Energy Efficiency in Canadian Commercial Buildings: Evidence from 2000 and 2005

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Executive Summary

There are many aspects of commercial buildings that could potentially affect the intensity with which energy is used. In this study we examine individual building-level data for Canada from the year 2000 in an attempt to determine what sorts of features have an impact on whether or not a given building will be among the most energy efficient buildings in Canada. First, we use a cross tabulation approach in order to provide a preliminary examination of the impacts of a selection of building characteristics such as size, age, installed heating technologies and technology retrofits on the relative efficiency of buildings. We also examine factors such as building location, building ownership, and the main activity undertaken within the building. This is followed by a more formal statistical approach that uses Probit analysis in order to gauge the magnitudes of the impacts of these and other factors on the likelihood that a building will be among the set of relatively efficient buildings for given categories of commercial activities. The results indicate that location, physical building characteristics, the choice of and changes in technology, the extent to which the building is used, and whether or not a building is privately owned all affect efficiency, with the magnitudes of these effects varying across the types of activities undertaken within the building. At times the impacts are somewhat counterintuitive, especially in terms of the effects of energy-related retrofits, possibly due to the presence of rebound effects. Finally, to assess whether or not there has been progress in terms of energy efficiency in commercial and institutional buildings in recent years, we compare the results from the 2000 survey with information obtained in a newer 2005 survey. Since individual data from the 2005 survey were not made available, we compare aggregate summary statistics for buildings from the year 2000 with aggregate summary statistics for establishments (which may occupy more than one building) from 2005. This comparison yields mixed evidence, with improvements in energy efficiency seen for some of the most energy-inefficient categories and declines in energy efficiency observed for some of those that are the most energy-efficient.

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1. Introduction

A recent report from the National Round Table on the Environment and the Economy (NRTEE) and Sustainable Development Technology Canada (SDTC) suggests that commercial buildings offer an important potential for energy efficiency improvements in Canada. The report indicates that the commercial building sector accounts for 14% of end-use energy consumption and for 13% of the country's carbon emissions. Many technologies are available that, if adopted, could lead to improvements in energy efficiency in the sector. However, the sector faces barriers in the adoption of these technologies. One barrier specified in the report is the lack of information, especially the "lack of complete data and information regarding energy and electricity use within commercial buildings in Canada" (NRTEE, 2009).

Understanding energy consumption within commercial buildings, its determinants and its evolution over time will provide an essential step toward reducing energy waste and promoting the efficient use of energy. For the commercial building sector, however, obtaining such an understanding is complicated by the fact that a diverse set of activities are undertaken within the walls of commercial buildings. These activities range from warehousing to retail activities to accommodation to transportation terminals, with much of the energy use within a building being more appropriately attributed to the activities undertaken within that building than to the characteristics of the building itself. That is, the types of activities conducted within a building must be taken into account when making comparisons of energy use patterns across buildings as the ways and intensities with which occupants use many installed technologies will be dependent on the purposes for which the building is being used.

The present study attempts to address existing information barriers by examining data from two recent nationwide Canadian surveys on energy use in commercial buildings or establishments: the Commercial and Institutional Building Energy Use Survey (CIBEUS) conducted in 2001; and the Commercial and Institutional Consumption of Energy Survey (CICES) conducted in 2006. In particular, we use detailed data on individual buildings in the CIBEUS data set in order to characterize the most efficient buildings among those surveyed. We then explore the impacts of various factors including physical building characteristics and the activities housed within the building on whether or not an individual building is found to be among the set of relatively efficient buildings. Finally, we compare average energy efficiencies for buildings in the CIBEUS data set with those from the more recent CICES survey, for which we do not have access to the individual establishment-level data, in order to examine whether or not there is evidence of energy efficiency improvements in the intervening years between the two surveys.

The study is structured as follows. In Section 2 we apply a cross tabulation approach to obtain a series of snapshots of the ways in which major factors are associated with whether or not a building is among the set of relatively efficient buildings within the CIBEUS data set in terms of its energy intensity. This is followed, in Section 3, by a discussion of a series of Probit regression models of the determinants of energy efficiency for the eight major commercial activity categories in the CIBEUS survey. Section 4 provides a comparison of average building and establishment energy intensities from the CIBEUS and CICES surveys. Section 5 concludes.

2. Energy Efficiency in Commercial and Institutional Buildings – Summary Statistics from CIBEUS

The CIBEUS survey, conducted in 2001 by Statistics Canada on behalf of Natural Resources Canada, contains information on building features, occupancy and ownership characteristics, energy efficiency characteristics and energy consumption pertaining to a sample of institutional and commercial buildings for the reference year of 2000[1]. The target population for the survey consisted of buildings of at least 92 meters squared (1000 square feet), of which 50% or more of available space was devoted to commercial or institutional activities. Buildings were sampled from major urban areas in the 10 Canadian provinces. In the Atlantic region, buildings were surveyed in urban areas with populations of at least 50,000. For the remainder of the country, only buildings in urban areas with populations of at least 175,000 were surveyed.

[1] http://www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/cibeus_description.cfm?attr=0

Questionnaires were distributed to representatives of 5124 buildings of which 4564 responded. After filtering out observations which did not meet the survey criteria, the CIBEUS survey provides information on 4101 buildings, 3059 of which house commercial activities. In some cases the respondent supplied incomplete data for a building, resulting in missing values for major variables of interest being imputed by Statistics Canada based on known values of other buildings with similar characteristics. For further detail regarding the sampling process used in this survey, see Appendix A of Natural Resources Canada (2003a).

The CIBEUS survey provides information regarding several aspects of the buildings surveyed. Basic building characteristics such as location, age and size are provided. Information is also provided on the major activities undertaken in each building. These are broken down into eight major types of commercial activity (accommodation, entertainment and recreation, offices, retail, services, shopping centres, transportation and maintenance facilities, warehouse/wholesale) and six major types of institutional activity (accommodation, administration, education, health care – inpatient, health care – outpatient, and public assembly). Some details regarding the amount of activity in the building are provided via measures of the number of workers present during the main shift and hours of operation. The survey also includes information on building ownership (private, non-profit, or government). The bulk of the survey is devoted to the technologies in place within each building (including whether or not there have been recent retrofits) and the amounts of energy used.

Among the variables provided in the CIBEUS data set is a measure of energy intensity, which is calculated as the total amount of energy used from all sources (measured in gigajoules per year) per square foot of building area. Table 1 contains summary statistics for energy intensity for the buildings in our sample. We see that for both the full sample and for the sub-sample of commercial buildings, there is substantial variation in energy intensities across buildings. Energy intensities range from a minimum of 0.01 to a maximum of 1.80, with the most energy-intensive building housing an institutional activity. Note that this particular building is anomalous, with the next highest energy intensity for an institutional building being 1.43. In most respects, the summary statistics are similar across the full sample and the subset of commercial buildings.

