# ENERGY USE IN CANADIAN MULTI-FAMILY DWELLINGS

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## Abstract

This paper examines the energy-efficiency status of multi-family dwellings to determine whether or not this type of housing should be especially targeted for increased participation in energy efficiency programs. To some extent, the energy-efficiency challenges faced by occupants of multi-family dwellings are the same as those faced by occupants of single-family detached houses. Energy-efficiency will be a function of the types of technologies used by the household and their intensities of use. However, special challenges to improving energy-efficiency exist in multi-family units due to the fact that many occupants of such units are renters, most of whom do not select the major appliances that are used by the household, and some of whom have the cost of their utilities included in their monthly rental payments. Using Canadian data from 2003, this work provides a quantitative assessment of the effects of agency and asymmetric information problems involved in landlord-tenant relationships on the level of energy use in these dwellings, the choices over energy-efficient appliances and the adoption of energy saving practices.

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## 1 Introduction

According to the 2006 Canadian census, approximately 43% of private dwellings were multi-family units, such as semi-detached houses, row-houses or apartments. The pattern of dwelling types varies considerably across the country, with the lowest concentrations of multi-family units (under 25%) in New Brunswick, Prince Edward Island and Saskatchewan and the highest concentrations (over 45%) in British Columbia, Quebec and Nunavut.[1] In spite of the prevalence of this type of housing in Canada, owners and occupants of multi-family dwellings were among the least likely to participate in government-sponsored energy conservation efforts such as Canada's EnerGuide for Houses (EGH) program. Multi-family dwellings other than apartment buildings (which were not eligible for the EGH program) represented only about 10% of EGH participants[2], although they constitute about 15% of the Canadian housing market[1]. Given the prevalence of multi-family dwellings and their limited participation in (and/or eligibility for) government sponsored energy efficiency programs, it is of interest to examine the energy-efficiency status of this component of the housing sector to determine whether or not it should be especially targeted for increased participation in energy-efficiency efforts.

To a certain extent, the energy-efficiency challenges faced by occupants of multi-family dwellings are the same as those faced by occupants of single-family detached homes. That is, energy-efficiency will be a function of the types of technologies used by the household and their intensities of use. However, special challenges to improving energy-efficiency exist in multi-family units due to the fact that many occupants are renters, most of whom do not select the major appliances that are used by the household, and some of whom have the cost of their utilities included in their monthly rental payments. The corresponding agency and asymmetric information problems involved in landlord-tenant relationships complicate the sets of incentives faced by the owners and occupants of these dwellings.

In this study we use data from the 2003 Survey of Household Energy Use (SHEU 2003) to examine the energy-use characteristics of occupants of several types of multi-family dwellings. This survey, conducted by Statistics Canada on behalf of Natural Resources Canada, provides data on dwelling characteristics, installed technologies, energy use, and household demographics for 4551 Canadian households, 1244 of which resided in semi-detached houses, row houses or low-rise

[1] **Source:** Statistics Canada. *Cumulative Profile, 2006 - Provinces and Territories in Canada* (table), 2006 Census of Population (Provinces, Census Divisions, Municipalities) (database), Using E-STAT (distributor).
[2] **Source**: Office of the Energy Efficiency, Natural Resources Canada, EnerGuide for Houses database.

apartment buildings.[3] Our results provide mixed evidence regarding the impact of agency issues on energy-related behaviour. The reported intensity of total energy consumption is significantly higher for households when the heating bill is paid by a landlord; and the same holds for electricity consumption when households do not pay their own electricity bills. Furthermore, when a household is not responsible for directly paying for heat, temperatures are set at a higher level during daytime, evening and nighttime hours. The influence of the agency problem on various other aspects of energy-related behavior (renovations, the adoption of Energy Star® appliances, engaging in energy-saving practices) is less pronounced. Whether or not a household pays directly for electricity or heat has no significant impact on the prevalence of Energy Star® products in a dwelling. Even when landlords pay for the electricity or heat used by tenants, dwelling renovation rates remain quite low in the rental market. Landlords who pay for heat do, however, plan for more energy-saving renovations in the near future than their counterparts with tenants who pay their own heating bills.

