R 1.8 (10) full depth - weatherstrip - add heat recovery to large buildings

The annual space heating requirements were then calculated for several climatic areas using the Scanada adjusted degree-day method built into the Canada II model, and the results plotted against degree-days

(Fig. 3). Two straight lines were fitted to the points by eye. The first line is the best fit and has the expression –

$$\text{Budget (GJ/unit year)} = 0.022D - 34$$

The second line goes through the centroid of the points and has the simpler expression –

$$\text{Budget (GJ/unit year)} = 0.015D$$

This latter expression is favoured both for its simplicity and for its lower slope which would be consistent with the use of higher R values in colder regions rather than the same R values throughout the country, as was assumed in the calculation.

Time did not permit a detailed study to put this on per m^2 basis. However, assuming an average dwelling unit size of 105 m^2 the expression becomes –

$$\text{Budget (GJ/m}^2\text{ year)} = 0.00014D$$

A similar exercise for apartments (Fig. 4) results in the expression

$$\text{Budget (GJ/m}^2\text{ year)} = 0.00013D$$

The Canada II model has only limited data on row houses but the data there is suggests that the target for existing attached dwellings should be 75% of that for detached dwellings. This results in the expression

$$\text{Budget (GJ/m}^2\text{ year)} = 0.000105D$$

These budgets for existing houses are on the high side. Further study would be required to determine by how much this is so, but there can be little doubt that they are 15% too high as target standards. In any case, some caution is required before making them too stringent in view of moisture concerns.

MODIFICATION FACTORS

The energy budgets for new houses were based on calculations which assumed 100% heating efficiency, i.e. electric heat. It is suggested that where other types of heating make sense (eg. gas on the Prairies, oil in P.E.I) the budget figures for new housing be increased by 20%. This is consistant with a seasonal heating efficiency of 83%. For existing housing the factor could be 25% (80% seasonal efficiency).

If the budgets are used in any way which requires the voluntary participation of house builders it may be desirable to modify them to reflect local preferences for types of energy and local energy costs which are different than those assumed in deriving the budgets. The following factors are based on a suggestion prepared for the "Measures" Committee by J.K. Latta (DBR/NRC) but not yet considered by the Committee:

	Electricity	Gas	Oil
Maritimes	0.86	-	0.75
Central	1.00	1.06	-
Prairies	1.04	1.20	-
B.C.	0.97	1.15	-

These factors are intended to be applied simultaneously with the furnace efficiency factors.

IMPLEMENTATION STRATEGIES

The federal government has two basic strategies it can consider to implement energy conservation targets in housing -

- regulation
- incentive

The federal regulation mandate in housing is limited to NHA financed housing and federally owned housing (DND etc.) - a diminishing portion of the market. Thus the incentive route seems more promising.

In existing housing energy budgets such as those presented here could be made prerequisites for CHIP grants.

In new housing, there are strong arguments in favour of a CHIP program for new housing. This too arises from the discrepancy between the individual homebuyer's interest and the national interest, which was discussed under "Background". If the federal government chooses to subsidize energy costs (and this is not the place to gainsay this practice) it is in the government's own interest to also subsidize low energy housing since such housing reduces the amount of energy which must be subsidized. It is a better investment for the country than it is for the individual homebuyer.

