Energy Use in the Commercial Sector: Estimated Intensities and Costs for Canada Based on US Survey Data

This study uses survey data relating to the United States commercial sector to estimate and interpret annual energy demand relationships in which account is taken of energy and non-energy prices, building characteristics, and weather information. It applies the estimated US relationships to the Canadian context, where no comparable survey information is at present available, to infer energy use and cost in buildings with specified characteristics located in major cities across the country. The results provide strong evidence of the value of information, from a properly designed survey, for identifying and analysing patterns of energy use in the commercial sector.

Utilisant les informations provenant d'un sondage du secteur commercial américain, cette étude évalue et interprète les relations (à quoi...) de la demande annuelle en énergie. On a tenu compte des ((coûts énergétiques et non énergétiques))?, des caractéristiques des bâtiments, et des fluctuations de température. Lorsque l'information n'est pas disponible pour connaître l'usage et le coût énergétique de bâtiments ayant des caractéristiques spécifiques et situés dans les grandes villes du pays, l'étude applique l'évaluation américaine au contexte canadien. Les résultats permettent de tirer des preuves concluantes de la valeur des renseignements, extraits d'un sondage bien préparé, pour identifier et analyser des modèles de consommation énergétique dans le secteur commercial.

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Introduction

There is considerable interest relating to energy use in the commercial sector in Canada. Among other things, there is interest in forecasting energy use, partly in order to anticipate the volume of undesirable emissions and their associated environmental effects. One indication of the interest in the sector is the creation of CCEEDAC, the Canadian Commercial Energy End-use Database and Analysis Centre, at McMaster University.

A particular problem in learning about energy use in the commercial sector is that there is little in the way of survey data. Most of what is available derives from the energy audit programs that started in the 1980s in a number of provinces, encouraged by the cost-sharing arrangement that was offered under the terms of the National Energy Audit Program. In some provinces the programs continued for a time even after federal funding ceased in the mid-1980s, but all such programs have now ended. We completed earlier an analysis of the audit data bases assembled in Manitoba and Alberta (see CCEEDAC Reports 95:2 and 96:1). As we noted at the time, the buildings that were audited were self-selected. That is, information was collected about them not as a result of a survey sampling procedure, but rather because the owners or managers of the buildings wished to take advantage of the energy audit program as a low-cost means by which to learn more about energy-use in their buildings, and to get suggestions about how they might reduce costs. In a later study, we made a number of comparisons with US data collected in a proper survey in which the probabilities of buildings being included in the sample were known. As we have documented, there is strong evidence that self-selected observations in the Canadian energy audits are not representative of the sector as a whole (CCEEDAC Report 96:2). It is, therefore, a matter of some importance that plans are now under way for a proper survey of commercial sector buildings in Canada. Even so, it will still be some time before data will be available. Hence it is worth exploring other means of learning what we can.

The purpose of this report is two-fold. We first make use of survey data from the US commercial sector to estimate annual energy demand relationships in which account is taken not only of energy and non-energy prices but also of building characteristics and weather conditions. We then use those relationships to infer Canadian energy use for buildings with specified characteristics, taking into account Canadian prices, weather and longer-run climatic conditions.

Section 2 of the report provides a description of the US data source and the approach we have used in exploiting that source. Section 3 reports and interprets our analytical results for the US. In sections 4 through 7 the estimated relationships are applied in the Canadian context, and the results interpreted. The study concludes in section 8.

CBECS and the Empirical Approach

CBECS, the US Commercial Building Energy Consumption Survey, has been conducted on a triennial basis since 1983, and an earlier survey was conducted in 1979. The purpose of the survey is to provide basic statistical information on energy consumption and expenditures for US commercial buildings and to provide data on energy-related characteristics of those buildings. A few points about the survey that are likely to be of particular interest are noted in what follows. Further information is available in *Commercial Buildings Characteristics 1992* and *Commercial Buildings Energy Consumption and Expenditure 1992*, both published by the US Department of Energy (publications DOE/EIA-0246(92) and DOE/EIA-0318(92), respectively).[1]

There are two major data collection stages: a Building Characteristics Survey and an Energy Suppliers Survey. In the first stage information is collected about selected commercial buildings through voluntary personal interviews with the buildings' owners, managers, or tenants. Information about the buildings' energy consumption and cost are based on records from energy suppliers, obtained in the second stage. (An authorization form is signed to permit the Energy Information Administration to obtain such information from the suppliers.)

Since there is no comprehensive list of *buildings* in the target population, *areas* are sampled. More specifically, the design of CBECS includes a multistage *area* probability cluster sample that is supplemented by a sample from a list of 'large' buildings, recently constructed buildings, and 'special' buildings (Federal Government buildings, post offices, hospitals, nursing homes, colleges, universities, secondary schools, and elementary schools). The area sample portion of the survey design yields a sample from the broad spectrum of commercial buildings, as does the sample from buildings recently constructed. The supplemental list provides a basis for over-sampling both 'large' and 'special' buildings; such over-sampling is less costly than increasing the area sample as a means of improving the accuracy of the estimate of total energy use.

For the 1992 survey, the target sample of completed interviews was set at 6,400 buildings, of which 4,850 would be from the area sample and 1,550 from the supplemental list sample. To that end a sample of 7,699 buildings from the area sample was selected and 2,472 buildings from the supplemental list sample. That resulted in 6,637 completed interviews,[2] including 4,944 from the

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[1] The brief overview of the survey in this section was provided earlier in CCEEDAC Report 96:2; that report, in turn, drew heavily from DOE/EIA-0246(92), Appendix B.

[2] While 6,637 is the number reported in publications relating to CBECS, we note that there are, in fact, 6,734 completed records available in the public use file.

area sample and 1,693 from the supplemental list. In the view of the Energy Information Administration, the main purpose of the survey was satisfied, namely that the sample "adequately represents the US commercial buildings population" such that it can provide the basis "to efficiently measure commercial buildings energy consumption" (DOE/EIA-0318(92), p. 243).

One final observation about the sampling procedure. The 1992 CBECS sample attempted to include all buildings in the 1986 sample; that is to say, the survey involved a longitudinal revisit of buildings that were included in the earlier survey, and efforts were made to attain the greatest possible overlap with the earlier sample. As we noted in an earlier report (CCEEDAC 96:3), such a sampling procedure potentially opens the door for a variety of comparative analyses of energy usage in the two years. Making effective use of the longitudinal aspect of those two surveys is to be the subject of a separate study.

The analysis in this study is based on a restricted set of observations relating to buildings that were included in both surveys -- namely, occupied buildings of less than one million square feet that are located in climate zones one, two, or three (the three zones in which major Canadian cities fall), which consumed only electricity, only electricity and natural gas, or only electricity and fuel oil, and for which there was no change in the reported building size or fuels used. In addition, a small number of observations for which errors were apparent in the data were excluded -- specifically, those for which reported fuel usage was too small to be believed (less than 2500 kWh/year) or for which the inferred unit price of energy was either too high or too low to be believed.[3] In the end we were left with 1,984 observations, two for each of 992 buildings that were included in both surveys, that were located in the three climate zones, and that met all other restrictions that we imposed. No attempt is made in this study to take further advantage of the longitudinal feature of the data. Instead, the 1986 and 1992 observations on each building are treated simply as two observations. As noted above, it is our intention to make use later of this same set of observations in a study that will make effective use of the longitudinal feature. However, for present purposes, this is a convenient and "clean" sample with which to work.