While the means, medians and 75th percentile values are slightly higher for the subset of commercial buildings, the 25th percentile values are virtually identical.

Table 1: Energy Intensity Summary Statistics (CIBEUS)

Characteristic	Commercial Buildings	Commercial and Institutional Buildings
Minimum	0.01	0.01
Maximum	1.41	1.80
Mean	0.1584	0.1519
25th percentile	0.0597	0.0597
Median	0.1004	0.0983
75th percentile	0.1694	0.1637
Sample Size	3059	4101

For the purposes of this study we define a building as being among the most efficient if its energy intensity lies at or below the 25th percentile. That is, we divide the sample of buildings within each category of use into two groups: those with relatively low energy intensity (high efficiency) and those with relatively high energy intensity (low efficiency). More formally, we create a binary variable, Deff, that is defined as follows: :

$Deff_i$ = 1 if building i's energy intensity lies at or below the 25th percentile
= 0 otherwise

Based on this classification, we are then able to use cross tabulations for an initial view of the characterization of the more efficient buildings (which have $Deff_i = 1$) in the sample. The factors that we take into consideration consist of a selection of physical characteristics (including technology choice and retrofits), building location, ownership type, and the types of activities undertaken within the building.

Cross tabulations

A series of 'snapshots' of the characteristics associated with relatively highly energy-efficient buildings can be obtained by examining cross tabulation tables. Note that, by construction, 75%

of buildings in our sample are classified as being relatively inefficient, and 25% as being relatively efficient. If a factor, such as the heating technology used in a building, is unrelated to a building's energy efficiency, it would be expected that for any given choice of technology approximately 25% of buildings in the subsample of buildings that use that particular technology will be in the relatively efficient set (with $Deff_i = 1$) and 75% will be in the relatively inefficient set (with $Deff_i = 0$).

On the other hand, substantial deviations from a 25% / 75% split for one or more technologies are indicative of a possible relationship between technology choice and overall energy efficiency within commercial buildings. For example, if the use of 'technology A' is associated with high energy efficiency, then when we examine the subset of buildings where 'technology A' is employed, we would expect to see that more than 25% of these buildings are among the group of relatively efficient buildings, that is, those defined according to the criterion that $Deff_i = 1$. In other words, these buildings are more likely to belong to the set of buildings with low energy intensities than those using other technologies.

Building Characteristics

Our first sets of cross tabulations pertain to physical building characteristics. Since it would be impractical to look at every building characteristic included in the CIBEUS data set, we examine four major characteristics (type of heating equipment, age, retrofit activities, and size) in order to obtain a preliminary view of whether or not these types of factors might be related to how well a building's energy use is managed. Tables 2a and 2b examine the choice of heating technology for the set of Commercial and Institutional buildings and the set of Commercial buildings, respectively, in the CIBEUS sample.

We observe that for buildings that rely primarily on a furnace or packaged heat unit for heating (Main Heating Equipment = 1 or 6), the split between buildings that are among the most and least efficient matches up very closely with the 25% / 75% split for the overall sample. The heating technologies that stand out as being associated with increased efficiency are heat pumps and individual space heaters. For observations in the subsamples of buildings that use these technologies, we see that substantially more than 25% of these correspond to observations where $Deff_i = 1$. On a similar note, we see that buildings that use boilers or district steam for heating are substantially less likely to be among the top 25% of buildings in terms of their energy efficiency.

Table 2a: Cross Tabulations for Main Heating Equipment and Energy Efficiency (Commercial and Institutional Buildings)

Main Heating Equipment (MHE)[a]		Energy Efficiency		Total
		Deff = 0	Deff= 1	
1	Number of Buildings	979	307	1286
	% within MHE=1	76.1%	23.9%	100.0%
2	Number of Buildings	115	64	179
	% within MHE=2	64.2%	35.8%	100.0%
3	Number of Buildings	384	287	671
	% within MHE=3	57.2%	42.8%	100.0%
4	Number of Buildings	67	6	73
	% within MHE=4	91.8%	8.2%	100.0%
5	Number of Buildings	737	136	873
	% within MHE=5	84.4%	15.6%	100.0%
6	Number of Buildings	709	194	903
	% within MHE=6	78.5%	21.5%	100.0%
7	Number of Buildings	80	26	106
	% within MHE=7	75.5%	24.5%	100.0%
Total Number of Buildings		3071	1020	4091[b]
Overall Percentages		75.1%	24.9%	100.0%

[a]MHE (1=furnaces, 2=heat pumps, 3=individual space heaters, 4=district steam or hot water, 5=boilers, 6=packaged heat units, 7=other);

[b] Missing values for MHE are omitted from the sample.

Table 2b: Cross Tabulations for Main Heating Equipment and Energy Efficiency (Commercial Buildings)

Main Heating Equipment (MHE)[a]		Energy Efficiency Deff = 0	Energy Efficiency Deff= 1	Total
1	Number of Buildings	805	307	1043
	% within MHE=1	77.2%	22.8%	100.0%
2	Number of Buildings	85	46	131
	% within MHE=2	64.9%	35.1%	100.0%
3	Number of Buildings	323	230	553
	% within MHE=3	58.4%	41.6%	100.0%
4	Number of Buildings	16	1	17
	% within MHE=4	94.1%	5.9%	100.0%
5	Number of Buildings	370	56	426
	% within MHE=5	86.9%	13.1%	100.0%
6	Number of Buildings	624	168	792
	% within MHE=6	78.5%	21.5%	100.0%
7	Number of Buildings	69	21	90
	% within MHE=7	75.5%	24.5%	100.0%
Total Number of Buildings		2292	760	3052[b]
Overall Percentages		75.1%	24.9%	100.0%

[a]MHE (1=furnaces, 2=heat pumps, 3=individual space heaters, 4=district steam or hot water, 5=boilers, 6=packaged heat units, 7=other);

[b] Missing values for MHE are omitted from the sample.

Other technology-related building characteristics that may affect how much energy is used include a building's age and whether or not the owners have made retrofits in order to update the technologies that are in place within a building. In the absence of retrofits, a building's age will be strongly correlated with the types and vintages of technologies that are operated within the building. As more recent vintages of technology tend to be more energy efficient, it might be expected that older buildings would be less energy efficient than newer ones. To the extent that retrofits are undertaken, these effects might be mitigated. Tables 3a and 3b examine building age, while Tables 4a and 4b examine whether or not a building's owner had made retrofits prior to the year 2000.

Table 3a: Cross Tabulations for Vintage and Energy Efficiency (Commercial and Institutional Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Vintage (VI)	1995 - 1999	Count	397	151	548
		% within VI	72.4%	27.6%	100.0%
	1975 - 1994	Count	1144	412	1556
		% within VI	73.5%	26.5%	100.0%
	1974 or earlier	Count	1533	463	1996
		% within VI	76.8%	23.2%	100.0%
Total		Count	3074	1026	4100[a]
		%	75.0%	25.0%	100.0%

[a] Missing values for Vintage omitted from sample.