The structure of the paper is as follows. In Section 2 we provide an overview of the literature on energy use in multi-family dwellings, with an emphasis on the agency problems that can occur when the occupants are tenants rather than owners. Section 3 provides a statistical overview of the portion of the multi-family dwelling sector in Canada covered in the SHEU 2003 survey. This is followed in Section 4 by a more formal econometric analysis of energy-related behaviour in these dwellings. Section 5 concludes.

## 2 Energy Efficiency Challenges in Multi-Family Dwellings

As is the case for single-family dwellings, energy efficiency gains by households living in multi-family dwellings will be determined primarily by the types of technologies that are in place and the intensity with which these technologies are used. Households with newer, more energy-efficient technologies will have the ability to heat / cool their dwelling space and perform basic household tasks with less purchased energy than other households. Although lower income households will be less likely to own newer technologies, they will also be less likely to own other energy-using equipment such as digital cable boxes and plasma televisions. For higher income households, energy bills will be a relatively small

[3] Apartment buildings with more than four floors were excluded from the survey.

portion of their budget, and it is hypothesized that they will be less likely to react to energy price changes than lower income households in so far as their energy consumption habits are concerned.

At any given point in time, many households will not be using the most efficient among currently available technologies. The stock of household appliances is only replaced gradually over time as older models exit from use and are replaced by newer ones. And when choosing a new appliance, 'first-cost' purchase price considerations, which tend to be higher for more energy-efficient models, may dominate future energy savings in the selection process for some households, especially those with lower incomes. Even if a household does select one of the most efficient models, the lower energy costs related to the use of the appliance may lead to a standard 'rebound effect' of an increased intensity of use ( Sorrell and Dimitropoulos, 2008 ). Furthermore, while the use of energy will in theory be affected by current and expected future prices, the extent to which prices affect behaviour is limited by the fact that energy bills are generally received with a lag of a month or more, and the bills do not reveal which appliance(s) / household activities are contributing most towards the cost of energy consumed by the household (Brown, 2001).

The choice of technologies and the intensity of their use in multi-family dwellings can be further complicated by agency problems that arise when the dwelling is rented. Counihan and Nemtzow (1981) were among the first to note the importance of agency problems in tenant-landlord relationships. They note that in situations where the tenants pay their own utilities, and therefore the landlord does not benefit directly from reduced energy use, the landlord's appliance purchase decisions will be influenced primarily by 'first-cost' considerations. Furthermore, they note that legislation, such as that introduced in the US in the late 1970s requiring separate electricity metering in new apartment buildings, may skew landlords away from central heating systems (which may be more likely to be properly maintained) and towards the use of, possibly less efficient, individual electric heating.

For tenants who pay their own utilities, given their relative transiency and restrictions in their lease agreements, benefits from the future energy cost savings from investments in energy efficient technologies will only be reaped for portable technologies that tenants can take with them when they move. Tenants who do not pay their own electricity, on the other hand, do not see a bill and will be unaware of the cost associated with their energy consumption habits.

The potential agency problems associated with occupants of multi-family dwellings are summarized succinctly into four possible cases, shown in Table 1, by the American Council for an Energy-Efficient

Economy (2007). In the first case, an owner-occupied unit where the occupant both chooses the stock of appliances and pays the energy bills, there will be no agency problems. In the second case where the occupant does not choose the major technologies – which will occur for instance when a landlord purchases the appliances – but pays the utilities, there will be a potential 'efficiency problem.' That is, the landlord's decisions regarding the equipment to be installed may be driven primarily by purchase price (borne by the landlord) and not the operating costs (borne by the tenant). Since newer more efficient appliances usually come with a higher price tag, it would be expected that a landlord will be likely to (i) wait longer to replace older appliances; and (ii) select less efficient models when new appliances are installed. The extent of this type of efficiency problem may be lessened in areas where vacancy rates are high, since landlords may have an incentive to install newer more energy-efficienct appliances in order to improve the attractiveness of their rental properties (Meyer-Rencschhausen, 1983; Stoecklein *et al*, 2005; Volker and Johnson, 2008).