We note at the outset that gaining a systematic understanding of patterns of fuel consumption in buildings in the commercial sector is inevitably a difficult task. The sector itself is highly heterogeneous, as has frequently been observed, and even if we know rather a lot about the physical characteristics of the buildings themselves and the uses made of them, it seems inevitable that much will be left unexplained.

Estimated Fuel Consumption Relationships: US Commercial Sector

The results of the estimation are reported in three tables, one for each combination of fuels used. Table 1 relates to buildings for which the only reported fuel was electricity, Table 2 to buildings that used both electricity and natural gas (and no other fuel), and Table 3 to buildings that used electricity and fuel oil (and no other fuel). In each case separate equations are reported for the consumption of each fuel used. (All Tables are at the end of the paper.)

The relationships estimated postulate that annual consumption of each fuel in each building is a linear function of price, climate variables, building characteristics, and the use made of the building. The specification of price is of particular interest. Fuel consumption (measured in kilowatt hours[4]) is made a function of the price of that fuel (its "own price", in cents per kilowatt hour) and the price of the other relevant fuel (the "substitute

[3] After much investigation, all residuals from a fitted regression equation greater than two standard deviations were inspected, and decisions were made about which of the associated observations to drop. The fitted equations related the log of fuel price to the log of fuel consumption and a set of regional dummy variables representing climate zones in various parts of the US.

[4] All energy use is converted into kilowatt hours using the following conversion factors: 1 cubic metre of natural gas = 10.64985 kwh; 1 cubic metre of fuel oil = 10,733.06 kwh.

Table 1: Estimated Regression Results for Buildings using Electricity Only

Variable	Electricity coefficient	Electricity t score
Relative prices		
Electricity/wage	-399.69	2.00
Natural gas/wage	--	
Fuel oil/wage	--	
Climate variables		
HDD * %heated	0.013	1.38
CDD * %cooled	0.067	1.45
Climate zone 1	reference	
Climate zone 2	-5.30	1.21
Climate zone 3	-2.58	0.58
Building characteristics		
Size ('000 sq.ft.)	-0.030	1.67
Number of storeys		
--one	reference	
--two	-12.02	3.11
--three	-14.34	2.26
--4-14	-8.66	1.15
--15-25	--	
--26+	--	
Has basement	-2.41	0.59
Number of attached exterior walls		
--none	reference	
--one	-6.62	0.94
--two or more	8.59	0.96
--not specified	-4.60	1.27
Roof material		
--wood shingles or other wood	-8.78	0.79
--slate or tile shingles	-12.54	1.16
--asphalt, fiberglass or other shingles	-10.19	2.72
--built-up (e.g. tar with stone ballast)	reference	
--metal surfacing	-14.86	2.57
--plastic, rubber or synthetic sheeting	-12.84	2.57
--concrete	24.74	2.46
--other	-6.90	0.56
Wall material		
--glass	-0.70	0.08
--sheet metal panel	13.04	2.13
--pre-cast concrete panel	12.01	1.60
--brick, stone, stucco, or concrete	reference	
--siding, shingles, tiles or shakes	6.75	1.57
–other	-6.02	0.53
Period of construction		
–before 1940	-2.19	0.46

Table 1: Continued

Variable	Electricity coefficient	t score
--1940-1949	9.69	1.23
--1950-1959	9.69	1.23
--1960-1969	-7.96	1.76
--1970-1974	-5.33	1.20
--1975-1979	reference	
--1980-1984	-4.00	0.98
--1985-1992	-4.95	1.04
Use of building		
Principal activity		
--office	reference	
--mercantile and service	-9.93	1.78
--laboratory	--	
--warehouse and storage, not refrigerated	-12.75	1.64
--food sales (e.g. grocery stores)	20.32	1.91
--public order and safety	-1.50	0.09
--health, out-patient service	--	
--warehouse and storage, refrigerated	--	
--public assembly or religious establishment	-8.77	1.42
--education	-16.27	2.77
--food service (e.g. restaurants)	29.38	3.37
--health, in-patient service	18.79	1.15
--residential care	-8.88	0.54
--hotel, motel or dormitory	-0.67	0.07
--other	-16.41	1.64
Number of workers		
--up to 5	reference	
--6-15	-1.68	0.42
--16-55	7.73	1.58
--56+	9.76	1.37
Weekly hours in use		
--40 or less	2.03	0.56
--41-70	reference	
--71-100	14.02	3.39
--101-168	-2.84	0.60
1986 survey observation	0.63	0.26
Constant	35.41	3.51
Number of observations	316	
F-statistic	3.82	
R-squared, adjusted	0.3089	

Note: The dependent variable is annual energy consumption in kilowatt hours per square foot. The symbol -- indicates no observations for a particular category.

Table 2: Estimated Regression Results for Buildings using Electricity and Natural Gas

Variable	Electricity coefficient	Electricity t score	Natural gas coefficient	Natural gas t score
Relative prices				
Electricity/wage	-253.12	4.41	120.02	1.18
Natural gas/wage	-120.22	0.37	-3277.21	5.65
Fuel oil/wage	--		--	
Climate variables				
HDD * %heated	0.006	2.52	0.021	4.79
CDD * %cooled	0.025	2.18	--	
Climate zone 1	reference		reference	
Climate zone 2	1.26	1.25	1.61	0.92
Climate zone 3	2.43	1.90	2.98	1.41
Building characteristics				
Size ('000 sq.ft.)	-0.005	1.50	-0.022	3.76
Number of storeys				
--one	reference		reference	
--two	-1.61	1.65	-2.83	1.64
--three	-2.73	2.05	-2.93	1.25
--4-14	-2.36	1.45	-0.91	0.32
--15-25	-4.04	0.84	-3.28	0.39
--26+	-9.09	1.41	16.74	1.47
Has basement	0.52	0.53	-0.73	0.42
Number of attached exterior walls				
--none	reference		reference	
--one	-1.55	1.07	-7.75	3.04
--two or more	-1.07	0.68	-6.13	2.22
--not specified	-0.42	0.54	-3.79	2.78
Roof material				
--wood shingles or other wood	-2.04	0.83	-7.27	1.68
--slate or tile shingles	-1.88	0.96	-5.81	1.68
--asphalt, fiberglass or other shingles	-0.82	0.90	-1.58	0.99
--built-up (e.g. tar with stone ballast)	reference		reference	
--metal surfacing	-0.80	0.54	-3.27	1.25
--plastic, rubber or synthetic sheeting	-0.17	0.18	-1.85	1.11
--concrete	-0.55	0.11	-4.32	0.47
--other	-4.52	1.74	-4.21	0.92
Wall material				
--glass	-0.51	0.18	-3.00	0.58
--sheet metal panel	2.37	1.49	5.01	1.78
--pre-cast concrete panel	0.41	0.25	1.20	0.41
--brick, stone, stucco, or concrete	reference		reference	
--siding, shingles, tiles or shakes	1.26	0.98	1.39	0.61
--other	-1.08	0.17	-0.86	0.08
Period of construction				
--before 1940	-3.77	2.91	8.04	3.53
--1940-1949	-2.44	1.62	8.99	3.38
--1950-1959	-2.98	2.15	4.03	1.65
--1960-1969	-0.72	0.58	6.55	3.02