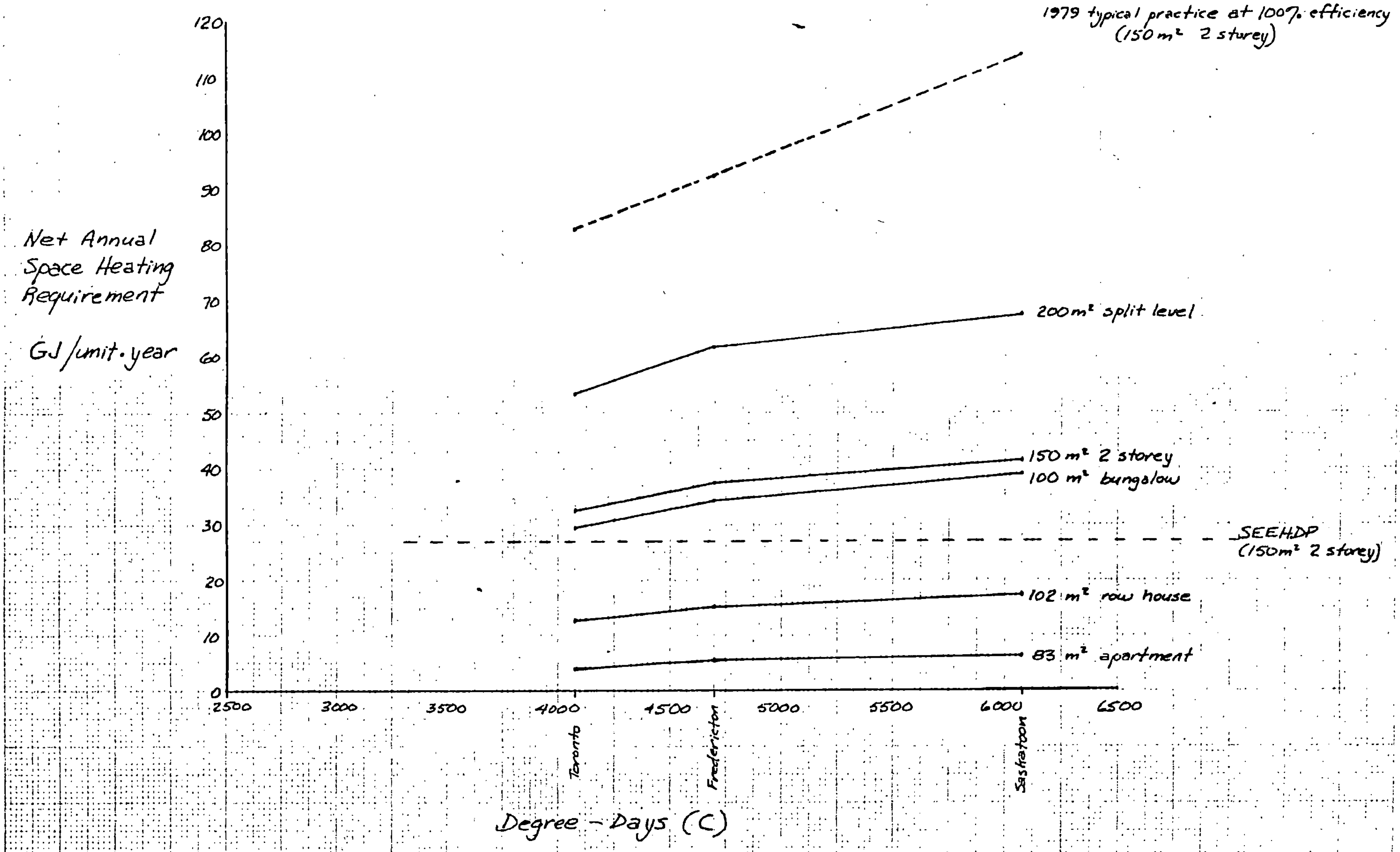

Figure 1. Net annual space heating requirements of dwelling units with "optimal" R values