A third case occurs in situations where a landlord both chooses the technologies and pays the utility bills. As the landlord reaps the benefits of energy cost savings from the installation of energy-efficient equipment, there will be no 'efficiency' problem. There will be, however, a potential 'usage' problem that arises due to the fact that the marginal cost of using appliances and heating / cooling technologies is effectively zero for the tenants who decide on the intensity of use of energy-using equipment (Munley *et al*, 1990; Levinson and Nieman, 2004). It would be expected that tenants who do not pay for utilities would, *ceteris paribus*, use more of these 'free' inputs. A fourth case, which is less common in practice since tenants do not usually have a legal right to install major appliances and heating/cooling technologies, would be one in which the tenant chooses the technologies but the landlord pays for the energy that is used. In such a scenario, there would be both 'efficiency' and 'usage' problems as the purchaser of the technology does not pay for their use and the person paying the utilities does not determine the usage patterns.

**Table 1: Agency problems in rental dwellings**

| | ***Tenant chooses equipment*** | ***Landlord chooses equipment*** |
|---|---|---|
| ***Tenant pays the bill*** | Case 1: no principal- agent problem | Case 2: efficiency problem |
| ***Landlord pays the bill*** | Case 4: usage and efficiency problem | Case 3: usage problem |

**Source**: American Council for an Energy-Efficient Economy (2007)

Aside from agency problems, there can also be asymmetric information issues associated with landlord-tenant relationships. When the landlord purchases appliances, potential tenants cannot be sure of their energy efficiency characteristics (Meyer-Renschhausen, 1983; Levinson and Nieman, 2004). Although new major appliances are generally labelled with information regarding their energy-use characteristics, an unscrupulous landlord might remove or alter the labels (Murtishaw and Sathaye, 2007). Levinson and Nieman suggest that this sort of asymmetric information problem, where tenants are unsure about expected utility costs, may provide landlords with an incentive to offer to pay the utilities as a signaling device to indicate that a unit truly is energy-efficient.

These asymmetric information obstacles are in addition to the more general barriers associated with gathering sufficient information to make optimal decisions regarding the selection of energy-efficient technologies. Brown (2001) points out that energy audits can be useful in this regard. Volker and Johnson (2008) note that free energy audits provided by a Midwestern US utility company were often performed repeatedly on the same structure with the same recommendations being made each time. The dwellings where the energy-efficiency retrofits recommended in the audit were not implemented tended to be those where the occupants had low incomes and/or were renters.

Counihan and Nemtzow (1981) and Meyer-Rencshhausen (1983) note that landlords, as investors, consider the purchase of energy-efficiency technologies as one of many possible investment strategies. Therefore, especially for corporate landlords, the returns to increasing energy-efficiency in the units that they own will be compared to returns on other types of investments. In jurisdictions with rent-controls, the returns to energy-efficiency investments will tend to be lower given that the associated costs are less likely to be recouped by the landlord. Meyer-Rencschhausen finds that landlords in Germany are more likely to make energy-efficiency investments when the rental units are located close to the landlord's residence. In fact, multi-family dwellings where the landlord occupies one of the units tend to be better equipped. Laquatra (1992) focuses on rural rental dwellings and finds that different types of landlords (large/professional vs. small/family business) face different types of barriers regarding investments in energy efficiency improvements.

As far as access to government-sponsored initiatives to increase energy efficiency is concerned, this can be more difficult for owners of multi-family dwellings, especially when policies have multiple aims (which may include, for example, providing benefits that accrue primarily to low-income households). A recent example can be found in the Weatherization Assistance Program for Low-Income Persons in the U.S. To be eligible to participate in this program, owners of multi-family units are required to guarantee that the benefits accrue primarily to low-income tenants. In cases where utility costs are included in the rent this is somewhat problematic since landlords receive the pecuniary benefits related to the resulting lower energy costs (although there will be health and safety benefits that accrue to tenants). Other restrictions on landlords include guarantees that rents for low-income tenants will not increase as a result of expenditures on weatherization and a prohibition against expenditures that will lead to 'undue or excessive enhancement' of buildings that are weatherized under the program. The procedural burdens associated with applying to this energy-efficiency program were reduced after a ruling that deemed that certain buildings that fall under a set of assisted or public housing programs automatically meet one or more of the restrictions related to the accrual of benefits and rent restrictions on the eligibility for participation (US Department of Energy, 2010).