Table 2: Continued

Variable	Electricity coefficient	Electricity t score	Natural gas coefficient	Natural gas t score
--1970-1974	1.26	0.95	6.67	2.85
--1975-1979	reference		reference	
--1980-1984	1.04	0.73	3.98	1.58
--1985-1992	-2.71	1.53	0.53	0.17
Use of building				
Principal activity				
--office	reference		reference	
--mercantile and service	-2.63	2.34	-3.48	1.78
--laboratory	26.62	5.33	43.05	4.88
--warehouse and storage, not refrigerated	-5.58	3.51	-3.81	1.40
--food sales (e.g. grocery stores)	33.99	13.27	-0.02	0.01
--public order and safety	-10.86	4.28	-0.86	0.19
--health, out-patient service	4.10	0.95	21.50	2.81
--warehouse and storage, refrigerated	14.29	2.26	10.05	0.90
--public assembly or religious establishment	-4.66	3.55	-2.71	1.17
--education	-6.95	4.98	0.51	0.21
--food service (e.g. restaurants)	13.63	8.00	22.44	7.45
--health, in-patient service	-11.96	1.36	-5.79	0.37
--residential care	-8.62	2.26	28.51	4.24
--hotel, motel or dormitory	-2.82	1.11	11.36	2.52
--other	-2.76	0.84	2.17	0.38
Number of workers				
--up to 5	reference		reference	
--6-15	1.69	1.85	0.61	0.38
--16-55	3.63	3.50	1.83	1.01
--56+	7.29	5.46	-0.74	0.31
Weekly hours in use				
--40 or less	-1.37	1.31	-0.26	0.14
--41-70	reference		reference	
--71-100	3.16	3.33	5.11	3.05
--101-168	7.72	5.95	2.35	1.03
1986 survey observation	0.18	0.26	2.87	2.43
Constant	11.75	4.33	13.21	2.78
Number of observations	1428		1428	
F-statistic	19.06		7.34	
R-squared, adjusted	0.4148		0.1964	

Note: See note to Table 1.

Table 3: Estimated Regression Results for Buildings using Electricity and Fuel Oil

	Electricity		Fuel oil	
Variable	coefficient	t score	coefficient	t score
Relative prices				
Electricity/wage	-333.81	3.48	44.33	0.17
Natural gas/wage	--		--	
Fuel oil/wage	-910.40	1.14	-7940.86	3.64
Climate variables				
HDD * %heated	-0.002	0.41	0.021	1.98
CDD * %cooled	0.051	2.08	--	
Climate zone 1	reference		reference	
Climate zone 2	3.14	1.74	7.76	1.60
Climate zone 3	1.26	0.56	4.64	0.79
Building characteristics				
Size ('000 sq.ft.)	0.002	0.19	-0.032	1.42
Number of storeys				
--one	reference		reference	
--two	2.92	1.42	0.59	0.11
--three	2.11	0.87	1.52	0.23
--4-14	2.13	0.74	-0.82	0.10
--15-25	--		--	
--26+	--		--	
Has basement	-1.36	0.65	-0.04	0.01
Number of attached exterior walls				
--none	reference		reference	
--one	-2.92	1.28	1.46	0.24
--two or more	3.54	0.87	7.58	0.69
--not specified	-5.09	3.26	-2.45	0.58
Roof material				
--wood shingles or other wood	-9.41	1.26	3.92	0.19
--slate or tile shingles	2.50	0.82	-5.37	0.65
--asphalt, fiberglass or other shingles	-0.51	0.30	-2.07	0.44
--built-up (e.g. tar with stone ballast)	reference		reference	
--metal surfacing	5.84	2.14	24.17	3.24
--plastic, rubber or synthetic sheeting	-2.64	1.41	-3.82	0.75
--concrete	-2.29	0.37	25.14	1.49
--other	-2.83	0.45	-3.08	0.18
Wall material				
--glass	-0.29	0.07	-6.76	0.63
--sheet metal panel	-4.11	1.11	-30.04	2.97
--pre-cast concrete panel	31.82	3.57	-27.86	1.15
--brick, stone, stucco, or concrete	reference		reference	
--siding, shingles, tiles or shakes	-0.11	0.06	-0.99	0.20
--other	-6.61	1.28	-27.58	1.95
Period of construction				
--before 1940	-7.45	3.20	7.12	1.13
--1940-1949	-4.40	1.65	7.49	1.04
--1960-1969	-5.01	1.84	11.23	1.53
--1950-1959	-8.27	3.35	1.91	0.29

Table 3: Continued

Variable	Electricity coefficient	Electricity t score	Fuel oil coefficient	Fuel oil t score
--1970-1974	-8.82	3.25	-0.53	0.07
--1975-1979	reference		reference	
--1980-1984	-6.99	2.21	1.82	0.21
--1985-1992	-3.74	0.76	-8.13	0.61
Use of building				
Principal activity				
--office	reference		reference	
--mercantile and service	-1.73	0.87	-0.28	0.06
--laboratory	--		--	
--warehouse and storage, not refrigerated	-0.16	0.05	2.62	0.30
--food sales (e.g. grocery stores)	19.13	3.64	-5.70	0.40
--public order and safety	--		--	
--health, out-patient service	--		--	
--warehouse and storage, refrigerated	--		--	
--public assembly or religious establishment	-5.53	2.14	-5.25	0.74
--education	-2.37	1.00	-1.85	0.30
--food service (e.g. restaurants)	7.63	2.09	-8.15	0.82
--health, in-patient service	13.37	1.81	11.19	0.56
--residential care	--		--	
--hotel, motel or dormitory	--		--	
--other	18.85	3.04	11.69	0.69
Number of workers				
--up to 5	reference		reference	
--6-15	0.47	0.33	-3.85	0.99
--16-55	2.34	1.24	-11.85	2.34
--56+	6.17	2.48	-3.92	0.58
Weekly hours in use				
--40 or less	-1.32	0.74	-2.10	0.43
--41-70	reference		reference	
--71-100	2.22	1.23	6.71	1.37
--101-168	-2.86	0.76	6.01	0.59
1986 survey observation	-0.45	0.40	4.88	1.60
Constant	24.62	4.26	34.51	2.19
Number of observations	240		240	
F-statistic	5.17		1.38	
R-squared, adjusted	0.4558		0.0696	

Note: See note to Table 1.

price", again in cents per kilowatt hour).[5] Each fuel price is expressed relative to a wage rate, and in this case the wage rate is the average weekly earnings of workers in manufacturing.[6] Economic theory suggests that a *relative* price is appropriate, and the wage is taken here as representative of the cost of the labour input in the commercial sector (a wage rate relating directly to the commercial sector would have been preferred, but none was available). We turn now to the interpretation of the estimation results in Tables 1 through 3. The number of observations varies from 240 buildings in the case of buildings consuming only electricity and fuel oil (hereafter "oil-consuming buildings") to 1428 in the case of buildings consuming only electricity and natural gas ("gas-consuming buildings"), with buildings consuming only electricity ("electricity-only buildings") coming in between at 316. The overall measure of goodness of fit, R-squared, adjusted for degrees of freedom, ranges from 0.07 to 0.46 (for fuel oil and electricity, respectively, in oil-consuming buildings). All equations except the one for fuel oil have significant explanatory power at the 1 percent level, as indicated by the value of the F-statistic.