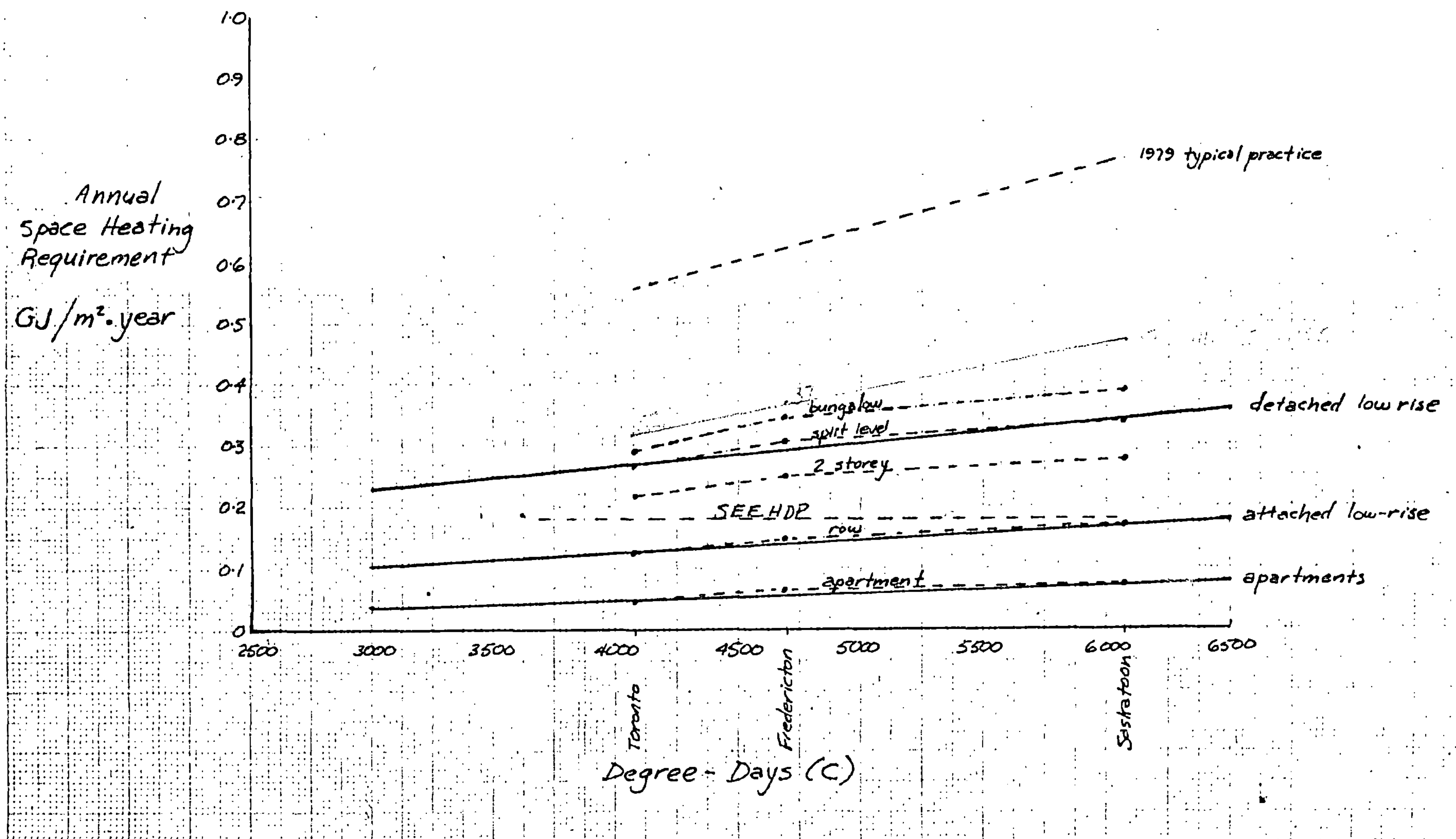

Figure 2. Unit annual space heating requirements of dwelling units with "optimal" R values