Table 3b: Cross Tabulations for Vintage and Energy Efficiency (Commercial Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Vintage (VI)	1995 - 1999	Count	348	124	472
		% within VI	73.7%	26.3%	100.0%
	1975 - 1994	Count	914	340	1254
		% within VI	72.9%	27.1%	100.0%
	1974 or earlier	Count	1031	301	1332
		% within VI	77.4%	22.6%	100.0%
Total		Count	2293	765	3058[a]
		%	75.0%	25.0%	100.0%

[a] Missing values for Vintage omitted from sample.

In Tables 3a and 3b, buildings are categorized in terms of three vintages: recent (built between 1995 and 1999), mid-range (built between 1975 and 1994), and early (built before 1975). The evidence, though not strong, is at least consistent with the idea that energy is used more efficiently in newer buildings. We see that for recent and mid-range years of construction, the split between relatively efficient and inefficient buildings is approximately 25% / 75%, with slightly more than 25% of buildings being in the relatively efficient category. For the earlier vintage, slightly fewer than 25% of buildings fall within the relatively efficient group.

The results that look at the relationship between whether or not retrofits had been undertaken within the 1995-1999 period and energy efficiency (Tables 4a and 4b) are somewhat counterintuitive, with fewer than 25% of buildings with retrofits belonging to the set of relatively efficient buildings. One possible reason for this is that while less efficient buildings may be more likely to be retrofitted, these retrofits may not always achieve sufficient gains in order to move a building into the most efficient category.

Table 4a: Cross Tabulations for Prior Retrofit Activity and Energy Efficiency (Commercial and Institutional Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Retrofits / renovations made prior to 2000 (PRA)[a]	1	Count	920	232	1152
		% within PRA	79.9%	20.1%	100.0%
	2	Count	2155	794	2949
		% within PRA	73.1%	26.9%	100.0%
Total		Count	3075	1026	4101
		%	75.0%	25.0%	100.0%

[a](One or more retrofits made between 1995 and 1999=1, No retrofits made between 1995 and 1999 =2)

Table 4b: Cross Tabulations for Prior Retrofit Activity and Energy Efficiency (Commercial Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Retrofits / renovations made prior to 2000 (PRA)[a]	1	Count	622	159	781
		% within PRA	79.6%	20.4%	100.0%
	2	Count	1672	606	2278
		% within PRA	73.4%	26.6%	100.0%
Total		Count	3075	3075	1026
		%	75.0%	75.0%	25.0%

[a](One or more retrofits made between 1995 and 1999=1, No retrofits made between 1995 and 1999 =2)

Another possible reason for these results is that retrofits may, in some cases, be made in order to accommodate new tenants who may be involved in activities that are relatively energy intensive. It also may be the case that rebound effects are present, whereby an increase in the energy efficiency of technologies reduces the energy costs associated with their use, leading to an increased frequency or intensity of the use of heating, lighting, air-conditioning or other services provided by the technologies affected (Sorrell and Dimitropoulos, 2008).

The final physical building characteristic that we examine via cross tabulations is building size. The results corresponding to building size are presented in Tables 5a and 5b. We see that very large buildings (with areas that exceed 100,000 square feet), and possibly very small ones (1,000 to 5,000 square feet), tend to use energy more intensely than their medium-sized counterparts.

Table 5a: Cross Tabulations for Building Size and Energy Efficiency (Commercial and Institutional Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Building size in square feet (SIZE)	1,000-<5,000	Count	863	251	1114
		% within SIZE	77.5%	22.5%	100.0%
	5,000-<10,000	Count	561	236	797
		% within SIZE	70.4%	29.6%	100.0%
	10,000-<50,000	Count	1028	382	1410
		% within SIZE	72.9%	27.1%	100.0%
	50,000-<100,000	Count	260	78	338
		% within SIZE	76.9%	23.1%	100.0%
	100,000-<500,000	Count	279	69	348
		% within SIZE	80.2%	19.8%	100.0%
	500,000+	Count	84	10	94
		% within SIZE	89.4%	10.6%	100.0%
Total		Count	3075	1026	4101
		%	75.0%	25.0%	100.0

Table 5b Cross Tabulations for Building Size and Energy Efficiency (Commercial Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Building size in square feet (SIZE)	1,000-<5,000	Count	709	189	898
		% within SIZE	79.0%	21.0%	100.0%
	5,000-<10,000	Count	471	180	651
		% within SIZE	72.4%	27.6%	100.0%
	10,000-<50,000	Count	746	286	1032
		% within SIZE	72.3%	27.7%	100.0%
	50,000-<100,000	Count	166	60	226
		% within SIZE	73.5%	26.5%	100.0%
	100,000-<500,000	Count	160	43	203
		% within SIZE	78.8%	21.2%	100.0%
	500,000+	Count	42	7	49
		% within SIZE	85.7%	14.3%	100.0%
Total		Count	3075	2294	765
		%	75.0%	75.0%	25.0%

Other Factors

The factors that affect energy consumption in a building are not restricted to physical characteristics. Some factors, such as climate, are beyond the control of the building owner. In some regions of Canada, such as the prairies, where the winters tend to be colder, the demand for energy for space heating will be higher. Other areas of the country have a greater demand than average for energy in order to provide space cooling in the summer months. These factors, along with differences in fuel prices and availability, underlie at least part of the patterns that are observed across regions.

Location

From Tables 6a and 6b, we see that the Atlantic region and Quebec stand out as having relatively less energy intense buildings, as they have substantially more than 25% of their buildings among the 25% most efficient ones in the overall dataset (38.1% and 33.4%, respectively for the full data set, and 42.3% and 34.8% respectively for the subset of Commercial buildings). Likewise, buildings in the Prairie region use energy relatively more intensely with substantially fewer than 25% of its buildings belonging to the set of relatively efficient buildings For Ontario and BC, the split between relatively efficient and inefficient buildings matches up closely to the 25% / 75% ratio.