The dependent variable in each equation is annual energy consumption per square foot. It is convenient to interpret the effects of each category of right-hand variables by looking across all fuel combinations (that is, across Tables 1 through 3). We start with the relative price variables. The most striking feature is that all estimated own-price coefficients have the expected negative sign and all are statistically highly significant. It is helpful in interpreting the results to consider the values of the price elasticities of demand that are implied. Since the estimated functional form is linear, the values of the elasticities are affected by both fuel consumption and prices. The following values are based on the 1992 prices and the means of 1986 and 1992 degree days reported in Table 4, below.[7]

Implied own-price elasticities

Electricity-only buildings	electricity	- 0.180
Gas-consuming buildings	electricity	- 0.376
	gas	- 0.698
Oil-consuming buildings	electricity	- 0.350
	oil	- 1.955

Three own-price elasticities are estimated for electricity, one for each fuel combination. The estimates range from about -0.2 to -0.4; that is, electricity consumption is quite inelastic in all three cases. The estimated elasticity for gas is greater at -0.7, and that for oil much greater still, at about -2.0.

We observe that the response to the price of the other fuel (the cross-price response) is not statistically significant. That is probably to be expected, since the observations have been restricted to buildings in which there was no fuel switching over a six-year period. One might expect cross-price effects to show up largely through changes of equipment (e.g., the change from an oil-burning heating system to one that burned natural gas), but such changes have been ruled out here.

Consider now the climate. Three climate variables are included. Two relate to the number of degree days and the other refers to the zone in which a building is located. Of the two degree day variables, one measures the number of heating degree days (HDD) and the other the number of cooling degree days[8] (CDD); in both cases they are multiplied by the percent of the building area reported as heated or cooled. The estimated coefficients can be summarized as follows:

[5] As noted, our estimation is limited to build-ings in which there was no change over a six-year period in the fuels consumed. The inclusion of "other fuel" should, therefore, be thought of as relating to short-run and not long-run substitution.

[6] We used the series "average earnings of production workers on manufacturing payrolls," as published by the US Bureau of Labor Statistics in *Employment and Earnings*.

[7] More precisely, the elasticities relate to buildings having "reference" characteristics, as described below.

[8] As defined for CBECS, a heating (cool-ing) degree day is the difference between the average daily temperature and 65 degrees Fahrenheit, if posi-tive (negative), and zero otherwise. Annual heating and cooling degree days are expressed as absolute values, and obtained by summing over all days with-in the year.

Degree-day coefficients

		Elec.	Gas	Oil
HDD	Electricity-only bldgs	0.013*	--	--
	Gas-consuming bldgs	0.006**	0.021**	--
	Oil-consuming bldgs	-0.002	–	0.021**
CDD	Electricity-only bldgs	0.067*	–	--
	Gas-consuming bldgs	0.025**	--	--
	Oil-consuming bldgs	0.051**	--	--

* indicates statistical significance at the 10 percent level or better, based on a one-tail test, and ** at the 5 percent level or better

Calculated degree-day elasticities

		Elec..	Gas	Oil
HDD	Electricity-only bldgs	.193	--	--
	Gas-consuming bldgs	--	.770	--
	Oil-consuming bldgs	--	--	.793
		Elec.	Gas	Oil`
CDD	Electricity-only bldgs	.101	--	--
	Gas-consuming bldgs	.126	--	--
	Oil-consuming bldgs	.180	--	--

The CDD variables are excluded from the demand equations for gas and oil since only electrical energy is normally used to cool. The level of statistical significance in the estimated equations is generally high, except in the case of electricity in oil-consuming buildings, and with that one exception, the estimated coefficients bear the expected positive sign. That is, consumption increases with both colder and warmer temperatures. We note that electricity consumption is much more responsive to heating requirements when it is the only fuel consumed, as one would expect, and that the other fuels are much more responsive to heating requirements when they are in use, again as one would expect. We note also that in electricity-only buildings the estimated degree-day energy requirements for cooling exceed those for heating. That is consistent with the relatively great energy requirements associated with running a compressor.

It is informative also to consider the elasticity values implied by the estimated effects. The values reported below are calculated at the mean of degree days, as reported below in Table 4.[9] The relatively low HDD elasticity value for electricity-only buildings is to be expected, since electricity is used for non-heating as well as heating purposes.

Climate zone dummy variables are included in the equations as well. Their purpose is to pick up any additional effects that may be associated with location once all the effects associated with other variables have been taken into account. No clear pattern is found.

We turn now to the building characteristics. Consider first *size*. The results suggest that larger buildings generally consume less energy per square foot, other things equal. The results for electricity consumption in electricity-consuming buildings are strikingly similar to those for natural gas and oil consumption in other buildings: for each additional 1,000 square feet, consumption of those fuels declines by a statistically significant but modest 0.02 to 0.03 kWh per square foot per year. The results suggest also that electricity consumption is even less affected by size when other fuels are in use, after taking other factors into account. Again, it is convenient to express the results in elasticity form; the estimates are all very close to zero, which suggests that fuel intensities are relatively insensitive to building size.

Calculated size elasticities

	Elec.	Gas	Oil
Electricity-only bldgs	-0.002	--	--
Gas-consuming bldgs	-0.001	-.004	--
Oil-consuming bldgs	0.000	--	-.006

[9] Also, the calculations are at the predicted values of the dependent variable, for a building with specified reference characteristics.

Consider now the *number of storeys*. One might expect some effect. In terms of energy efficiency, for example, one might anticipate that the closer a building is to being cube shaped, other things equal, the less energy it might use. There is some evidence that supports that notion -- for electricity-only and gas-consuming buildings the estimates suggest that two- and especially three-storey buildings use less fuel per square foot than do those of one storey.

We find little by way of clear patterns associated with the remaining building characteristics. Whether or not there is a basement level appears not to matter. One might expect that a building with walls attached to another building would consume less energy, and we find some support for that notion in connection with gas but not for other fuels. There is no clear pattern across the various fuel combinations associated with the roof and wall construction materials, although there is evidence that the materials matter. Also, there is no clear pattern even with the period of construction. It is evident that the year of construction would have little bearing on current energy use for those older buildings in which wall and ceiling insulation had been improved, original windows as well as heating and cooling equipment had been replaced, and so on. No information about such retrofitting is available from the survey.

Respondents are asked also to identify the *principal activity* in the building, and for present purposes the responses are organized into 15 categories with "office" chosen as the reference case. One might expect to find major differences in fuel consumption depending on the activity, and this expectation is born out. Among the more interesting and readily interpretable findings, we note the high electricity consumption associated with the categories involving food: as compared to offices, and after taking other factors into account, the estimates indicate that electricity consumption is significantly greater in food sales, food services, and refrigerated warehouse and storage facilities. By contrast, electricity consumption is relatively low in buildings where the principal activity is merchandise and services, nonrefrigerated warehousing and storage, public assembly, and education. The differences appear to be large -- for example, the estimated relationships indicate that a building used primarily for food sales, service, or storage would consume between 8 and 34 more kWh of electrical energy per square foot per year than would an otherwise similar office building. (The average total energy use in the sample is about 25.)

The remaining variables relate to the *number of workers*, the *number of hours the building is in use per week*, and whether the *observation was from 1986 or 1992*. We find, for all fuel combinations, that electricity consumption increases with the number of workers, but that no effect can be discerned for the other fuels. We find also that, for buildings that consume both electricity and natural gas, electricity use increases with the number of hours in use. Finally, we find no difference between electricity consumption in 1986 and 1992, once other factors (including temperature) have been taken into account, but there is evidence of some reduction in the consumption of both natural gas and oil.

Canadian Price, Wage, and Weather Variables

In order to make use of the fuel consumption relations based on US survey data to infer fuel consumption in various parts of Canada, it is necessary to assign to each of the variables in the relations values that reflect the Canadian situation. Of particular concern are values relating to energy prices, wage rates, and weather, and they are shown in Table 4 for each of the provinces. Also shown, for comparison, are values drawn from the two CBECS surveys and, in the case of the wage rate, the average across all states.

