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Energy Use in Malls and Shopping Centres: Evidence from Canada

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Executive Summary

Shopping centres and malls house a variety of commercial activity types such as medical clinics, retail stores, supermarkets, food services, hotels, swimming pools, hair salons, offices, etc. In order to house a large set of tenants, these buildings have design characteristics that are different from most other commercial buildings. These design characteristics, along with tenancy characteristics, location, and the extent of energy conservation measures that have been adopted, are expected to play an important role in the patterns of energy utilization of different shopping centres and malls.

In this paper, we examine data for the calendar year 2000 pertaining to a set of malls and shopping centres in large urban areas across Canada. These data were collected as part of the Commercial and Institutional Building Energy Use Survey (CIBEUS), conducted in 2001. We provide summary statistics of energy use and building characteristics separately for strip malls and for enclosed shopping centres that illustrate the similarities and differences across these different buildings in terms of both design characteristics and energy usage.

Along with being larger than strip malls, on average enclosed malls in the sample also have larger numbers of people working in them and are open longer hours. They are more likely to have a supermarket as a major tenant but less likely to have a restaurant. On average, enclosed malls provide air-conditioning to a larger proportion of their building area than do strip malls. In terms of energy intensity – measured as energy use per square foot of area – on average enclosed shopping malls are more energy efficient than strip malls, although variation in energy intensity across individual shopping centres is greater for strip malls.

A regression model is used to examine the extent to which design and occupancy characteristics impact significantly on energy intensity in shopping centres. While building size is important, with larger malls using energy less intensively, other design and construction characteristics also have important effects on energy intensity. An examination of tenancy characteristics, to the extent that the data set allows, indicates that the type of tenant is important, with malls housing restaurants (supermarkets) using more (less) energy per square foot than other malls.

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1. Introduction

Building design and occupational patterns for malls and shopping centres differ from those of other types of commercial buildings such as stand-alone retail stores or office buildings. Furthermore, across the many malls and shopping centres that are in operation, there are a variety of configurations in terms of size, layout, construction materials, tenant activities, and other characteristics. As a result, one would expect energy usage patterns to be different in malls and shopping centres than in other types of buildings, and to vary within this particular subset of the commercial building sector.

In order to examine these energy utilization patterns, we examine a set of Canadian malls and shopping centres that were included in the Commercial and Institutional Building Energy Use Survey (CIBEUS) conducted in 2001 (with data pertaining to 2000) by Statistics Canada on behalf of Natural Resources Canada. These malls and shopping centres vary widely in terms of location, age, and other building characteristics. They also vary widely in terms of their consumption of energy. In this paper, we examine the main characteristics of these buildings and use a regression framework to determine the major factors that impact on the intensity of energy utilization.

In Section 2, we survey some recent literature on energy utilization in shopping centres and on energy use for supermarkets and large retailers who are often major tenants in these buildings. Section 3 provides a summary of the major characteristics of the subset of malls and shopping centres in the CIBEUS data set for which we have reliable information on energy utilization. In Section 4, a regression framework is used to examine the contributions of various building and other characteristics to total energy usage and electricity usage. Section 5 contains conclusions and recommendations for future work in the area.

2. *A Review of the Literature*

Among other features, malls and shopping centres utilize large amounts of floor space, tend to be spread out over large expanses of land, and have several separate tenants (which may include, for example, supermarkets, other retail outlets, restaurants, hotels, medical/dental clinics, amusement parks) with varying energy requirements. Given the unique design characteristics and usage patterns of these buildings, it is not surprising that this subset of the commercial building sector is treated separately in the literature on commercial energy utilization.

Previous studies have shown that much of the energy used in malls and shopping centres is dedicated to the provision of light and temperature control. In a study of four recently constructed fully air-conditioned malls in Hong Kong, ranging from 2 to 4 storeys, with floor space ranging from 6,550 to 29,900 m^3, it was found that 85% of energy use was dedicated to the provision of lighting and air-conditioning. With a large percentage of energy use in these buildings devoted to temperature control, usage exhibited seasonal fluctuations. The correlations between mean monthly temperature and electricity use per unit of floor area were very high, ranging from 0.87 to 0.97 for these malls (Lam and Li, 2003).