Table 6a Cross Tabulations for Region and Energy Efficiency (Commercial and Institutional Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Region (REG)	Atlantic	Count	314	193	507
		% within REG	61.9%	38.1%	100.0%
	Quebec	Count	621	312	933
		% within REG	66.6%	33.4%	100.0%
	Ontario	Count	976	249	1225
		% within REG	79.7%	20.3%	100.0%
	Prairies	Count	837	151	988
		% within REG	84.7%	15.3%	100.0%
	B.C.	Count	327	121	448
		% within REG	73.0%	27.0%	100.0%
Total		Count	3075	1026	4101
		%	75.0%	25.0%	100.0%

Table 6b Cross Tabulations for Region and Energy Efficiency (Commercial Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Region (REG)	Atlantic	Count	199	146	345
		% within REG	57.7%	42.3%	100.0%
	Quebec	Count	460	245	705
		% within REG	65.2%	34.8%	100.0%
	Ontario	Count	728	172	900
		% within REG	80.9%	19.1%	100.0%
	Prairies	Count	662	109	771
		% within REG	85.9%	14.1%	100.0%
	B.C.	Count	245	93	338
		% within REG	72.5%	27.5%	100.0%
Total		Count	2294	765	3059
		%	75.0%	25.0%	100.0%

Ownership

The extent to which energy is used efficiently within a building will depend on how it is operated. Among other things, the extent to which building owners react to energy prices may depend on whether or not the owner reacts to market signals such as energy prices, and the costs of installing more energy-efficient technologies. Furthermore, required payback periods for investments in renovations or retrofits may vary across private business interests and government or non-profit organizations. The cross tabulations provided in Table 7a indicate that for the set of commercial and institutional buildings, there are no obvious differences in terms of observed energy efficiency across ownership types. However, for the subset of commercial buildings, presented in Table 7b, ownership by a government or non-profit organization tends to be associated with lower energy efficiency.

Table 7a: Cross Tabulations for Ownership Type and Energy Efficiency (Commercial and Institutional Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Type of ownership (OWN)	Private	Count	2275	780	3055
		% within OWN	74.5%	25.5%	100.0%
	Non-profit	Count	303	103	406
		% within OWN	74.6%	25.4%	100.0%
	Government	Count	497	143	640
		% within OWN	77.7%	22.3%	100.0%
Total		Count	3075	1026	4101
		%	75.0%	25.0%	100.0%

Table 7b: Cross Tabulations for Ownership Type and Energy Efficiency (Commercial Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Type of ownership (OWN)	Private	Count	2115	732	2847
		% within OWN	74.3%	25.7%	100.0%
	Non-profit	Count	84	19	103
		% within OWN	81.6%	18.4%	100.0%
	Government	Count	497	143	109
		% within OWN	87.2%	12.8%	100.0%
Total		Count	2294	765	3059
		%	75.0%	25.0%	100.0%

Activity

For our examination of the association between the intensity of energy use and building activity, we first divide the full set of buildings between those whose main activity involves an institutional operation and those whose main activity is commercial in nature. From Table 8 we see that, at this level of aggregation for activities, there is no evidence that a building that houses commercial activities tends to be any more or less energy efficient than a building that houses an institutional activity.

Table 8: Cross Tabulations for Main Activity Type and Energy Efficiency (Commercial and Institutional Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Main Activity (MA)	Institutional	Count	761	260	1021
		% within MA	74.5%	25.5%	100.0%
	Commercial	Count	2294	765	3059
		% within MA	75.0%	25.0%	100.0%
Total		Count	3055	1025	4080[a]
		%	74.9%	25.1%	100.0%

[a] Missing values omitted from sample.

We look next at a more disaggregated set of activities within the commercial building sector. These cross tabulation results are presented in Table 9. Here, there is evidence of substantial differences in the intensity of energy use across activities. It is not surprising that commercial buildings that provide accommodation, such as hotels, are less likely to be among the most efficient, as these buildings generally operate on a 24-hour period and must provide thermal comfort as well as a variety of amenities to their customers. Buildings in the entertainment category, which includes movie theatres and fitness centres, for example, are also relatively more intense in their use of energy. Again, many of these buildings tend to operate for long hours and have customers on site who expect adequate space heating or cooling while they are present. In other types of facilities, such as warehouses and transportation facilities, where customers are not present for long periods of time, space heating and cooling may not be as important. These types of facilities tend to use energy less intensely. While retail operations in general exhibit a 25% / 75% split between relatively efficient and relatively inefficient energy use, shopping centres exhibit a higher likelihood of being included among the group of relatively energy efficient buildings. This may possibly be due to the low window-to-wall ratio in these buildings, which is beneficial in terms of space heating and cooling.

Table 9: Cross Tabulations for Main Commercial Activity and Energy Efficiency (Commercial Buildings)

			Energy Efficiency (EE)		Total
			Deff = 0	Deff= 1	
Main Commercial Activity (MCA)	Accommodation	Count	78	19	97
		% within MCA	80.4%	19.6%	100.0%
	Entertainment	Count	148	32	180
		% within MCA	82.2%	17.8%	100.0%
	Offices	Count	404	100	504
		% within MCA	80.2%	19.8%	100.0%
	Retail	Count	431	158	589
		% MCA	73.2%	26.8%	100.0%
	Services	Count	598	126	724
		% within MCA	82.6%	17.4%	100.0%
	Shopping Centre - Enclosed	Count	58	25	83
		% within MCA	69.9%	30.1%	100.0%
	Shopping Centre - Other	Count	232	107	339
		% within MCA	68.4%	31.6%	100.0%
	Transportation facility	Count	88	36	124
		% within MCA	71.0%	29.0%	100.0%
	Warehouse	Count	257	162	419
		% within MCA	61.3%	38.7%	100.0%
Total		Count	2294	765	3059
		%	75.0%	25.0%	100.0%

Overview

The series of cross tabulations that have been presented in this section indicate the possibility of causal relationships between energy efficiency and a variety of factors ranging from physical building characteristics to geographical location to the activities housed within a building. In these tables individual factors are examined one at a time. However, it may be the case, for example, that buildings using a particular heating technology only appear to be more efficient because these same buildings also happen to house activities that require relatively less energy than other activities. In order to control for these types of possibilities, in the following section we estimate a set of Probit regression models for the set of commercial buildings.

3. Probit (Regression) Models of Commercial Building Energy Efficiency

Our working definition of an energy efficient building is that it has an energy intensity (energy use per square foot of building area) that places it at or below the 25th percentile. That is, at least 75% of buildings in the (relevant portion of the) CIBEUS data set use more energy per square foot than any building that is classified as being relatively efficient. In this section, we consider regression models that examine the impacts of a variety of factors on the probability that a building belongs to the set of efficient buildings ($Deff_i$=1).

In order to determine whether there are particular factors such as building characteristics or location that significantly influence the energy efficiency of a commercial building, we consider a binary choice model of the form:

$$\text{Prob}\ (Deff_i = 1 \mid x_i) = F(x_i'\beta)$$

where: $Deff_i$ = 1 if a building's energy intensity is at or below the 25th percentile
= 0 otherwise;

x_i is a vector of characteristics which may affect energy efficiency;

Prob(.) denotes probability, so that Prob ($Deff_i$ = 1 | x_i) refers to the probability that a building is among the most efficient ($Deff_i$=1), given its characteristics;

F(.) is a cumulative probability density function (cdf), such as that associated with a normal or some other distribution, so that F(*a*) refers to the probability that a random variable having the specified distribution is less than the value "*a*", that is, the probability that it takes a value less than "*a*"; and

$x_i'\beta$ is the usual regression specification, $\beta_1 + \beta_2 x_{i2} + \cdots + \beta_k x_{ik}$.