For each of the provinces the measures of fuel prices and wage rates are for the year 1994 (the latest year for which data were available at the time the calculations were made), and relate to the province as a whole. In the case of cooling and heating degree days, the measures relate to a major city in each province, as specified below. The means of the annual degree-day values are shown for the 33-year period 1961-1993, together with the minimum and maximum annual values over that period.

Electricity and oil prices are shown for all provinces, and gas prices are shown for all but the Atlantic provinces (that fuel not being available there). Average prices are shown, although it is recognized that underlying the average is typically a declining rate structure. All prices are expressed in cents per kWh.

Table 4: Energy Price, Wage, and Weather Variables for Canada and US

	Province										CBECS	CBECS
	NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC	1986	1992
Fuel prices (¢/kWh)												
Electricity	7.47	8.55	11.83	8.12	6.40	7.62	5.38	6.68	6.81	5.55	8.38	9.00
Natural gas	--	--	--	--	2.26	1.67	1.48	1.46	1.13	1.74	1.81	1.76
Light fuel oil	1.80	1.80	1.80	1.80	1.80	1.84	1.56	1.50	1.36	2.01	1.82	2.01
Wage rate in manufacturing ($/week)												
	571.21	527.59	377.31	584.02	556.69	671.72	494.90	517.34	579.65	656.92	423.70	501.80
Cooling degree days												
Maximum	167	250	317	148	617	753	655	558	283	162	1,797	1,273
Mean	55	122	165	59	411	486	338	277	147	70	726	475
Minimum	7	43	67	5	249	211	124	142	67	13	29	34
Heating degree days												
Maximum	9,499	8,319	9,284	9,295	8,915	7,499	11,628	11,439	10,663	6,061	10,672	11,489
Mean	8,812	7,766	8,587	8,674	8,275	6,957	10,545	10,334	9,528	5,376	5,976	6,123
Minimum	7,972	7,084	7,632	7,902	7,510	6,219	8,582	8,287	7,868	4,673	3,817	3,839

Note: Prices and wage rates for the provinces relate to 1994 and are in Canadian currency. The provincial electricity prices are from SC 57-202, Electric Power Statistics and the natural gas prices from SC 57-205, Gas Utilities; the fuel oil prices were obtained from the National Energy Board; the provincial wage rates were obtained from CANSIM.
Prices and wage rates for the US are in US currency. The US wage rates are an average of the regional rates used in the regression analysis. The cooling and heating degree days relate to a major city in each province, for the period 1961-1993 while those for CBECS relate to locations represented in the year of the survey.

It is evident that fuel prices differ markedly across the country. Electricity is far more expensive than oil in all provinces, and far more expensive also than natural gas in those provinces where gas is available. Electricity is most expensive in the Atlantic region, excepting Newfoundland, and least expensive in BC and Manitoba. Natural gas is least expensive on the Prairies, especially in Alberta, and most expensive in Quebec. Fuel oil also is least expensive on the Prairies but most expensive in BC. The differences are quite striking -- electricity in PEI is more than twice as expensive as it is in Manitoba or BC, natural gas in Quebec is twice as expensive as it is in Alberta, and fuel oil is half again as expensive in BC as in Alberta. We note also that fuel prices in Canada are generally lower than the calculated prices in either of the CBECS surveys, even without an adjustment for the exchange rate.

The wage rate in manufacturing also varies considerably across the country, being highest in Ontario and lowest by far in PEI.

Economic theory indicates that *relative* (rather than *absolute*) prices are relevant for resource allocation decisions, and as noted above, we have chosen to express each of the fuel prices relative to the wage rate. On this basis electricity remains (relatively) expensive in the Atlantic region and cheapest in Manitoba and especially BC, fuel oil is (relatively) expensive in the Atlantic region except NB and in Quebec, and cheaper in the provinces to the west of Quebec, especially Ontario and Alberta; natural gas is (relatively) expensive in Quebec and cheap in Alberta.

Turning now to the degree-day variables, we note that the figures for heating and cooling degree days relate to a major city in each province (St. John's, NFLD, Halifax, NS, Charlottetown, PEI, St. John, NB, Montreal, QUE, Toronto, ONT, Winnipeg, MAN, Regina, SASK, Edmonton, ALTA, and Vancouver, BC). Of these cities, only Vancouver falls in climate zone 3 and only Toronto falls in zone 2.[10] All the rest are in climate zone 1. It is not surprising to see that there are typically more heating degree days and fewer cooling degree days in these Canadian cities than in the US survey data. At the same time we see that the 33-year minimum and maximum values in Canada fall within the range of experience shown in the US survey data.

Inferred Energy Intensities and Costs in Canada for Buildings with Various Characteristics

As explained above, our approach is to assume that the energy demand relations that apply in the US apply also in Canada. Hence we make use of the relations estimated with US survey data in combination with Canadian price, wage, weather, and longer-run climate information, to infer energy demand for buildings in Canada with a range of characteristics.

Tables 5 and 6 relate to buildings in which the "principal business activity" is *offices*. Table 5 shows the inferred level of annual energy use per square foot and Table 6 shows the cost. Similar pairs of tables are provided for the categories *mercantile and services* (Tables 7 and 8) and *public assembly* (Tables 9 and 10).

Consider first Table 5. In keeping with the estimated relations, buildings are distinguished by the energy sources used -- those that consume only electricity, those that use electricity in combination with natural gas (and no other fuel), and those that use it in combination with fuel oil (and no other fuel). The energy intensities, as calculated, relate to a building with "reference" characteristics. More specifically, they relate to a one-storey detached structure of 3,000 square feet, all of which is both heated and cooled, that has no basement[11], has a built-up roof and walls of brick, stone, stucco, or concrete, was built in the period 1975 to 1979, is open from 41 to 70 hours per week, and has fewer than six people working in it. In the case of Table 5, the building is used principally as office space.

For electricity-only buildings we see a pattern of high energy demand in the prairie provinces, where the weather conditions are severe and the (relative) price of electricity is low, and low demand in the Atlantic region, where the weather conditions are somewhat less severe and the price of electricity is the highest in the country. It is noteworthy that the inferred demand in PEI, with its relatively severe climate, is less than in either Ontario (which is in climate zone 2) or BC (in climate zone 3). The reason, of course, is the high price of electricity in PEI and the low price in Ontario and BC. The associated costs are shown in the first panel of Table 6. Even with its low consumption of electricity, the cost is over $4 per square foot in PEI as compared to less than $3 in Ontario and about $2 in BC.

Turning now to buildings that consume natural gas as well as electricity, the total kilowatt hours of consumption are rather similar, but with more energy taken in the form of gas than of electricity (Table 5). Even so, far less is spent to purchase the gas, and the estimated total energy cost is reduced substantially (by at least half in four of the six provinces in which this fuel combination is available), as compared to a building in which only electricity is used.

Consider, finally, oil-consuming buildings. As compared to electricity-only buildings, they consume more kilowatt hours (the exception is PEI), but spend at least one-third less in most provinces.

Because of the functional form of the equation estimated, predicted fuel consumption for other principal activity categories differs from the office category by only a constant factor within each fuel using combination. For illustrative purposes, we have chosen two other building activity categories,

[10] Toronto, in fact, is located very much on the border between zones 1 and 2. A simple averaging of data from four weather stations in the Greater Toronto Area (Richmond Hill, Toronto Downtown, Toronto Island Airport, and Pearson Airport) puts Toronto in zone 1, while excluding Richmond Hill, as we have done, puts it in zone 2.