An energy audit study of a 16,000 m^3 Turkish shopping centre (housing a restaurant, a hypermarket, a playground, other retail outlets, and offices) notes that energy requirements are not constant from day to day, due to varying occupancy patterns and to seasonal fluctuations. The occupancy patterns impact energy usage as they determine the demand for the provision of occupant comfort via the heating, ventilation and air-conditioning (HVAC) systems. It was determined that HVAC and lighting systems accounted for approximately 50% of total electricity use, and that fuel use was distributed unevenly across the various tenants, with the restaurant and the heating system accounting for almost equal proportions of approximately 15% each. The authors conclude that the most cost effective way of increasing energy efficiency for this particular shopping centre would be through improvements in HVAC controls (Canbay et al., 2004).

Supermarkets, which are often major tenants of malls or shopping centres, are relatively intense energy users, largely due to their refrigeration needs. A study conducted in California, that examines five available thermal distribution systems that are appropriate for use in large (> 2000 m^3) commercial buildings in California (one supermarket and 3 office buildings), finds that air leakage and conduction losses vary with the choice of distribution system (Xu *et al.*, 2002). Another study posits that refrigeration equipment accounts for approximately one half of the energy use in supermarkets (Ducoulumbier et al, 2006).

Recent attempts to improve energy efficiency in supermarkets often exploit a set of related features that create synergies.   Careful design planning can allow the lighting system to optimize energy use when used in conjunction with skylights and windows. Air systems can be designed to optimize energy usage in conjunction with insulation features, and heat can be reclaimed from equipment used in the supermarket in order to reduce the use of heating fuels (Olawski, 2001).

The relationship between roof type and HVAC needs is highlighted in an account of the efforts of a large department store in Louisiana to increase its energy efficiency. The installation of an "energy star" white reflective roof made possible a decrease in the size of the HVAC system and a decrease in the running time required. The cost of achieving the HVAC energy savings was a function of the characteristics of the original roof, as removing the original gravel / coal tar pitch roof provided technical challenges for the installation of the new reflective roof (Anonymous, 2001).

While most of the literature on large commercial retail buildings considers the technological possibilities for energy savings, there are also energy efficiency guides that take into consideration the behaviour of tenants and building managers.   Aside from technological factors, there are also behavioural and organizational conditions that can affect energy efficiency. The state of knowledge that tenants have regarding energy features in the building and systems in place that reward energy efficiency (such as individual metering) can play important roles in conserving energy. Organizational efforts that track use or ask for input from tenants, for example, may impact the way in which energy is used. With improvements in technology, information-dissemination, and other behavioural and/or organizational features, it is estimated that energy savings of up to 20% could be attained in Canadian malls and supermarkets (Natural Resources Canada, 2003).

3. *A Snapshot of Energy Usage and Building Characteristics*

The Commercial and Institutional Building Energy Use Survey (CIBEUS) conducted in 2001 includes information on several characteristics pertaining to a set of enclosed shopping malls (main activity code 1510) and strip malls (main activity code 1520) in major Canadian urban areas. All data collected are for the calendar year 2000. Although over 400 malls were surveyed, complete energy data are available for only 28 enclosed shopping malls and 125 strip malls. In this section, we will examine some pertinent characteristics of these 153 buildings.

3.1 Strip Malls

Of the 125 strip malls, 18 are in Atlantic Canada, 23 in Québec, 36 in Ontario, 41 in the Prairies, and 7 in BC. The smallest strip mall in the sample (at 1,768 square feet) is located in the Atlantic region, and exhibits a below average energy utilization index (EUI) of 0.09[1]. The largest strip mall in the sample (120,000 square feet) is located on the Prairies and has an EUI of 0.19. The most energy intensive strip mall, with an EUI of 0.88, is a 2,300 square foot mall in Ontario that was built in 1994 and was open for 66 hours per week in 2000. The least energy intensive strip mall in the sample is located in Québec and has an EUI of 0.01. Compared to the most energy intensive strip mall in the sample, the least energy intensive strip mall is 5 years older and was open for almost twice as many hours per week.