In this study, we consider a Probit model (Greene, 2003), in which case $F(x_i'\beta)$ is the normal cdf, denoted $\Phi(x_i'\beta)$.

Two approaches are taken in our Probit modeling. First, we use the full set of commercial buildings and add a set of dummy variables to control for the main activity housed within the building. Second, to allow for more flexibility in terms of differences in the impacts of our various factors on energy efficiency, we run separate Probit regressions for each of the eight commercial activity categories. For this second set of regressions, we define our relatively efficient set of buildings within a given activity category as:

$Deff_{ji}$ = 1 if a building's energy intensity is at or below the 25th percentile for buildings whose main activity is in category j;
= 0 otherwise.

With this definition, we examine the determinants of whether or not a building is among the most energy efficient among the subset of buildings housing similar activities.

In all of our specifications, the probability of being efficient is modelled as a function of basic physical building characteristics (age, area, number of floors, number of shared walls, and the window-to-wall ratio), the main type of heating technology employed, whether or not the building has had any energy-related retrofits in recent years,[2] the percentages of the building that are heated and cooled, whether or not the building has heated parking, the climate (measured by heating degree days and cooling degree days), the building's location, and the ownership type (private, government, or non-profit). Given the relatively small sample sizes for some of our activity categories, only a limited number of factors are examined. A detailed set of variable definitions for the factors included in the regression models is provided in the Appendix.

The coefficients for the aggregate model that includes activity dummies are presented in the column labelled "All" in Table 10. The coefficients corresponding to the individual main activity categories are presented in the remaining columns. Note that the coefficients are of interest only to the extent that, along with their standard errors, they indicate which factors have a statistically significant impact on the probability of a building being among the relatively most efficient ones. The extent of the impact of a variable can be found by calculating the corresponding marginal effect. For continuous variables (such as age or size), the marginal effect is calculated as the change in the probability that the building is among the most efficient

[2] We include retrofits undertaken in 2000 separately from those undertaken between 1995 and 1999. This is done since some of the retrofits from 2000 would have been undertaken late in the year and may not have yet had an appreciable impact on a building's energy intensity.

as a result of a change in the value of that variable.[3] For binary variables (such as the regional dummies), marginal effects are calculated as the change in this same probability when the binary variable in question changes from 0 to 1. The marginal effects corresponding to variables with statistically significant coefficients are presented in Table 11.

Diagnostic statistics used to evaluate the suitability of the various models are presented at the bottom of Table 10 and in Table 12. From Table 12, all of the Probit models exhibit overall significance at a 5% level. The corresponding p-values that are less than 0.05 indicate that at least one of the variables in each of these regressions has an impact on the probability that a building is relatively efficient. Another way of gauging the usefulness of a Probit model is to see whether or not it predicts better than a "naïve model" (where the most common outcome is predicted for all observations). In this particular application, the naïve model would predict the most common outcome (a building is energy inefficient) for all observations, and by construction would yield a correct prediction 75% of the time. For a model to offer an improvement over the naïve model, it would have to predict correctly more than 75% of the time. From the bottom of Table 10, we see that in all cases the Probit models perform better than a naïve model, albeit only slightly for some categories. The final general diagnostic provided in Table 10 is the Estrella R^2, which provides a measure that is akin to the standard R^2 measure for standard regression models (Greene, 2003). The Estrella R^2 values range from 0.121 to 0.758, indicating that the Probit model performs much better when examining buildings housing some types of activities than others.

Before proceeding to a discussion of the marginal effects implied by our Probit models, it is of interest to examine some general results pertaining to tests of the joint significance of several groupings of the variables in our models presented in Table 12. In our first model where all of the observations are included and a set of main activity dummies is added to our specification, we see that at a 5% level of significance (indicated by a p-value less than 0.05) the main activity undertaken has a significant impact on energy use. So do the region where the building is located, the type of heating equipment used, and whether or not there have been recent retrofits.

[3] Formally, this is the derivative of Prob ($Deff_i = 1 \mid x_i$) with respect to the value of a particular variable. Marginal effects depend on building characteristics, and therefore differ for each building. Those reported here have been evaluated at the sample averages for the variables.

Table 10 Probit Results – Coefficients

Variable	All[a]	Accommodation	Entertainment	Offices	Retail	Services	Shopping Centres	Transportation	Warehouse
Atlantic	0.558*	5.958	-0.339	-1.134	0.114	1.421**	1.917**	-5.666	0.594
Quebec	0.503	0.944	-0.969	-1.763	-0.001	1.613*	2.040**	-7.324	0.122
Ontario	0.032	-3.500	-0.307	-2.579**	-0.451	0.932	1.224	-7.327	-0.585
Prairies	-0.080	3.150	-1.052	-2.666*	-0.768	1.486	2.253*	-9.060	-1.179
Private	0.401**	-9.246	1.098**	5.752	5.309	1.024*	5.407	0.618	0.685
Non-Profit	0.208	-9.878	0.810	5.600	5.258	0.476	4.742	-3.010	0.362
Age	0.000	0.010	0.009	0.001	-0.005**	0.001	-0.005	-0.050***	0.002
Area	0.000	0.000	-0.000**	-0.000	-0.000	0.000	0.000	-0.000	-0.000
Floors	-0.011	-2.882*	-0.648***	-0.028	0.132*	0.012	-0.078	0.184	0.155
Shared Walls	0.030	---[b]	0.722**	0.168	0.234**	-0.061	-0.275*	-0.354	-0.386
Occupants	-0.001***	-0.235	-0.001	0.000	-0.001	-0.000	-0.001**	-0.024	0.001
Hours	-0.005***	0.013	0.007	0.002	-0.009***	-0.009***	-0.005*	0.002	-0.000
Win-to-Wall	-0.004**	0.045	0.019**	-0.005	-0.006	-0.001	-0.002	0.011	-0.018**
Heat Parking	-0.179	-0.512	-1.936	-0.319	-5.565	0.513	0.225	0.607	-4.547
% Heated	-0.001	-0.032	0.015*	-0.005	-0.003	-0.006*	-0.008	-0.014	-0.002
% Cooled	-0.002***	-0.005	-0.003	0.001	-0.004**	-0.002	0.000	-0.009	-0.005*
Heat2	0.300**	-4.172	1.177*	0.628**	0.781**	-0.190	-0.312	-13.27	1.168*
Heat3	0.345***	-4.352	1.599***	0.703***	0.250	0.101	-0.012	1.011**	0.223
Heat4	-0.923*	-1.116	-6.545	-5.219	-6.064	-5.216	-6.469	--[b]	-5.444
Heat5	-0.256***	-5.233*	-0.525	-0.225	-0.197	-0.387*	-0.575*	1.243*	-0.877
Heat6	0.009	-6.552	-0.814*	0.115	0.162	-0.053	-0.372*	0.429	0.011
Heat7	0.098	-1.650	-5.586	-0.361	0.224	-0.015	-0.535	-4.917	0.808
HDD	-0.000	-0.002	0.000	0.001	0.000	-0.001*	-0.001	0.000	-0.000
CDD	-0.000	0.009	0.003	0.006**	0.001	-0.002	-0.001	-0.001	0.002
Retc1	0.257	-10.27	1.336*	-5.568	0.037	-0.111	1.051	-1.496	-0.833
Retc2	-0.558***	-21.90	0.240	-0.206	-0.239	-0.094	-0.595	-3.111	-0.351
Retc3	-0.026	21.79	-1.538	0.330	0.027	0.073	0.193	-2.549	1.284*
Retc4	0.089	114.5	2.036**	1.393*	0.426	0.233	-0.855	---[b]	-5.638
Retc5	0.516*	12.05	2.338	10.29	0.390	0.484	0.874	---[b]	-5.723
Retp1	-0.122	-6.818	1.776***	-0.176	0.269	-0.455	-0.501	0.380	0.108
Retp2	-0.302**	5.491*	-0.055	-0.361	-1.052***	-0.517*	0.215	-0.298	-0.548
Retp3	0.161	-0.112	-8.204	0.012	0.803*	0.200	0.045	-6.351	0.237
Retp4	0.079	-0.809	1.662**	0.422	0.080	0.186	0.389	0.965	-1.740
Retp5	-0.166	4.251	0.009	0.114	-0.179	-0.913	-0.380	3.371	1.150
Constant	0.216	25.14	-5.214	-7.638	-5.719	1.861	-2.270	8.715	-0.403
Type							-0.291		
N	3051	97	179	503	587	724	422	124	415
Estrella R^2	0.139	0.758	0.484	0.223	0.179	0.159	0.121	0.439	0.283
% correct predictions	77.55	93.81	84.36	78.73	79.22	75.28	76.30	80.65	81.45
Log-Likelihood	-1498.6	-14.55	-56.09	-225.11	-276.10	-349.02	-210.98	-39.628	-165.07