Previous empirical studies on energy use in multi-family provide evidence of a significant 'usage' effect in rental units with landlord-paid utilities. Levinson and Nieman (2004) find that renters in the U.S. who do not pay their own utilities tend to keep their apartments warmer while they are out than those who pay for their own heat. This effect is at least partially mitigated by the landlord's provision of more energy-efficiency technologies in these apartments. Evidence of a usage effect is also provided in Munley *et al* (1990) who, using data from the late 1970s, find that in otherwise identical blocks of centrally heated apartments (equipped with identical appliances) where one half of tenants paid their own electricity bills, those tenants who had their electricity costs included in their rent used on average a little over 30% more electricity than their counterparts. Further evidence of efficiency problems is found in Davis (2009) who, using a subset of observations from the US 2005 Residential Energy Consumption Survey that excludes dwellings with utility–included rental payments, finds that owner-occupied dwellings are more likely than rental dwellings to have at least one Energy Star® product in each appliance category. Finally, a set of case studies commissioned by the International Energy Agency estimates the proportion of aggregate energy use that is subject to split-incentives or other barriers for a variety of sectors (refrigerators, water and space heaters, commercial office leasing, vending machines) for a number of OECD countries. It is a frequent finding in these case studies that relatively large shares of energy use are subject to split-incentives, but the actual effect of these barriers on the level of energy use is difficult to quantify (American Council for an Energy-Efficient Economy, 2007).

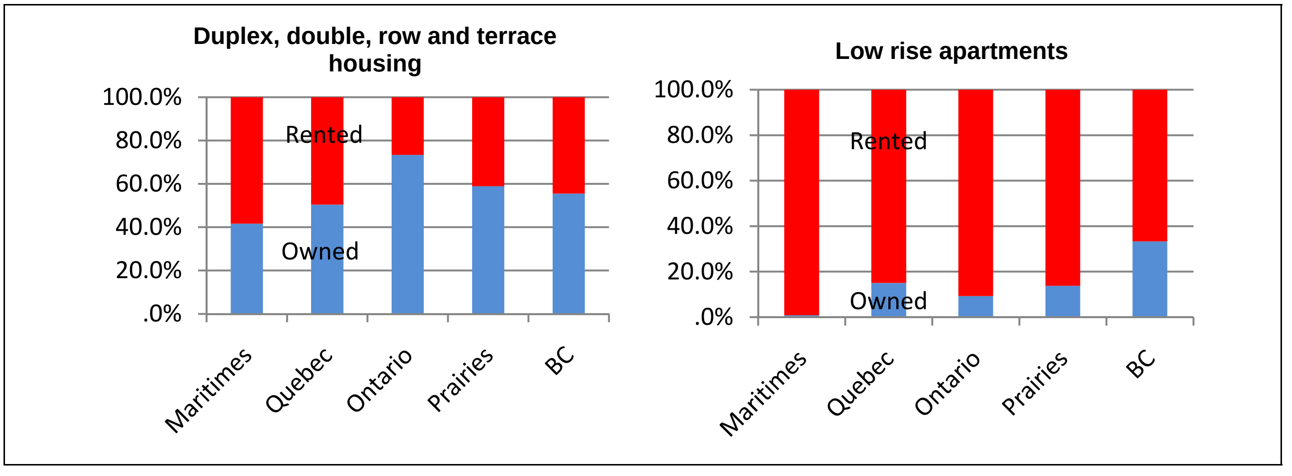
## 3 Characteristics of Multi-family Dwellings: SHEU 2003

Before proceeding to an econometric analysis of energy technology choices and energy use in Canada's multi-family dwelling sector, we present some stylized facts from the SHEU 2003 data set. Note, that the buildings constructed before 1920 are removed from the initial dataset and that the survey did not include any high-rise (>4 storey) apartment buildings. 28% of the remaining sample consists of households living in multi-family dwellings. These 1139 multi-family dwellings can be divided into two main types: low-rise apartments (LRA) and duplex / double / row / terrace type (DDRT) housing.