Basic summary statistics for the set of strip malls in our sample are provided in the final column of Tables 1 and 2. From these tables, we see that the average age of a strip mall in the sample, at the time of the survey, was approximately 19 years. On average, these malls were open for about 77 hours per week, with a wide amount of variation across the sample. Very few (2%) of the

[1] The energy utilization index (EUI) used is calculated as GJ of energy consumed per square foot of building area, where the building area excludes indoor parking and mechanical areas.

strip malls sampled housed a supermarket as a major tenant. A much larger percentage of these malls (39%) report the presence of one or more restaurants.[2]

Generally, most of the building area in strip malls is heated, but on average only 66% of the gross building area in strip malls is air-conditioned. Only 10% of the strip malls in the data set have single glazed windows, and fewer than 1% have triple glazed windows. The remaining strip malls use some type of double glazed window. The most common wall type is concrete block (54%), with a variety of other wall types being used in the remaining buildings.

Strip malls on average are smaller than enclosed malls, in terms of both building area (18,000 compared to 344,000 square feet) and the number of people working in the building (36 compared to 406). Although they tend to be open four fewer hours per week on average than enclosed malls (77 hours compared to 81 hours), there is much more variation in the hours of operation for strip malls (possibly due to the fact that it is easier for a single tenant, such as a 24-hour coffee shop, to remain open for long hours in a strip mall than in an enclosed mall).

3.2 Enclosed Malls

The geographical distribution of the enclosed malls in our sample differs from that of the strip malls. Of the 28 enclosed malls, 6 are located in the Atlantic region, 9 in Québec, 7 in Ontario, 4 on the Prairies, and 2 in B.C. The enclosed malls tend to be much larger than the strip malls, with the average-sized enclosed mall (344,000 square feet) being substantially larger than the largest strip mall in our sample (120,000 square feet). The smallest enclosed mall (having 10,332 square feet) is located in Quebec and is also the mall with the lowest energy intensity rating, having an EUI of 0.03. The largest enclosed mall in the sample (1,539,203 square feet) is located on the Prairies and also has one of the lowest EUI values in the sample at 0.04. The most energy intensive enclosed mall in the sample – with an EUI of 0.62 – is approximately 250,000 square feet in size, is located in the Atlantic region, operates for 78 hours per week, and was built

[2] There is more detailed information on tenants for some malls than others. As a result, the various indicator (dummy) variables used to reflect whether the mall includes supermarkets and restaurants may under-represent the presence of these services. The restaurant dummy variable includes identifiable full-service restaurants, fast food outlets, and bars with food services.

in 1967 (which is the same as the year of construction for the mall with the second lowest energy intensity in the sample).

Along with being larger than strip malls, on average enclosed malls also have larger numbers of people working in them and are open longer hours. They are more likely to have a supermarket as a major tenant (32% versus 2%). Some enclosed malls have indoor parking, but only one mall in the sample provides heat to the indoor parking area. On average, enclosed malls provide air-conditioning to over 96% of the gross building area, and in all cases air condition at least 50% of the building area.

The enclosed malls in the sample are on average older than the strip malls, with the most recently constructed enclosed mall having been built in 1990. There is a wide range of window, wall and roof types, but not as much variation as for the set of strip malls. Almost 90% of the enclosed malls use double-glazed windows, and over 70% of the enclosed malls that report the wall type have concrete-block walls. Of those that report roof type, over 60% have deck-type roofs. The type of heating equipment used in enclosed malls differs from that used in strip malls, with fewer furnaces and more boilers and individual space heaters being used.