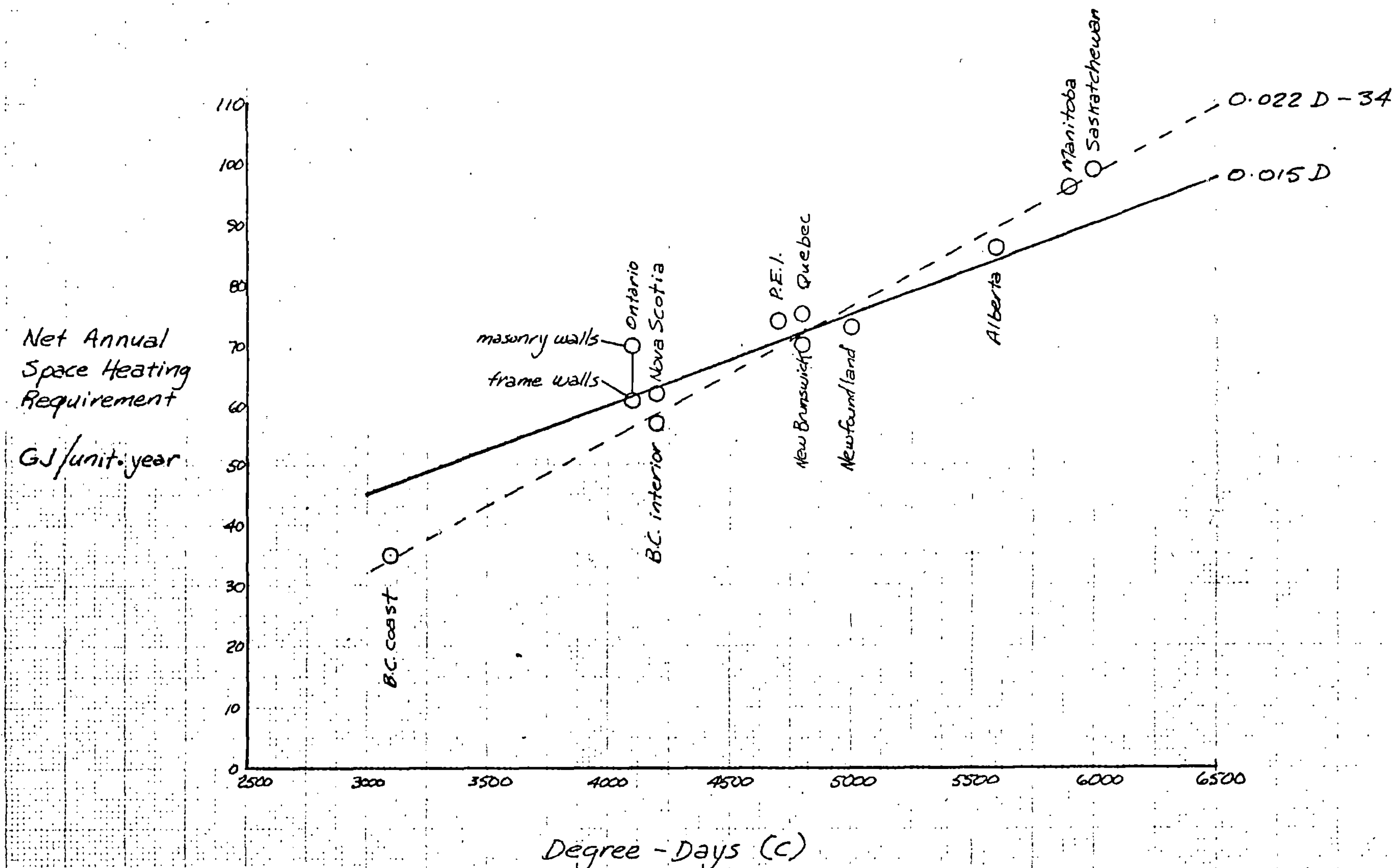

Figure 3. Net annual space heating requirements of upgraded existing detached dwelling units