[a] A (jointly significant) group of Dummy variables for Main Activity were included in this regression but are not reported in the table.
[b] Variable dropped from regression due to exact multicollinearity problems.

Table 11 Probit Results – Marginal Effects

Variable	All[a]	Accommodation	Entertainment	Offices	Retail	Services	Shopping Centres	Transportation	Warehouse
Atlantic	0.19657					0.30695	0.36418		
Quebec						0.37992	0.41168		
Ontario				-0.78451					
Prairies				-0.79385			0.49588		
Private	0.10120		0.20573			0.03133			
Non-Profit									
Age					-0.00120			-0.00068	
Area			-0.00000						
Floors		-0.00000	-0.01714		0.03246				
Shared Walls			0.01909		0.05742		-0.07805		
Occupants	-0.00018						-0.00020		
Hours	-0.00153				-0.00219	-0.00266	-0.00130		
Win-to-Wall	-0.00106		0.00050						-0.00339
% Heated			0.00039			-0.00161			
% Cooled	-0.00062				-0.00110				-0.00087
Heat2	0.09951		0.44148	0.10650	0.29886				0.44012
Heat3	0.11557		0.57366	0.11398				0.00000	
Heat4	-0.17833								
Heat5	-0.06901	-0.00000				-0.02022	-0.01034	0.00000	
Heat6			-0.17676				-0.00822		
HDD						-0.00019			
CDD				0.00136					
Retc1			0.49550						
Retc2	-0.13038								
Retc3									0.47910
Retc4			0.66731	0.14972					
Retc5	0.18024								
Retp1			0.61723						
Retp2	-0.07977	0.01907			-0.22954	-0.02407			
Retp3					0.30730				
Retp4			0.59005						
Retp5									

Table 12 Probit Results – Tests of Joint Significance (p-values)

Variable	All	Accommodation	Entertainment	Offices	Retail	Services	Shopping Centres	Transportation	Warehouse
Overall	0.000	0.000	0.000	0.000	0.000	0.000	0.035	0.004	0.000
Main Activity	0.000								
Region	0.000	0.318	0.901	0.000	0.004	0.000	0.007	0.334	0.000
Ownership	0.058	0.941	0.051	0.916	0.994	0.080	0.600	0.664	0.711
Heating Equipment	0.000	0.55	0.002	0.006	0.162	0.536	0.430	0.308	0.109
Current Retrofits	0.019	0.908	0.183	0.618	0.887	0.935	0.530	1.000	0.697
Past Retrofits	0.077	0.639	0.052	0.710	0.122	0.056	0.786	0.963	0.451

At a 10% level of significance, having made retrofits made between 1995 and 1999, as well as the type of owner for the building, affect whether the building is among the most energy efficient. An examination of the other columns in Table 12 indicates that none of the sets of factors considered are universally important for all of the main activity categories. For the two categories with the fewest available observations (accommodation and transportation), although the regressions are significant overall, the variables included in these groupings do not appear to affect efficiency. The regional variables matter for most of the remaining main activity categories (except for entertainment). Ownership type seems to matter only (at a 10% level of significance) in buildings whose main activity housed is in the entertainment or service category. The type of heating equipment used is only jointly significant in the entertainment and office category. Although current retrofits were jointly significant in the aggregate case, they are not found to be significant in any of the disaggregated regressions. Past retrofits, however, appear to have impacts (at a 10% level) in the entertainment and services categories.

The magnitudes of the impacts of individual variables are presented in Table 11. From the aggregate regression, we see that compared to buildings in the comparison region of B.C., buildings in the Atlantic region have about a 0.2 higher probability of being in the relatively efficient group. The disaggregated regressions indicate that this result is largely driven by a much higher probability of buildings housing services and shopping centres being efficient in the Atlantic region. In fact, shopping centres in Quebec and the Prairies, and buildings housing services in Quebec, are also more energy efficient than those in B.C. On the other hand, office buildings in Ontario and the Prairies have a substantially lower probability of being efficient in comparison with those on the west coast. Ownership type also matters, with buildings owned privately being more likely to be efficient (an increase of 0.1 in the corresponding probability) than those that are owned by one of the levels (municipal, provincial or federal) of government. This result appears to be driven by a fairly substantial effect (0.21) for buildings housing entertainment facilities, with a less substantial effect (0.03) for buildings whose main activity is in services.

When examining the marginal effects corresponding to cases where the intensity of use variables (number of workers on the main shift and hours of operation) have significant coefficients in the

Probit regressions, it is important to take into account the fact that the reported impacts are for one additional worker or hour of operation. We see that these marginal effects are of the expected sign, with more intense use of a building leading to a lower probability that a building will be classified as belonging to the relatively efficient group. The impacts themselves tend to be quite small. An additional 100 employees working in a shopping centre will decrease the probability of that building being in the relatively efficient group by only 0.02. Similarly, an increase of 10 operating hours per week for a building in the service grouping will lead to a decrease of about 0.03 in the probability that it will be relatively efficient.