In terms of energy use and energy intensity, on average enclosed shopping malls are more energy efficient than strip malls (with an average EUI of 0.10 compared to 0.15). Although the range of this energy utilization index is greater for strip malls (0.01 to 0.88) than for enclosed malls (0.03 to 0.62), it is interesting to note that both the most energy efficient and the least energy efficient of the shopping centres in the sample are strip malls. On average, strip malls use 6.1% as much electricity as enclosed shopping malls, and 6.7% as much energy in total. Of course to a large extent this difference in energy usage reflects differences in building size and operating characteristics.

To examine the extent to which energy usage in different centres can be explained by factors other than building size, and to assess the extent to which particular building design or occupancy characteristics factors affect energy use, in the following section we report on estimation of regression models of overall energy intensity in shopping centres.

4. ***Determinants of Energy Usage in Canadian Malls: Regression Analysis***

In the previous section, a substantial amount of variation was noted in terms of energy utilization and in terms of the basic construction and occupancy characteristics of the malls in the CIBEUS data set. In this section, we examine which, if any, of these design and occupancy characteristics impact significantly on energy intensity. For this purpose we consider a regression model of the form:

$$Y_i = \beta_1 + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + e_i$$

where:

Y_i is total energy usage per square foot (EUI) of shopping centre i;

$X_{2i}, X_{3i}, \ldots, X_{ki}$ are explanatory variables thought to impact Y_i;

$\beta_1, \beta_2, \ldots, \beta_k$ are parameters to be estimated; and

e_i is a random error term.

In all regressions, the dependent variable is the EUI index. The set of explanatory variables (listed in the Appendix) attempts to capture the major factors that are thought to influence energy intensity in shopping malls. General physical characteristics are captured through variables such as size, age, and a series of indicator (0-1 dummy) variables related to the types of walls, roof, and windows, and whether or not the mall is enclosed. Occupancy characteristics include information on the number of people employed during the main shift, and hours of operation per week. Given that supermarkets are inherently intensive users of energy, we also include a dummy variable that indicates whether or not a supermarket is listed as a major tenant in the survey. In addition, a restaurant dummy is included in order to control for any additional energy demands that may result from food storage and preparation requirements.

An attempt is made to control for energy efficiency efforts on the part of management, and possibly general attitudes towards energy conservation, through the inclusion of dummy variables indicating the presence of energy efficiency features on windows (awnings and tinted glass), lighting, and HVAC equipment. The type of HVAC equipment used is included in the regressions, as well as indicators of the percentage of the building that is heated and cooled. In all regressions, an attempt is made to control for region-specific influences via a set of regional dummy variables as well as heating degree day and cooling degree day variables.

Four versions of the estimated regression model are reported in Table 3. The model is estimated for both the sample of all malls and for the sub-sample of strip malls, in each case including those shopping centres for which there are data available for all the control variables.[3] Two functional forms are considered in the analysis. In the first, all explanatory variables are entered linearly. In the second "log-linear" specification, continuous explanatory variables taking strictly positive values (except those measured as a percentage) are entered in natural logarithmic form. Based on a comparison of adjusted R^2 values (since both models have the same form of the dependent variable), the log-linear model would appear to be preferable. However, in view of the RESET test values reported in Table 3, it would probably be advisable to consider more general functional forms. Due to the small sample sizes available in the current data set, functional forms allowing for interaction terms (cross-products of the explanatory variables) are not considered here, but this is an issue that should be taken into account in future research.

The regression results indicate that there are some factors which are significantly related to the intensity of energy use in shopping malls. One result that is robust across all specifications is that there are returns to scale in energy efficiency in these buildings, as larger malls use energy less intensively than smaller ones. It is also found, not surprisingly, that holding the effects of all other factors constant, enclosed malls – which generally have 'common areas' where thermal comfort and lighting are provided – tend to use energy more intensively than strip malls.