[11] More than half of the buildings in the CBECS survey reported having no basement.

Table 5: Estimated Energy Intensities for Buildings with Reference Characteristics: Offices

Energy Source	NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC
	Province									
	-- Energy use, kWh per square foot --									
Electricity only	41.6	39.5	34.8	41.2	44.0	37.6	46.6	45.1	43.7	36.7
Electricity and natural gas only										
Electricity					14.5	15.4	16.1	15.3	14.8	15.2
Natural gas					18.6	22.5	26.8	27.1	28.1	19.7
Total					33.1	37.9	42.8	42.4	43.0	35.0
Electricity and fuel oil only										
Electricity	16.4	15.7	9.6	16.3	18.8	23.0	18.4	17.6	17.9	20.0
Fuel oil	30.4	26.4	18.7	30.7	28.6	37.2	34.0	35.5	37.8	28.2
Total	46.8	42.1	28.3	46.9	47.4	60.3	52.4	53.1	55.7	48.1

Note: The "reference characteristics" refer to building characteristics, weather conditions, energy prices, and non-energy prices represented by wage rates. The building characteristics are as follows: it is a one-storey detached structure with 3,000 square feet; the building has no basement, built-up roofing (e.g., tar with stone ballast), and walls of bricks, stone, stucco, concrete, etc., and was constructed in the period from 1975 to 1979; it is open from 41 to 70 hours per week, and fewer than six people work there. The cooling and heating degree days relate to a major city in each province, as noted in the text. The entire reference building is assumed to be both cooled and heated. All prices relate to 1994.

Table 6: Estimated Energy Costs for Buildings with Reference Characteristics: Offices

Energy Source	NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC
	Province									
	-- Energy cost per square foot ($) --									
Electricity only	3.11	3.38	4.12	3.34	2.81	2.86	2.51	3.01	2.98	2.03
Electricity and natural gas only										
Electricity					0.93	1.17	0.86	1.02	1.01	0.85
Natural gas					0.42	0.38	0.40	0.40	0.32	0.34
Total					1.35	1.55	1.26	1.42	1.33	1.19
Electricity and fuel oil only										
Electricity	1.23	1.34	1.13	1.32	1.20	1.75	0.99	1.18	1.22	1.11
Fuel oil	0.51	0.44	0.31	0.52	0.48	0.64	0.50	0.50	0.48	0.53
Total	1.74	1.78	1.45	1.84	1.68	2.39	1.48	1.67	1.70	1.64

Note: See Note to Table 5.

Table 7: Estimated Energy Intensities for Buildings with Reference Characteristics: Mercantile and Services

Energy Source	NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC
	-- Energy use, kWh per square foot --									
Electricity only	31.5	29.0	24.1	31.0	32.1	25.4	35.1	33.9	33.1	26.4
Electricity and natural gas only										
Electricity					11.2	11.9	12.8	12.2	12.0	12.5
Natural gas					15.1	19.1	23.3	23.6	24.7	16.3
Total					26.3	31.0	36.1	35.8	36.6	28.7
Electricity and fuel oil only										
Electricity	14.5	13.5	7.2	14.3	15.6	19.6	15.4	14.9	15.7	18.0
Fuel oil	30.1	26.1	18.4	30.4	28.3	37.0	33.8	35.2	37.5	27.9
Total	44.6	39.6	25.7	44.7	43.9	56.5	49.2	50.1	53.2	45.9

Note: See Note to Table 5.

Table 8: Estimated Energy Costs for Buildings with Reference Characteristics: Mercantile and Services

Energy Source	NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC
	-- Energy cost per square foot ($) --									
Electricity only	2.35	2.48	2.85	2.51	2.06	1.93	1.89	2.26	2.25	1.46
Electricity and natural gas only										
Electricity					0.72	0.91	0.69	0.81	0.81	0.69
Natural gas					0.34	0.32	0.34	0.35	0.28	0.28
Total					1.06	1.23	1.04	1.16	1.09	0.98
Electricity and fuel oil only										
Electricity	1.08	1.16	0.86	1.16	1.00	1.49	0.83	0.99	1.07	1.00
Fuel oil	0.51	0.44	0.31	0.51	0.48	0.64	0.49	0.49	0.48	0.52
Total	1.59	1.60	1.17	1.67	1.48	2.13	1.32	1.49	1.54	1.52

Note: See Note to Table 5.

Table 9: Estimated Energy Intensities for Buildings with Reference Characteristics: Public Assembly

Energy Source	Province									
	NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC
	-- Energy use, kWh per square foot --									
Electricity only	32.9	30.7	26.0	32.4	35.1	28.6	37.7	36.3	34.9	27.9
Electricity and natural gas only										
Electricity					9.8	10.7	11.4	10.6	10.2	10.6
Natural gas					15.9	19.8	24.1	24.4	25.4	17.0
Total					25.7	30.5	35.4	35.0	35.6	27.6
Electricity and fuel oil only										
Electricity	10.9	10.1	4.0	10.7	13.2	17.4	12.7	12.0	12.4	14.4
Fuel oil	25.2	21.1	13.4	25.4	23.3	32.0	28.8	30.3	32.6	22.9
Total	36.1	31.2	17.4	36.1	36.5	49.4	41.5	42.3	44.9	37.3

Note: See Note to Table 5.

Table 10: Estimated Energy Costs for Buildings with Reference Characteristics: Public Assembly

Energy Source	Province									
	NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC
	-- Energy cost per square foot ($) --									
Electricity only	2.45	2.62	3.07	2.63	2.24	2.18	2.03	2.42	2.38	1.55
Electricity and natural gas only										
Electricity					0.63	0.81	0.61	0.71	0.69	0.59
Natural gas					0.36	0.33	0.36	0.36	0.29	0.30
Total					0.99	1.14	0.97	1.06	0.98	0.88
Electricity and fuel oil only										
Electricity	0.81	0.87	0.47	0.87	0.84	1.32	0.69	0.80	0.84	0.80
Fuel oil	0.42	0.36	0.23	0.43	0.39	0.55	0.42	0.42	0.41	0.43
Total	1.24	1.22	0.70	1.30	1.24	1.87	1.11	1.23	1.26	1.23

Note: See Note to Table 5.

namely mercantile and services, and public assembly, to show how implied fuel consumption differs. These activity categories are among the major ones in terms of number of buildings, square footage, and energy use.

As noted above in the discussion of regression equations, for electricity the estimates of lower consumption, as compared to the office category, are statistically significant for buildings of public assembly for all fuel combinations, and also for mercantile and services buildings in two of the three cases. The lower levels of electricity use, as compared to offices, are to be expected, since it is common to have less energy-using equipment. Beyond that, the consumption of natural gas is lower in the *mercantile and service* category, but the difference is not large.

The implied differences in energy intensities are apparent from comparisons of Tables 5, 7, and 9. As one would anticipate from what has just been said, total energy intensities are greater in the *office* category than in the other two. In the case of buildings using only electricity, for example, those in the *mercantile and services* and *public assembly* categories are found rather typically to consume one-quarter to one-third less energy. The implied costs of energy consumption (as reported in Tables 6, 8, and 9) vary in the same proportions.

Inferred Impact on Energy Intensities of Building Features and Weather Variables

In this section we infer the impact on energy intensity of building features (size and number of storeys) and weather variables. Unlike the previous section, this is done for only one principal activity, namely *offices*.[12]

[12] These and other inferred values as they relate to the *mercantile and service* and *public assembly* categories are reported in our research paper bearing the same title as this paper; it is available as McMaster University Research Institute for Quantitative Studies in Economics and Population Research Report No. 337 and CCEEDAC Report 97:1.