### *3.1 Tenancy and Age Characteristics*

Figure 1 indicates the occupancy status (owned or rented) of the multi-family dwelling respondents in the survey. While apartment-style units tend to be occupied by renters, other types of multi-family dwellings have a more even split across owners and renters. Regional differences are evident, with the highest rate of apartment ownership being found in B.C. and the lowest rate in the Maritimes. Fewer than 50% of DDRT style dwellings are owner-occupied in the Maritimes, with higher ownership rates found in the central and western regions of the country.

**Figure 1: Share of rented versus owner-occupied dwellings by province**

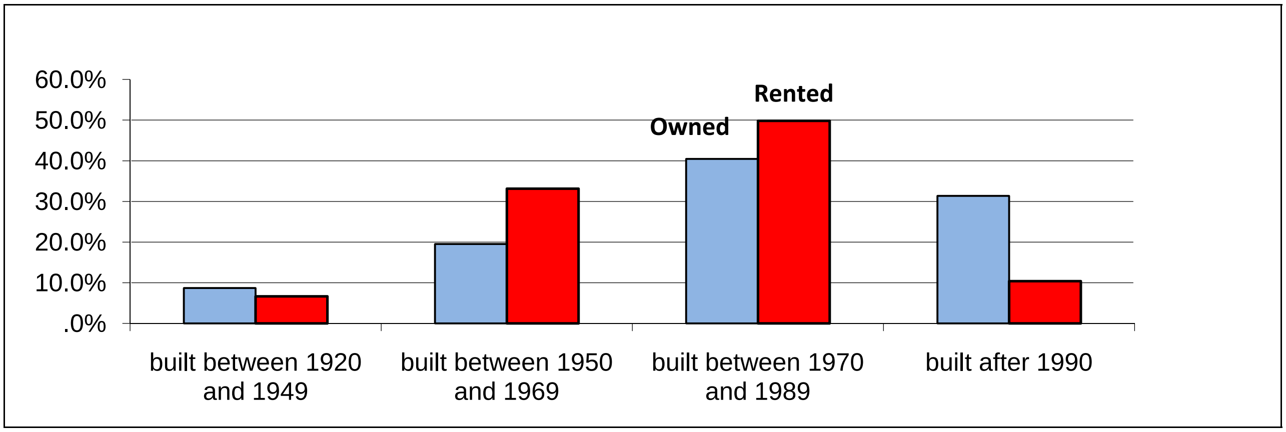



**Source: SHEU 2003**

According to Counihan and Nemtzow (1983), rented buildings tend to be older and less energy efficient. Figure 2 shows that the age structure of multi-family rental housing units in SHEU follows a similar pattern. The majority of multi-family dwellings occupied by tenants were constructed between

1950 and 1990, while a large proportion of owner-occupied multi-family dwellings have been built more recently. These observations are likely to have repercussions for the amount of energy consumed by renters relative to owners, since newer buildings are likely to incorporate newer technologies and are expected to be more energy efficient.

**Figure 2: Age composition of multi-family dwellings**




**Source: SHEU 2003**

Aside from building age, another factor that determines energy efficiency is whether or not the end-user pays for energy. The occupant is responsible for paying for utilities in owner-occupied units, while the responsibility for paying for utilities in rental accommodations is set out in the rental agreement. Table 2 shows, for each major energy type and for space and water heating, the share of households in rental accommodations that pay their own bill and the share for which the landlord pays (and where, therefore, the marginal cost of energy to the tenant is zero).