As far as the occupancy variables are concerned, there is evidence that the type of tenant is more important than the number of employees or the hours of operation. The only statistically significant occupancy coefficients are those related to the restaurant and supermarket dummy variables. Malls that provide restaurant-type services (including fast food outlets) use significantly more energy per square foot than other malls. A possibly surprising result is that the presence of a supermarket has a negative impact on energy intensity. One consideration to

[3] Since there are only 24 observations for enclosed malls for which we have information on all of the explanatory variables, separate results for enclosed malls are not provided.

keep in mind when interpreting this result is that the presence of a supermarket may not always be accurately reported in the data, as some shopping centres provide more detailed information than others in terms of occupancy characteristics. Also, it should be noted that none of the strip malls in the sample used in our regressions has a supermarket listed as a tenant. Therefore the supermarket variable is only included in the pooled sample of enclosed and strip malls.

The results in the literature point out that a large percentage of energy use is directed at the provision of lighting and thermal comfort. In our regressions, there are several variables that are related to these factors. Some features, such as window type, will have an impact on both heat retention and lighting. There is evidence here, especially in the linear regressions, that window type matters. However, from the coefficients on dummy variables for the specific window-types (not individually reported), where 'double glazed low-E gas filled' windows constitute the base case, there are generally no individually significant impacts. The one exception is a positive coefficient that is significant at the 10% level for triple glazed windows only in the linear regression using all shopping centres.

Other factors related to windows, such as the presence of reflective or shading film, the presence of awnings, or the window-to-wall ratio, do not have significantly significant impacts in any of the regressions considered. Similarly, the lighting-conservation feature dummy does not contribute significantly to explaining variations in energy utilization rates across the malls in the sample.

The set of HVAC dummies (ener1-ener3, hteq1-hteq4, and cleq1-cleq5) are never statistically significant, possibly indicating that these malls have selected appropriate systems for their particular sets of characteristics and needs. However, this result contrasts somewhat with the fact that malls that report the presence of energy-efficient features or practices in terms of HVAC equipment (reflected in the dummy variable "hvac") use significantly more energy than other malls. The latter result implies that there may be some other HVAC-related factors that are not being captured in our regression models.

The remaining major building characteristics that play a significant role in terms of energy utilization are basic construction features: wall and roof type. The baseline roof type is a non-insulated deck type roof. In most cases, there are no individually significant roof parameters. The only individually significant coefficient appears in the linear regression for the full set of malls, and this indicates that malls using an insulated wood-truss roof are more intensive consumers of energy. As a result, it is not possible to make any firm conclusions regarding the most energy efficient type of roof.

The wall type dummies are jointly significant in all of the regressions, while the roof type dummies are jointly significant in most cases. The baseline wall type in the regressions is precast panel. Precast panel walls are always among the types of walls associated with lower energy intensity in the sample of malls. The only included wall type dummy that never has a positive and significant associated coefficient is ‘wood frame without insulation’. A possible explanation for the latter result is that any malls using uninsulated wood frame walls are not housing tenants that require thermal comfort for their customers.

These regression results provide some tentative results in terms of the impacts of various features and characteristics of malls on the intensity of energy use. Building characteristics and occupancy patterns matter. In some instances, such as the results relating to roof-type, it is not clear which features are ‘optimal’ in terms of energy efficiency. This could be due to synergies related to other factors that are not being captured in our model. Due to the size of the sample, it was not feasible to consider fully flexible functional forms, or to include dummy variables for all of the individual conservation features and other characteristics of the buildings. As a result, there are still many questions remaining as to the nature and extent of the various influences on energy intensity.

5. ***Summary and Conclusions***

Our results from an examination of a set of Canadian enclosed and strip malls are generally in agreement with the previous literature that has investigated the impacts of building design and occupancy characteristics on energy utilization. We find that building design features such as size, window-type, wall-type and roof-type affect energy efficiency. The type of tenants occupying space in a mall also plays a role, with the presence of restaurants having a significant impact on energy use due (at least partially) to the energy intensity of food storage and preparation activities. Variables that capture the presence of lighting and HVAC efficiency characteristics, which might be considered to crudely proxy for management attitudes towards energy conservation, are either insignificant or have an unexpected relationship with overall energy intensity.