Looking first at square footage (Table 11), the results suggest that size makes rather little difference to energy intensity: buildings of 15,000 square feet are estimated to use only 1 to 2 percent less energy per square foot than buildings one-fifth that size. That is, of course, consistent with size elasticities of approximately zero, as noted in Section 3.

By contrast, it appears that there are substantial economies associated with the number of storeys (Table 12). For example, energy intensities in all-electric *office* buildings are reduced by between one-quarter and one-third in two-storey buildings, as compared to those of one storey, and by somewhat more in three-storey buildings. Generally similar results are obtained in the case of buildings in which natural gas as well as electricity is consumed. For buildings in which oil is used, the estimates go in the opposite direction. However, they should be ignored, in that the parameter estimates that underlie them are not statistically significant.

We consider now the impact of variations in weather, as indicated by the number of degree days. For each category of building activity we compare two measures of extreme weather with the mean or average. The extremes are defined by combining maximum and minimum heating and cooling degree days within each province. Specifically, "high demand" means that the numbers of both heating and cooling degree days are at their maximum recorded values over the 33-year period for which we have data, while "low demand" means that both are at their minimum values. (The values are recorded in Table 4.) As a typical example, for Alberta the number of degree days in the "high demand" case is 13 percent above the mean, while in the "low demand" it is 18 percent below. The estimates in Table 13 suggest that energy intensity response is about half as great. That result reflects the degree-day elasticities discussed in Section 3. In the case of *offices* in Alberta, for example, the "high demand" total energy consumption is some 5 to 8 percent above the mean and the low is some 6 to 11 percent below, depending on the fuels used.

Table 11: Estimated Energy Intensities for Buildings of Different Sizes: Offices

Energy Source	Province									
	NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC
Buildings for which electricity is the only energy source										
-- electricity use, kWh per square foot --										
3,000 sq ft (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
7,500 sq ft	99.7	99.7	99.6	99.7	99.7	99.6	99.7	99.7	99.7	99.6
15,000 sq ft	99.1	99.1	99.0	99.1	99.2	99.0	99.2	99.2	99.2	99.0
Buildings for which electricity and natural gas are the only energy sources										
-- electricity use, kWh per square foot --										
3,000 sq ft (reference)					100.0	100.0	100.0	100.0	100.0	100.0
7,500 sq ft					99.8	99.9	99.9	99.9	99.9	99.9
15,000 sq ft					99.6	99.6	99.6	99.6	99.6	99.6
-- natural gas use, kWh per square foot --										
3,000 sq ft (reference)					100.0	100.0	100.0	100.0	100.0	100.0
7,500 sq ft					99.5	99.6	99.6	99.6	99.7	99.5
15,000 sq ft					98.6	98.8	99.0	99.0	99.1	98.7
-- total energy use, kWh per square foot --										
3,000 sq ft (reference)					100.0	100.0	100.0	100.0	100.0	100.0
7,500 sq ft					99.6	99.7	99.7	99.7	99.7	99.7
15,000 sq ft					99.0	99.2	99.3	99.2	99.3	99.1
Buildings for which electricity and fuel oil are the only energy sources										
-- electricity use, kWh per square foot --										
3,000 sq ft (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
7,500 sq ft	100.0	100.0	100.1	100.0	100.0	100.0	100.0	100.0	100.0	100.0
15,000 sq ft	100.1	100.1	100.2	100.1	100.1	100.1	100.1	100.1	100.1	100.1
-- fuel oil use, kWh per square foot --										
3,000 sq ft (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
7,500 sq ft	99.5	99.5	99.2	99.5	99.5	99.6	99.6	99.6	99.6	99.5
15,000 sq ft	98.8	98.6	98.0	98.8	98.7	99.0	98.9	98.9	99.0	98.7
-- total energy use, kWh per square foot --										
3,000 sq ft (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
7,500 sq ft	99.7	99.7	99.5	99.7	99.7	99.8	99.7	99.7	99.8	99.7
15,000 sq ft	99.2	99.1	98.7	99.2	99.2	99.4	99.3	99.3	99.4	99.3

Note: Energy intensities are in index form, with the value when reference characteristics apply set at 100.0; except as stated, the reference characteristics noted in Table 5 apply.

Table 12: Estimated Energy Intensities for Buildings of Different Numbers of Storeys: Offices

Energy	Province									
Source	NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC
Buildings for which electricity is the only energy source										
-- electricity use, kWh per square foot --										
One floor (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Two floors	71.1	69.5	65.3	70.7	72.6	67.9	74.1	73.3	72.4	67.1
Three floors	65.4	63.6	58.6	65.0	67.3	61.7	69.1	68.1	67.1	60.7
Buildings for which electricity and natural gas are the only energy sources										
-- electricity use, kWh per square foot --										
One floor (reference)					100.0	94.4	90.5	95.2	97.9	95.4
Two floors					88.9	83.9	80.5	84.6	87.0	84.8
Three floors					81.2	76.7	73.5	77.3	79.5	77.5
-- natural gas use, kWh per square foot --										
One floor (reference)					100.0	82.3	69.2	68.3	65.9	94.0
Two floors					84.7	69.7	58.6	57.9	55.8	79.6
Three floors					84.2	69.2	58.2	57.5	55.4	79.1
-- total energy use, kWh per square foot --										
One floor (reference)					100.00	87.2	77.2	78.0	77.0	94.6
Two floors					86.5	75.5	66.8	67.5	66.6	81.9
Three floors					82.9	72.3	64.0	64.6	63.8	78.4
Buildings for which electricity and fuel oil are the only energy sources										
-- electricity use, kWh per square foot --										
One floor (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Two floors	117.7	118.6	130.5	117.9	115.5	112.7	115.9	116.6	116.3	114.6
Three floors	112.8	113.5	122.1	113.0	111.2	109.2	111.5	112.0	111.8	110.6
-- fuel oil use, kWh per square foot --										
One floor (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Two floors	102.0	102.3	103.2	101.9	102.1	101.6	101.8	101.7	101.6	102.1
Three floors	105.0	105.8	108.2	105.0	105.4	104.1	104.5	104.3	104.0	105.4
-- total energy use, kWh per square foot --										
One floor (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Two floors	107.5	108.4	112.5	107.5	107.4	105.8	106.7	106.6	106.3	107.3
Three floors	107.8	108.7	112.9	107.8	107.7	106.0	107.0	106.9	106.5	107.6

Note: Energy intensities are in index form, with the value when reference characteristics apply set at 100.0;
for all number of storey categories, the building is assumed to have 7500 square feet, but otherwise reference characteristics noted in Table 5 apply.

Fuel Price Effects and Inferred Fuel Price Elasticities

The implied effects of changing fuel prices are shown in Table 14; again results are reported only for the *offices* category.[13] The experiments here involve "high" and "low" price scenarios which can be compared to the reference case. "High" fuel prices means that the prices of all relevant fuels are increased by 30 percent while "low" means that all are reduced by 30 percent. The dollar value of a 30 percent price change varies considerably from one province to another, since fuel prices vary across the country, and that means that the responses differ by province as well as by the fuel consumed. A general observation is that the estimated responses to price changes are relatively small in the case of electricity-only buildings, somewhat greater in the case of gas-consuming buildings, and greater still in oil-consuming buildings.