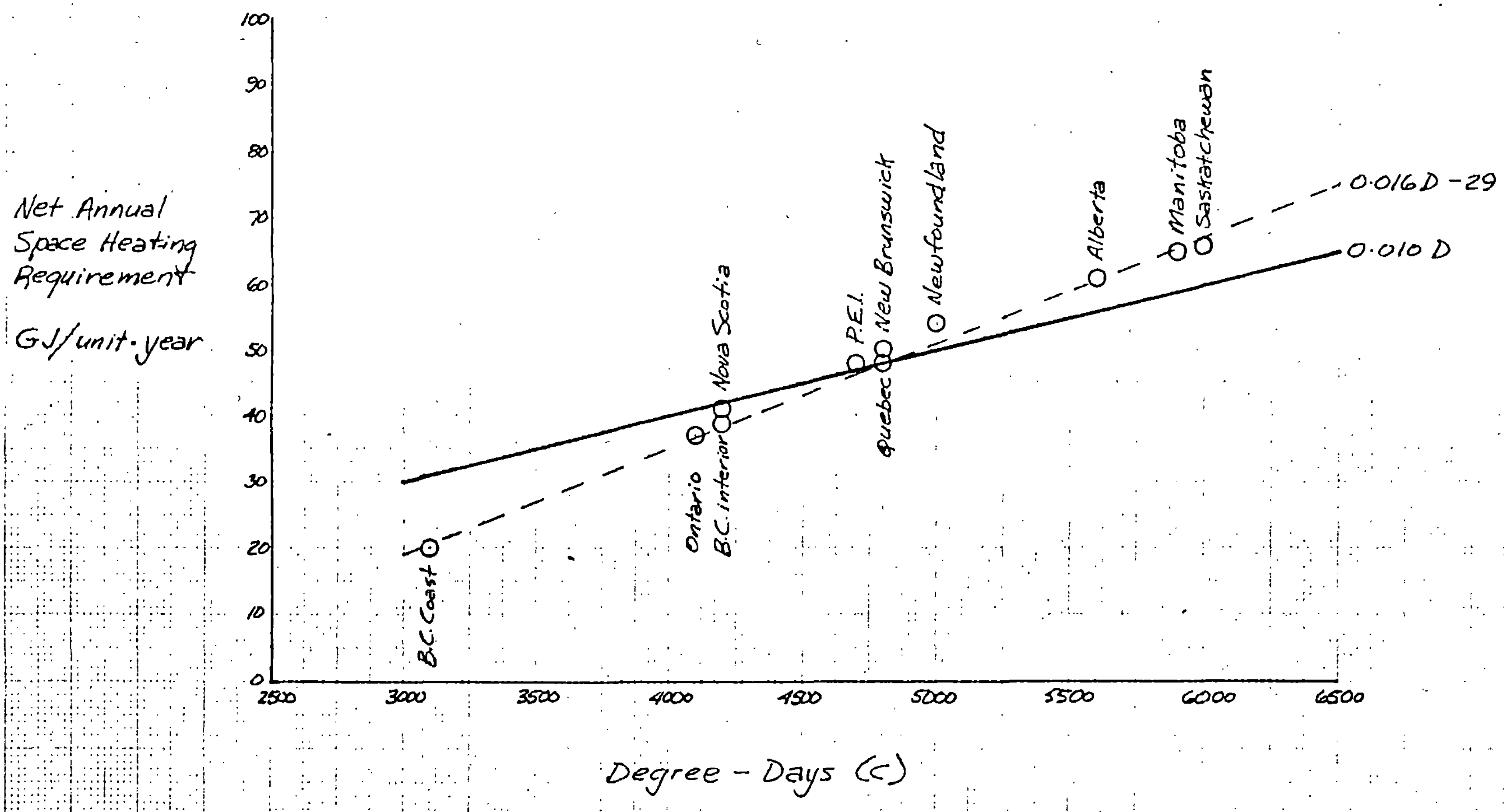

Figure 4. Net annual space heating requirements of upgraded existing apartment units