Although the CIBEUS data set is able to provide us with a certain level of understanding of energy utilization in malls, there are still many questions that could be addressed with a richer data set. In the CIBEUS data set, there are more details provided on tenancy characteristics for some malls than others. So, the presence of a supermarket, for example, may be measured with error if any of the malls with less detailed occupancy listings house a supermarket. More detailed information on mall tenancy might lead to more conclusive results. Furthermore, there is little in the way of direct measurements available in terms of management and tenant attitudes towards energy conservation. As a result, it is not possible to accurately gauge the potential impact of programs aimed at improved energy efficiency behaviour on the part of managers and tenants.

The CIBEUS data set is rich in terms of detailed information on construction and HVAC features of the malls. However, especially for enclosed malls, the relatively small sample size makes it difficult to examine synergies that may result from optimal mixes of features. Additional survey information, possibly including “follow-up” information on the malls included in the original data set could possibly be used to increase the effective sample size and improve our understanding of available synergies in this sector.

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Table 1: Shopping Centre Summary Statistics

Variable		Enclosed Malls (N=28)	Strip Malls (N=125)
Year of Construction	Minimum Maximum Mean	1910 1990 1969.54	1920 1999 1981.56
Building area (excluding indoor parking and mechanical areas)	Minimum Maximum Mean	10332 1539203 343496	1768 120000 18202.43
Number of floors (excluding indoor parking and mechanical areas)	Minimum Maximum Mean	1 3 1.75	1 11 1.40
Indoor parking in building (Yes=1, No=0)	Minimum Maximum Mean	0 1 0.11	0 0 0.00
Indoor parking levels heated (Yes=1, No=0)	Minimum Maximum Mean	0 1 0.04	
Number of people worked in building during main shift 2000	Minimum Maximum Mean	20 1500 406.21	2 300 35.54
Total number of hours of operation per week	Minimum Maximum Mean	58.00 119.00 80.93	12.00 168.00 77.41
Supermarket listed as a major tenant (Yes=1, No=0)	Minimum Maximum Mean	0 1 0.32	0 1 0.02
Restaurant listed as a major tenant (Yes=1, No=0)	Minimum Maximum Mean	0 1 0.21	0 1 0.39
Window-to-Wall Ratio	Minimum Maximum Mean	1 100 23.64	1 75 21.82
Percentage of gross area of building cooled by cooling system	Minimum Maximum Mean	50 100 96.61	0 100 66.40
Percentage of gross area of building heated to at least 10 degrees Celsius	Minimum Maximum Mean	99 100 99.96	25 100 96.90
Total annual electricity consumption (GJ)	Minimum Maximum Mean	273.02 83991.36 20947.17	55.03 16862.89 1286.06
Total annual energy consumption (GJ)	Minimum Maximum Mean	273.02 155174.91 30880.92	101.42 23359.14 2074.62
Energy intensity for 2000 - total	Minimum Maximum Mean	.03 .62 .10	.01 .88 .15

Table 2: Other Building Characteristics: Walls, Windows, Roofs, Heating

	Enclosed Malls (N=28)	**Strip Malls (N=125)**
Window Type	% of buildings	% of buildings
single glaze	10.7	10.4
double glaze	57.1	59.2
triple glaze	0.0	0.8
double sealed glaze	21.4	23.2
double glaze	7.1	4.0
double glaze with low e gas filled	3.6	2.4
Wall Type	% of buildings	% of buildings
curtain walls	3.6	5.6
metal stud framing with surface insulation	10.7	12.8
metal stud framing without surface insulation	0.0	1.6
wood frame walls with surface insulation	3.6	12.8
wood frame walls without surface insulation	0.0	4.0
concrete block with interior finishing	60.7	47.2
concrete block without interior finishing	10.7	6.4
precast panel	3.6	0.8
information missing	7.1	8.8
Roof Type	% of buildings	% of buildings
attic roof fully insulated	14.3	8.8
attic roof partially insulated	0.0	3.2
insulated wood truss roof	0.0	12.8
not insulated wood truss roof	0.0	2.4
insulated metal truss roof	10.7	20.8
not insulated metal truss roof	0.0	4.0
insulated deck type roof	57.1	37.6
not insulated deck type roof	3.6	0.8
information missing	14.3	9.6
Main Heating Equipment	% of buildings	% of buildings
furnaces	7.1	34.4
heat pumps	3.6	4.0
individual space heaters	17.9	12.8
boilers	21.4	3.2
packaged heat units	46.4	44.0
other	3.6	1.6