Not surprisingly, tenants residing in DDRT-style dwellings are more often responsible for paying their own bills than are tenants of LRAs (where heating and water systems are more likely to be common for the entire building and separate billing more difficult to implement). Most tenants pay for their own electricity consumption: 80% of the households living in DDRTs and 75% of households living in LRAs. When natural gas is used in a LRA building, the landlord almost always pays the bill, while for DDRT buildings the landlord pays the natural gas in only 40% of the cases. Finally, oil, which is not commonly used, tends to be paid for by landlords rather than by tenants. Regarding heat and hot water, nearly three fourths of DDRT tenants are responsible for paying for their own consumption while this is the case for only approximately 60% of LRA tenants.

**Table 2: Responsibility for utility bills in rental units (SHEU 2003)**

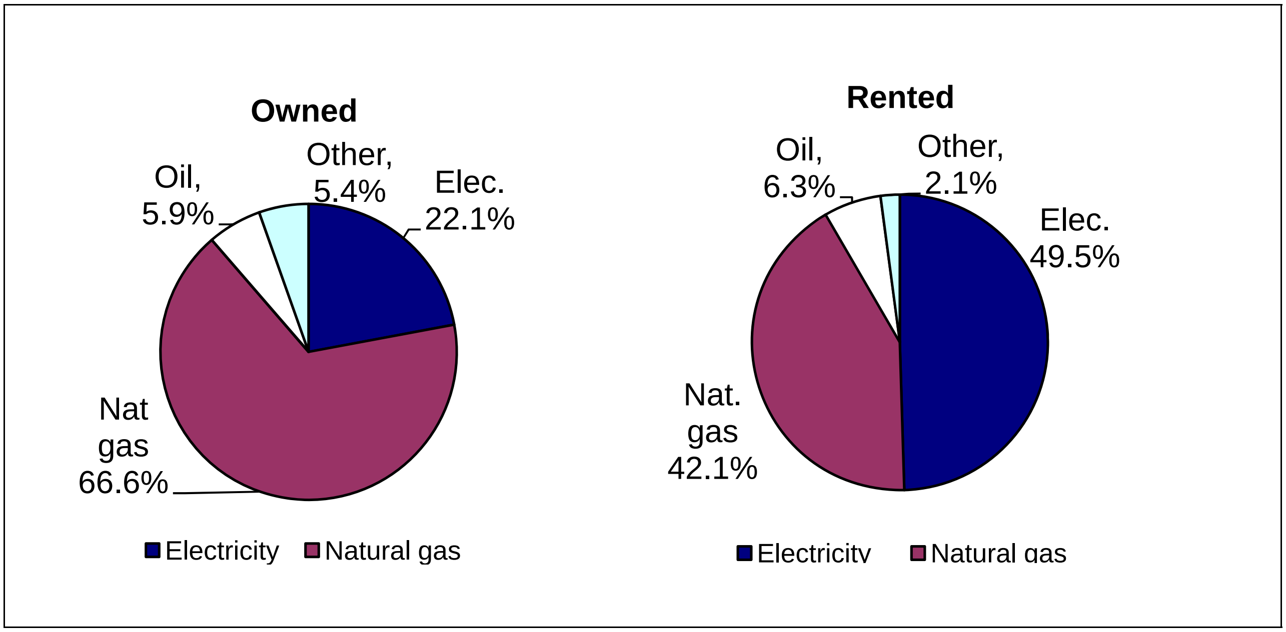
| *Utility bill* | Row, terrace, duplexes or double house | | Low-rise apartment | | Total | |
|---|---|---|---|---|---|---|
| | Occupant pays | Landlord pays | Occupant pays | Landlord pays | Occupant pays | Landlord pays |
| Electricity | 81% | 19% | 74% | 26% | 76% | 24% |
| Natural gas | 61% | 39% | 4% | 96% | 24% | 76% |
| Oil | 33% | 67% | 6% | 94% | 12% | 88% |
| *Purpose* | | | | | | |
| Space heating | 73% | 27% | 55% | 45% | 60% | 40% |
| Hot water | 75% | 25% | 63% | 37% | 66% | 34% |