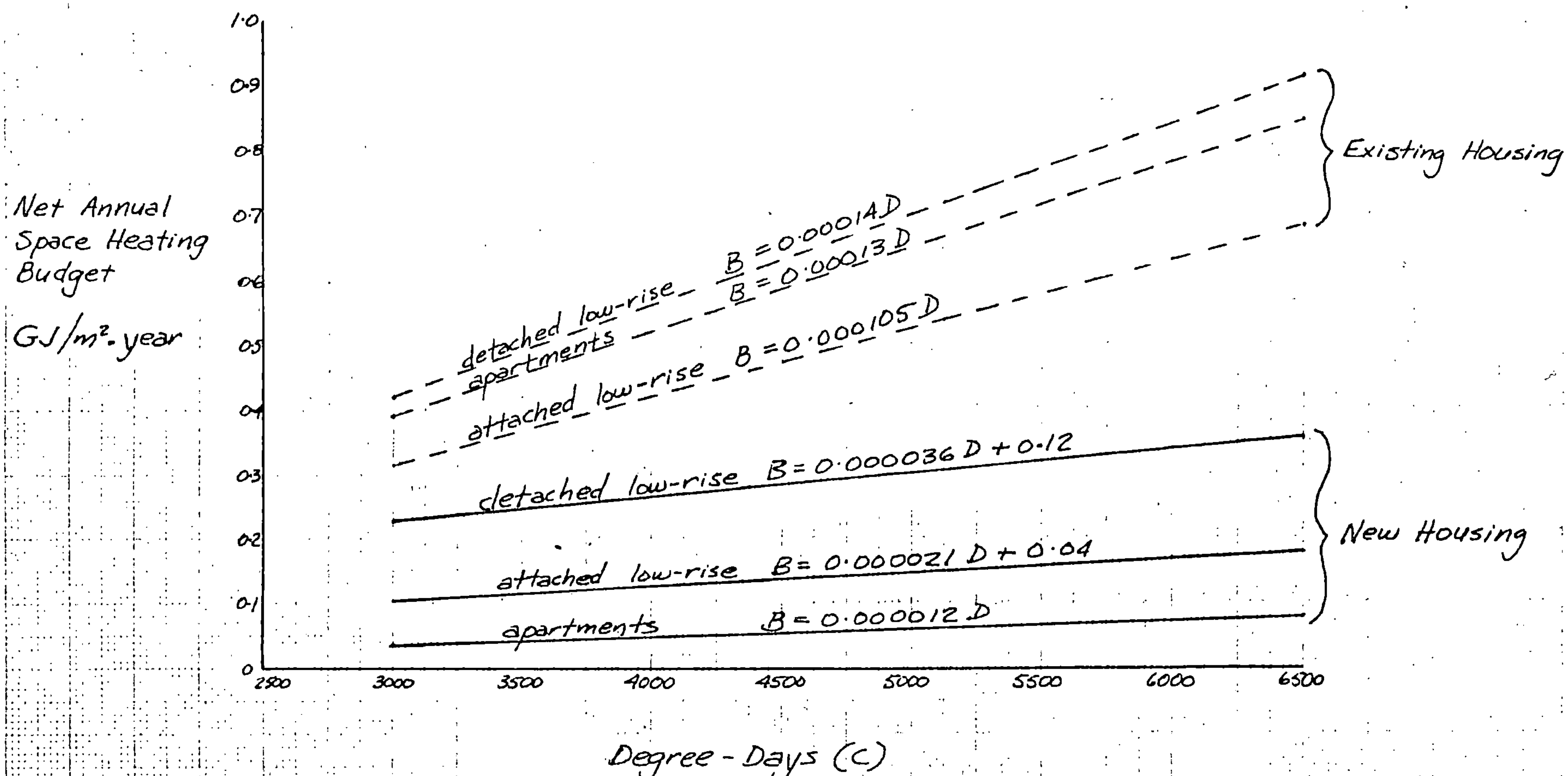

Figure 5. Summary of recommended energy budgets