Table 3: Regression Results: Linear and Lin-Log Models

Variable	All Malls Linear	Strip Malls Linear	All Malls Lin-log	Strip Malls Lin-log
Coefficient (standard error)				
Intercept	.312753 (.5740)	.127191 (.6330)	2.77377 (4.080)	3.15553 (4.714)
Age †	-.000570 (.0014)	-.000516 (.0019)	.023357 (.0233)	.010053 (.0231)
Area †	-.000001*** (.0000)	-.000002* (.0000)	-.082492*** .023406	-.073734*** .025957
Floor †	.011179 (.0185)	.019041 (.0180)	.006503 (.0455)	.050266 (.0528)
Hdd †	-.000112 (.0002)	-.000119 (.0002)	-.239418 (.4919)	-.290196 (.5749)
Cdd †	-.000567 (.0007)	-.000640 (.0008)	-.054478* (.0313)	-.053595 (.0340)
Heatpk	1.03372*** (.3928)		.113247 (.0754)	
Occ †	.000460** (.0002)	.0001001 (.0004)	.025667 (.0247)	.007428 (.0274)
Hours †	-.000781 (.0007)	-.001211 (.0009)	-.044076 (.0476)	-.067636 (.0596)
Winref	-.050970 (.0429)	-.037073 (.0498)	-.059481 (.0418)	-.043419 (.0449)
Winawn	.021454 (.0404)	.009014 (.0480)	.057031 (.0373)	.025394 (.0435)
Light	.001619 (.0315)	.025713 (.0363)	.047216 (.0354)	.044504 (.0377)
Hvac	.118963** (.0556)	.129005** (.0593)	.117614** (.0450)	.124312** (.0480)
Wtw	-.000046 (.0015)	.000643 (.0017)	-.000251 (.0015)	.000654 (.0015)
Heatarea	.000071 (.0011)	.000691 (.0015)	-.000538 (.0012)	-.000211 (.0015)
Coolarea	-.000527 (.0005)	-.000360 (.0006)	-.000276 (.0006)	-.000114 (.0006)
Supermarket	-.245869*** (.0722)		-.173108*** (.0647)	
Enclosed	.143510* (.0777)		.158907** (.0761)	
Restaurant	.189950*** (.0496)	.181198*** (.0614)	.137046*** (.0444)	.153063*** (.0512)

… continued

Table 3 (continued)

Variable(s)	All Malls Linear	Strip Malls Linear	All Malls Lin-log	Strip Malls Lin-log
Wald tests for joint significance [p-value]				
reg1-reg4	0.7881 [0.940]	0.7703 [0.942]	1.1698 [0.883]	0.7131 [0.950]
win1-win5	15.301 *** [0.009]	10.952 * [0.052]	9.7180 * [0.084]	8.9151 [0.112]
wall1-wall7	14.867 ** [0.038]	17.865 ** [0.013]	16.843 ** [0.018]	20.907 *** [0.004]
roof1-roof7	17.876 ** [0.013]	12.844 * [0.076]	14.624 ** [0.041]	11.167 [0.132]
ener1-ener3	1.2177 [0.749]	1.1547 [0.764]	1.3509 [0.717]	0.7897 [0.852]
hteq1-hteq5	6.6228 [0.250]	7.6053 [0.179]	6.4654 [0.264]	6.1607 [0.291]
cleq1-cleq6 [1]	2.6090 [0.856]	0.7833 [0.941]	5.5717 [0.473]	1.3360 [0.855]
Number of shopping centres (N)	135	111	135	111
Adjusted R-square	0.2297	0.1962	0.2756	0.2567
LM test for heteroskedasticity	20.223 [.000]	18.353 [.000]	26.567 [.000]	14.805 [.000]
Reset test for functional form	27.840 [.000]	19.996 [.000]	27.120 [.000]	16.198 [.000]

Notes: •Numbers in round parentheses (.) are heteroskedasticity-consistent standard errors.