Table 15 shows the values for the own price elasticities implied by the estimated equations for each of the provinces. The values are calculated at the fuel prices shown in Table 4 and the fuel consumption levels in Tables 5. The interpretation of these elasticities is conditional on no change in the types of fuels used. For office buildings using only electricity, the elasticities are all in the inelastic range, with typical values of the order of -0.1. The values in NB, NS, and especially PEI are higher, reflecting the higher electricity prices in those provinces. The calculated own-price elasticities for electricity in buildings burning other fuels as well are generally much higher (in absolute value terms), but typically still in the inelastic range. The exception is PEI, which is just inside the elastic range for oil-consuming buildings. The values for natural gas and fuel oil are much higher than for electricity, but still in the inelastic range (again, with the exception of PEI).

Conclusions

This study had two major purposes: (1) to utilize survey data relating to the US commercial sector to estimate and interpret annual energy demand relationships in which account is taken of
not only energy and non-energy prices, but also of building characteristics and weather information; and (2) to apply those estimated relationships in the Canadian context, where no comparable survey information is available, to infer energy use and cost in buildings with specified characteristics located in major cities throughout the country, and experiencing Canadian prices and climatic conditions.

The results of the study provide strong evidence of the value of information from a properly designed survey for learning about patterns of energy use, and how responsive they are to the price of fuel, building characteristics and weather variables. Access to such information in Canada could greatly extend knowledge of our commercial sector.

Acknowledgements

This study was supported by CCEEDAC, the Canadian Commercial Energy End-Use Database and Analysis Centre, at McMaster University, under the terms of an agreement with Natural Resources Canada. The authors thank Huan Nguyen-Dinh and Christine Feaver for their assistance with the computational aspects of the research.

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[13] But results for other categories are available; see footnote 11.

Table 13: Estimated Energy Intensities for Buildings Experiencing Different Degree Days: Offices

Energy Source	Province NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC
Buildings for which electricity is the only energy source										
-- electricity use, kWh per square foot --										
High demand	103.9	103.9	105.5	103.4	105.0	106.6	107.5	107.3	105.4	104.0
Mean values (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Low demand	96.7	96.5	94.6	96.7	95.3	92.6	91.6	92.2	94.0	96.5
Buildings for which electricity and natural gas are the only energy sources										
-- electricity use, kWh per square foot --										
High demand					106.3	106.6	109.2	109.2	107.1	104.3
Mean values (reference)					100.0	100.0	100.0	100.0	100.0	100.0
Low demand					93.9	92.5	89.0	89.4	91.7	96.2
-- natural gas use, kWh per square foot --										
High demand					107.2	105.0	108.5	108.5	108.5	107.3
Mean values (reference)					100.0	100.0	100.0	100.0	100.0	100.0
Low demand					91.4	93.1	84.6	84.2	87.6	92.5
-- total energy use, kWh per square foot --										
High demand					106.8	105.7	108.7	108.8	108.0	106.0
Mean values (reference)					100.0	100.0	100.0	100.0	100.0	100.0
Low demand					92.5	92.9	86.3	86.1	89.0	94.1
Buildings for which electricity and fuel oil are the only energy sources										
-- electricity use, kWh per square foot --										
High demand	102.8	103.6	107.0	102.2	105.1	105.6	107.9	107.2	102.9	101.8
Mean values (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Low demand	99.3	98.1	96.4	99.1	96.3	94.4	95.8	97.9	99.2	99.1
-- fuel oil use, kWh per square foot --										
High demand	104.8	104.5	108.0	104.3	104.8	103.1	106.8	106.6	106.4	105.2
Mean values (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Low demand	94.1	94.5	89.1	94.6	94.3	95.8	87.7	87.7	90.6	94.7
-- total energy use, kWh per square foot --										
High demand	104.1	104.2	107.6	103.6	104.9	104.0	107.2	106.8	105.3	103.8
Mean values (reference)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Low demand	95.9	95.8	91.6	96.2	95.1	95.2	90.5	91.1	93.4	96.5

Note: See note to Table 11.

Table 14: Estimated Energy Intensities for Buildings Assuming Different Fuel Prices: Offices

Energy Source	NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC
	Province									
Buildings for which electricity is the only energy source										
	-- electricity use, kWh per square foot --									
High -- price up by 30%	96.2	95.1	89.2	96.0	96.9	96.4	97.2	96.6	96.8	97.2
Provincial reference values	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Low -- price down by 30%	105.1	106.7	114.7	105.5	104.3	104.9	103.8	104.7	104.4	103.8
Buildings for which electricity and natural gas are the only energy sources										
	-- electricity use, kWh per square foot --									
High -- price up by 30%					93.0	93.8	94.2	92.9	93.5	95.2
Provincial reference values					100.0	100.0	100.0	100.0	100.0	100.0
Low -- price down by 30%					109.5	108.4	107.9	109.6	108.8	106.6
	-- natural gas use, kWh per square foot --									
High -- price up by 30%					80.7	91.0	90.5	91.5	94.7	88.4
Provincial reference values					100.0	100.0	100.0	100.0	100.0	100.0
Low -- price down by 30%					126.2	112.3	112.9	111.6	107.2	115.8
	-- total energy use, kWh per square foot --									
High -- price up by 30%					86.1	92.1	91.9	92.0	94.3	91.3
Provincial reference values					100.0	100.0	100.0	100.0	100.0	100.0
Low -- price down by 30%					118.9	110.7	111.0	110.9	107.8	111.8
Buildings for which electricity and fuel oil are the only energy sources										
	-- electricity use, kWh per square foot --									
High -- price up by 30%	87.1	84.1	54.4	86.6	89.5	92.0	89.7	88.5	90.1	91.8
Provincial reference values	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Low -- price down by 30%	117.5	121.6	162.0	118.2	114.3	110.8	114.0	115.7	113.5	111.1
	-- fuel oil use, kWh per square foot --									
High -- price up by 30%	77.5	72.0	45.3	78.2	75.3	84.0	79.8	82.3	86.6	76.2
Provincial reference values	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Low -- price down by 30%	130.7	138.1	174.4	129.7	133.6	121.7	127.5	124.1	118.3	132.4
	-- total energy use, kWh per square foot --									
High -- price up by 30%	80.9	76.5	48.4	81.1	81.0	87.1	83.3	84.3	87.7	82.7
Provincial reference values	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Low -- price down by 30%	126.0	132.0	170.2	125.7	125.9	117.6	122.8	121.3	116.8	123.6

Note: See note to Table 11.

Table 15: Estimated Own Price Elasticities for Buildings with Reference Characteristics: Offices

Energy Source	NFLD	NS	PEI	NB	QUE	ONT	MAN	SASK	ALTA	BC
	Province									
	-- Energy use, kWh per square foot --									
Electricity only	-0.123	-0.161	-0.354	-0.133	-0.103	-0.119	-0.092	-0.112	-0.106	-0.090
Electricity and natural gas only										
Electricity					-0.202	-0.189	-0.173	-0.216	-0.203	-0.142
Natural gas					-0.716	-0.361	-0.366	-0.341	-0.227	-0.439
Electricity and fuel oil only										
Electricity	-0.266	-0.345	-1.096	-0.286	-0.204	-0.165	-0.198	-0.245	-0.219	-0.142
Fuel oil	-0.767	-0.958	-1.889	-0.744	-0.837	-0.544	-0.685	-0.604	-0.459	-0.803

Note: See note to Table 5; elasticities are calculated at the levels of fuel consumption given in Table 5, using 1994 prices.