### 3.2 *Fuel Use for Water and Space Heating in Rental Dwellings*

Nearly 60% of LRA occupants surveyed use electricity for space heating, around 30% use natural gas, 4% heating oil and 6% other sources of energy. The pattern is the same for rented and owner-occupied units. For DDRT dwellings, Figure 3 illustrates major differences in the choice of heating fuel between dwellings that are rented and those that are owned. In owned dwellings, natural gas is the primary source of heating, followed by electricity. In rental dwellings, there is an almost even split between natural gas and electricity. It should be noted that in our data set, the choice of energy source for water and space heating is strongly correlated with the type of heating equipment installed in the building and also with the distribution of bills between landlord and tenant. In other words, the equipment selected for space and water heating, along with the energy source used, often limits the billing options for the utility supplier. In situations where separate billing for each unit is not feasible, it will generally be the landlord who pays the corresponding energy bill. If separate metering is available for each unit, the landlord has the option of making the tenant responsible for the energy bill.

Around 60% of LRA occupants use electricity and 40% natural gas as their fuel source for hot water. This is the case regardless of whether the dwelling is rented or owner-occupied. In DDRTs, electricity is used as a fuel source for hot water in approximately 40% of owned and 60% of rental dwellings, with the remaining households using natural gas.

**Figure 3: Heating Fuel Sources for Double / Duplex / Row / Terrace dwellings**




**Source: SHEU 2003**

From Table 3, we see that buildings where the occupant pays the heating bill are primarily heated by means of electricity. This is especially predominant in LRAs. In cases where the landlord pays, the fuel for heating is more likely to be natural gas or oil. This likely reflects the fact that when a building uses natural gas or oil, central heating technologies tend to be used. The share of buildings using oil is somewhat low, although it is higher in buildings where heat is included in the rent. This is true for the two categories of multi-family buildings under consideration. Table 4 provides the corresponding statistics for water heating. Electricity is used in close to 60% of the rental dwellings and natural gas in close to 40% of them. For the subset where the occupant pays the bill, these shares move to two thirds of dwellings using electricity and one third using natural gas. And in the subset where the landlord pays for hot water, close to 40% of dwellings use electricity and 60% use natural gas. There are no major differences between the types of dwellings. It seems that the use of electricity facilitates separate billing since it is more often used in buildings where the occupant pays for the bill while natural gas is more often used in buildings where the landlord pays the hot water bill.

**Table 3: Energy used for space heating in rental dwellings**

| | Row, terrace, duplexes or double house | | Low-rise apartment | | Total | | |
|---|---|---|---|---|---|---|---|
| *Space heating energy source* | Occupant pays | Landlord pays | Occupant pays | Landlord pays | Occupant pays | Landlord pays | Total |
| Electricity | 56.7% | 30.1% | 77.3% | 35.4% | 70.3% | 34.4% | 55.9% |
| Natural gas | 36.8% | 56.6% | 9.3% | 52.5% | 18.6% | 53.2% | 32.6% |
| Oil | 3.7% | 13.3% | 2.2% | 12.1% | 2.7% | 12.3% | 6.6% |
| Other | 2.9% | .0% | 11.2% | .0% | 8.3% | .0% | 5.0% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

**Table 4: Source of energy used for water heating in rental dwellings**

| | Row, terrace, duplexes or double house | | Low-rise apartment | | Total | | |
|---|---|---|---|---|---|---|---|
| *Water heating energy source* | Occupant pays | Landlord pays | Occupant pays | Landlord pays | Occupant pays | Landlord pays | Total |
| Electricity | 63.5% | 37.6% | 68.2% | 38.8% | 66.7% | 38.6% | 57.2% |
| Natural gas | 32.4% | 62.4% | 22.5% | 61.2% | 25.6% | 61.4% | 37.8% |
| Oil | .0% | .0% | .0% | .0% | .0% | .0% | .0% |
| Other | 4.1% | .0% | 9.3% | .0% | 7.7% | .0% | 5.1% |
| Total | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% | 100.0% |

### *3.3 Effects of Split Incentives in Rental Dwellings*

The determination of the agent whose responsibility it is to pay for utilities is expected to have an impact on energy usage and technology choices due to agency and asymmetric information problems (outlined above in Section 2). Below we examine the energy usage of dwellings based on whether it is the tenant or the landlord who pays for utilities. We also examine the prevalence of energy-efficient appliances in dwellings by looking at the ages of major appliances and the adoption of Energy Star® qualified major and small appliances. [4] Finally, we look at a variety of energy saving practices of building occupants and at renovations made by landlords.