•Numbers in square parentheses [.] are p-values.

•Wald tests are used to test the joint significance of the group of dummy variables, where significance (low p-value) indicates that the coefficients are not all equal to the coefficient for the base case (omitted category).

•The LM test for heteroskedasticity is used to test for evidence of heteroskedasticity (non-constant variances of the error terms across shopping centres) in the estimated model. A low p-value indicates evidence of heteroskedasticity (which is why heteroskedasticity-consistent standard errors are used in place of usual standard errors).

•The RESET test for functional form is used to test whether the functional form is appropriate or there is evidence of omitted variables, either of which is indicated by a low p-value.

† In the log-lin version these explanatory variables are in natural logarithmic (log) form (no log transformation is applied to the dependent variable).

[1] cleq3 and cleq5 are omitted for strip malls.

***, **, and * indicate significance at 1%, 5%, and 10%, respectively.

APPENDIX: List of Explanatory Variables for Regression Models

age	= Age of building (=2000-Year of construction)
area	= Building area (excluding indoor parking and mechanical areas) – square feet.
floor	= Number of floors (excluding indoor parking and mechanical areas)
hdd	= Heating Degree Days
cdd	= Cooling Degree Days
heatpk	= Heated indoor parking in building (Yes=1, No=0)
occ	= Number of people worked in building during main shift 2000
hours	= Total number of hours of operation per week
winref	= Windows-reflective or shading film (Yes=1, No=0)
winawn	= Windows-awnings or blinds (Yes=1, No=0)
light	= Lighting conservation features* (more than 25% of lighting uses a major conservation feature=1; otherwise=0)
hvac	= HVAC conservations features** (at least one measure in place=1, otherwise =0)
wtw	= Window to wall ratio (%)
heatarea	= Percentage of gross area of building heated to at least 10 degrees Celsius
coolarea	= Percentage of gross area of building cooled by cooling system
supermarket	= Supermarket dummy (Yes=1, No= 0)
enclosed	= Mall type dummy (Enclosed=1, Strip mall = 0)
restaurant	= Restaurant dummy (Yes=1, No=0)
reg1-reg4	= Set of regional dummy variables (Atlantic, Quebec, Ontario, Prairies – base case=B.C.)
win1-win5	= Set of window-type dummy variables (single glaze, double glaze, triple glaze, double sealed glaze, double glaze with low e coating – base case=double glaze with low e gas filled)
wall1-wall7	= Set of exterior wall-type dummy variables (curtain walls, metal stud framing with surface insulation, metal stud framing without surface insulation, wood frame walls with surface insulation, wood frame walls without surface insulation, concrete block with interior finishing, concrete block without interior finishing, – base case= pre-cast panel)
roof1-roof7	= Set of roof-type dummy variables (attic roof fully insulated, attic roof partially insulated, insulated wood truss roof, not insulated wood truss roof, insulated metal truss roof, not insulated metal truss roof, insulated deck type roof – base case= not insulated deck type roof)
ener1-ener3	= Set of main energy source for heating dummy variables (electricity, natural gas, fuel oil – base case=bottled gas, liquefied petroleum gas, or propane)
hteq1-hteq5	= Set of main heating equipment dummy variables (furnaces, heat pumps, individual space heaters, boilers, packaged heat units – base case=other)
cleq1-cleq6	= Set of main cooling equipment dummy variables (residential type air conditioners, heat pumps, individual room air conditioners, district chilled water, central chillers, packaged air conditioning units – base case=other)

* Lighting conservation features considered include: reflectors, energy efficient ballast, daylight controls, occupancy sensors, time clocks, manual dimmer switches, energy efficient lamps, other.

** HVAC conservation features considered include: variable air volume system, outdoor air economizer, temperature setback, equipment reset, heat recovery system, regular maintenance.