Several building characteristics have statistically significant but small impacts on the probability that a building is among the most efficient. The impact of building size measured in terms of area is negligible. The number of floors seems to lead to a slightly lower probability of a building being efficient for entertainment complexes (a decrease in the probability by -0.02 for one additional floor), but a slightly higher probability of being efficient in buildings housing retail operations (an increase in the probability by 0.03 for one additional floor). For entertainment, and more so for the retail category, shared walls increase the probability of being efficient. Unexpectedly, shared walls decrease the probability of being efficient for shopping centres. The window-to-wall ratio, when significant, has a very small practical impact on the probability of being efficient.

The choice of heating technology has an important impact in many cases. The base case to which comparisons are made in our regressions is that of a furnace. The use of a heat pump substantially increases the chance that a building is one of the most efficient in its class both in the aggregate regression and in the entertainment, offices, retail, and warehouse groupings. Individual space heaters substantially increase the likelihood of efficiency both on aggregate and for the entertainment and offices groupings. On the other hand, buildings that rely on district steam heat or hot water or boilers tend to be less likely to be among the least intensive users of energy, although the marginal effects are smaller than for heat pumps and individual space heaters.

The evidence on retrofits is mixed. The most successful retrofits in terms of energy efficiency appear to be in buildings whose main activity is in the entertainment category. In that category, buildings whose owners undertook lighting and roof insulation retrofits, either in the reference year of 2000 or in the previous 5 years, substantially increased their likelihoods of being among the most efficient buildings, with marginal effects ranging from 0.50 and 0.67. Roof insulation retrofits undertaken in 2000 also led to efficiency gains among office buildings. Ventilation retrofits led to a higher probability of being among the most efficient buildings for the retail and warehouse groupings. The only type of retrofit with mixed results is heating retrofits. These seemed to have a small positive impact for buildings providing accommodation, but negative impacts in the service and retail groupings (possibly due to classic rebound effects).

Building age is only related to the probability of being among the most efficient for two main activity groupings: retail and warehouse. The impacts of a one year increase in age in these groupings are quite small. For an increase in age of 25 years, for example, we see decreases in the probability that a building is among the group of relatively efficient ones of approximately 0.03 and 0.02, respectively.

The Probit regression results reported in this section suggest that there are several factors that influence a building's likelihood of having a low intensity of energy use in comparison to others in the CIBEUS sample. The sizes of the marginal effects discussed above, although they may be roughly indicative of how various factors influence the relative energy intensity of buildings, should be taken as being only approximately valid as the sample sizes involved in some of the commercial activity groupings did not allow for a thorough examination of all of the possible technology choices and other factors available in the CIBEUS data set. And, of course, the factors included in the regression do not include potentially important determinants that are not available in the data set, such as the actual and expected energy prices faced by building owners when they make their decisions regarding technologies and retrofits.

4. Changes in Energy Efficiency over Time

The CIBEUS data that were analyzed above are from a survey that has been conducted only once, in 2001. An assessment of what has been happening over time in terms of the evolution of energy efficiency in commercial buildings would ideally be based on a follow-up survey that includes the same buildings. This, however, would be a costly endeavour, and has not been undertaken. Limited information which can be used as a basis of comparison is available from another survey: the Commercial and Institutional Consumption of Energy Survey (CICES) 2005, conducted between January and April of 2006.

The CICES survey differs from CIBEUS in terms of both its scope and in the questions asked of survey recipients. The CICES survey targets commercial and institutional establishments (i.e., not buildings) across Canada which have at least one employee and are not located within a private dwelling. The survey itself is much shorter than the CIBEUS survey, asking respondents to provide information on total floor area for the establishment (which may include more than one building), year of construction (for the largest portion or majority of the buildings), the number of occupants, quantities of activity-related equipment (such as computers and microwaves), energy sources, energy consumption, and energy costs. As with the CIBEUS survey, in cases of partial responses to the questionnaire, imputation methods were used by Statistics Canada in order to eliminate missing values for key questions (Natural Resources Canada, 2007). In addition to the differences in the scope of the survey, an additional major limitation exists in terms of our ability to make comparisons across the 2000 CIBEUS data and the 2005 CICES data: CBEEDAC was not given access to the original establishment level responses in CICES, and were therefore limited to aggregate information published in Natural Resources Canada (2007).

Given that only aggregate statistics were made available from the CICES survey, in the tables below we present comparisons between the results from the CICES summary document (Natural Resources Canada, 2007) and the CIBEUS summary document (Natural Resources Canada, 2003b). Some variable definitions in these tables differ slightly from those used above. Notably, area is measured in terms of metres squared, energy efficiency is measured in terms of gigajoules per metre squared, and the set of activities is broken down into a different set of categories (and it is not always clear whether or not the CICES categories refer to commercial establishments only or a combination of commercial and institutional establishments).

Activity

Table 13 provides a comparison of energy intensities for a variety of activities. The most striking result is that energy intensity has increased for many of these activities between 2000 and 2005, leading to a decrease in energy efficiency for these buildings / establishments. Only the office and food services and drinking places categories exhibit substantial reductions in energy intensity, while a slight drop is observed for retail food. One promising aspect of these numbers is the fact that these improvements in efficiency have been observed in the most in energy-intensive activity categories.

Table 13: Comparison of Energy Intensities by Activity

Activity	2000 Energy Intensity (CIBEUS)	2005 Energy Intensity (CICES)
Wholesale and warehousing	1.32	1.55
Non-food retail	1.35	1.55
Food retail	2.79	2.78
Offices (excluding public administration)	2.08	1.42
Accommodation services	1.58	1.88
Food services and drinking places	3.34	3.06

It is interesting to consider these figures in the context of the rates of energy efficiency retrofits that were undertaken. According to the CIBEUS summary report (Natural Resources Canada, 2003b), the accommodation sector, whose energy intensity has increased, had the highest rate of renovation (20%) of all commercial buildings, while food services (10%) had one of the lowest. While accommodation retrofits had a positive impact in our Probit regressions reported above, these positive effects do not seem to have carried through in the intervening years. This may possibly be due to other changes in these establishments, such as increased use of computers by guests or increased provision of energy intensive entertainment options in guest rooms. These, however, are merely conjectures given a lack of data on these features.

The increased energy efficiency in offices and in food services and drinking places is generally consistent with the evidence with respect to the benefits of retrofits from our Probit analysis. Recall that roof insulation retrofits yielded benefits in the office category, while both heating and roof insulation retrofits proved to be beneficial in the entertainment sector which includes drinking establishments such as night clubs.

Location

A comparison of overall energy intensities for commercial and institutional buildings across regions from the two surveys is presented in Table 14. Energy efficiency in the Atlantic region and Ontario appears to have remained stable, while there was an improvement in energy efficiency in British Columbia and Quebec. The Prairie region, which includes Alberta with its energy-intensive resource sector, witnessed an increase in energy intensity between 2000 and 2005. The Atlantic region and Quebec remain the least energy-intense regions.

Table 14: Comparison of Energy Intensities by Region

Region	2000 energy intensity (CIBEUS)	2005 energy intensity (CICES)
Atlantic	1.13	1.14
Quebec	1.40	1.26
Ontario	1.72	1.71
Prairies	1.62	1.74
British Columbia	1.68	1.56

Vintage

In Table 15, we see that while buildings within some vintages have improved in terms of energy efficiency, the opposite has occurred for other vintages. In most of the older vintage buildings (built before 1980), energy efficiency has improved. This may be due to the fact that these buildings are most likely to have been retrofitted. Furthermore, possibly due to retrofits (and possibly due to other factors such as shifts in activities), some of the older vintage buildings appear to have become relatively energy efficient compared to newer buildings. For example, with the exception of buildings constructed in the 1960s, older vintage buildings use energy less intensely than those constructed in the 1980s. A notable trend that may be somewhat disconcerting is that the energy intensity figures for newer buildings (constructed after 1980) have increased between 2000 and 2005.

Table 15: Comparison of Energy Intensities by Year of Construction

Year of construction	2000 energy intensity (CIBEUS)	2005 energy intensity (CICES)
Prior 1920	1.43	1.39
1920-1959	1.68	1.58
1960-1969	1.64	1.80
1970-1979	1.83	1.52
1980-1989	1.36	1.67
1990-1999	1.33	1.41

Size

The information regarding physical building characteristics in CICES is limited to a measure of the total floor area (excluding indoor parking and mechanical areas) for each establishment. Table 16 presents average energy intensities for buildings / establishments according to their size. General trends have not changed between 2000 and 2005; with mid-sized buildings tending to be more energy efficient in comparison to smaller and larger ones. As was seen with building vintages, the least efficient categories have experienced improvements in their energy efficiency, while the opposite has occurred with the relatively most efficient buildings / establishments.

Table 16: Comparison of Energy Intensities by Building Size

Building size in m²	2000 energy intensity (CIBEUS)	2005 energy intensity (CICES)
Less than 465	2.06	1.68
465 to 929	1.80	1.59
930 to 4645	1.35	1.35
4646 to 9290	1.18	1.40
9291 or more	1.77	1.65

Overview

Given that the CICES survey looks at establishments while the CIBEUS survey examines individual buildings, comparisons across the two surveys are somewhat problematic. Nevertheless, the data reveal that it is likely that there have been gains in some areas and losses in others in terms of energy efficiency in the commercial (and institutional) building sector. The fact that energy intensity appears to have increased in many instances points to the need for a close examination of the reasons behind this apparent negative turn of events, especially in newer buildings / establishments.

5. Conclusions

A wide range of activities are undertaken within the walls of commercial buildings. It is therefore not surprising that the intensity with which energy is used varies widely within this sector. While many of the differences observed are due to the fact that some activities require more energy than others, this does not account for all of the variation. Our examination of the factors that affect energy efficiency starts with a classification of buildings within the CIBEUS data set as being either relatively efficient or relatively inefficient based on whether or not the energy intensity of a building lies at or below the 25th percentile. A series of cross tabulations for the sets of commercial and institutional buildings and separately for solely commercial buildings reveal that several factors appear to be associated with this measure of relative efficiency.

Our analysis then proceeds to the estimation of the magnitudes of the impacts of building characteristics on our measure of energy efficiency for the eight major commercial activity classifications used in the CIBEUS survey. The result that may be of most interest to policy makers is that energy-related retrofits, while often having the desired effect of improving energy efficiency, are not universally beneficial in terms of their impacts on the intensity of energy use within commercial buildings.

Finally, we compare aggregate summary statistics for commercial and institutional buildings from the CIBEUS survey that provides a snapshot of energy use in the year 2000 with aggregate summary statistics for establishments (which may occupy more than one building) covered in the 2005 CICES survey. This comparison yields a mix of evidence regarding whether or not progress has been made in terms of energy efficiency in commercial and institutional buildings in recent years. Improvements in efficiency are seen for some of the most energy-inefficient categories, but the declines in energy efficiency observed for some of the most energy-efficient categories may be of concern to policy makers.

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Appendix

Control Variables used in Probit Regressions

Atlantic	= 1 if building is in the Atlantic Region; 0 otherwise
Quebec	= 1 if building is in Quebec; 0 otherwise
Ontario	= 1 if building is in Ontario; 0 otherwise
Prairies	= 1 if building is in the Prairie Region; 0 otherwise
Private	= 1 if building privately owned; 0 otherwise
Non-Profit	= 1 if building owned by a non-profit organization; 0 otherwise
Age	= 2000 – year of construction
Area	= building area (in square feet)
Floors	= number of floors
Shared Walls	= number of shared walls
Occupants	= number of workers on main shift
Hours	= number of hours building is open in a typical week
Win-to-Wall	= window-to-wall ration
Heat Parking	= 1 if building has (partially) heated parking, 0 otherwise
% Heated	= % of building area heated to at least 10 degrees Celsius
% Cooled	= % of building area cooled by a cooling system
Heat2	= 1 if main heating equipment heat pump; 0 otherwise
Heat3	= 1 if main heating equipment individual space heaters; 0 otherwise
Heat4	= 1 if main heating equipment district steam or hot water; 0 otherwise
Heat5	= 1 if main heating equipment boiler; 0 otherwise
Heat6	= 1 if main heating equipment packaged heat unit; 0 otherwise
Heat7	= 1 if main heating equipment other (except furnace); 0 otherwise
HDD	= heating degree days for building's Census Metropolitan Area
CDD	= cooling degree days for building's Census Metropolitan Area
Retc1	= 1 if building had a lighting retrofit in 2000; 0 otherwise
Retc2	= 1 if building had a heating retrofit in 2000; 0 otherwise
Retc3	= 1 if building had a ventilation retrofit in 2000; 0 otherwise
Retc4	= 1 if building had a roof insulation retrofit in 2000; 0 otherwise
Retc5	= 1 if building had a wall insulation retrofit in 2000; 0 otherwise
Retp1	= 1 if building had a lighting retrofit in 1995-1999; 0 otherwise
Retp2	= 1 if building had a heating retrofit in 1995-1999; 0 otherwise
Retp3	= 1 if building had a ventilation retrofit in 1995-1999; 0 otherwise
Retp4	= 1 if building had a roof insulation retrofit in 1995-1999; 0 otherwise
Retp5	= 1 if building had a wall insulation retrofit in 1995-1999; 0 otherwise
Type	= 1 if shopping centre is not enclosed; 0 if enclosed

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