#### *3.3.1 Energy Usage*

Table 5 compares energy consumption per square foot of heated dwelling space in owned and rented multi-family dwellings.[5] Shaded cells indicate potential cases of agency-related usage problems. Usage effects appear to be quite common, with the extent of additional energy consumption by tenants who do not pay their own utility bills varying substantially. In LRA buildings, the data suggest that tenants who do not pay for their own electricity use almost 70% more electricity per square foot than their counterparts who pay their own bills. This impact is larger than for DDRTs where the difference is approximately 40%. In DDRTs, natural gas consumption per square foot is also close to 40% higher in dwellings where landlords pay the utilities. There is no evidence of any corresponding usage problem for natural gas in LRAs. For electricity, consumption in owned dwellings is similar to that of rented dwellings where the tenant pays for the utility, but for other types of energy, the consumption in owned dwellings is consistently lower than consumption in rental dwellings.

[4] Energy Star® certification, introduced in Canada in 2001, guarantees relatively low consumption of energy for eligible products. More information can be found at http://oee.nrcan.gc.ca/residential/personal/appliances/energy-star.cfm?attr=4

[5] Note that much of the energy usage data for multi-family dwellings has been imputed by Statistics Canada. Interpretation of statistics related to energy use should therefore proceed with caution.

**Table 5: Energy usage in owned and rental dwellings**

| | Row, terrace, duplexes or double house | | | Low-rise apartment | | |
|---|---|---|---|---|---|---|
| | Owned | Occupant pays | Landlord pays | Owned | Occupant pays | Landlord pays |
| Electricity | .029739 | 0.0346 | 0.0484 | .040252 | 0.0423 | 0.0716 |
| | | | +39.86% | | | +69.34% |
| Natural gas | .031329 | 0.0646 | 0.0879 | .040673 | .129062 | .117079 |
| | | | +36.01% | | | -9.29% |
| Oil | .004952 | .062939 | .045562 | .004805 | .251593 | .226846 |
| | | | -27.61% | | | -9.84% |
| Total * | .066044 | 0.0635 | 0.0871 | .085730 | 0.0694 | 0.1483 |
| | | | +37.06% | | | +113.51% |

*Energy use is measured in gigajoules of energy per square foot of heated area*

### *3.3.2 Choice of Appliances*

The choice of appliances is also likely to be affected by the split incentives between landlords and tenants. And, unlike the case of energy use data, information on appliance choice is not complicated by imputation issues. In rental dwellings, equipment such as heating and cooling systems and major household appliances (stove or fridge) are basically chosen by the landlord and will remain attached to the dwelling as tenants move in and out. Smaller items such as light bulbs and entertainment appliances (TV, DVD, stereo) are typically bought by the tenant, who will keep them when moving from one dwelling to another.[6]

In terms of efficiency, major appliances tend to be more efficient when they are more recent models, since they incorporate newer technology, and will be especially more efficient when labelled as an Energy Star® product. For smaller items, fluorescent or halogen light bulbs are an efficient choice compared to regular incandescent light bulbs, and Energy Star® entertainment appliances will be more energy efficient than their counterparts. There is evidence of an efficiency problem if the appliances chosen by landlords tend to be older and/or non Energy Star® in dwellings where the tenant pays the

[6] While a tenant would not be likely to take an incandescent light bulb when moving, a tenant might consider moving more expensive CFL bulbs to a new residence.

utility bills. In other words, landlords are expected to invest more in newer and/or Energy Star® appliances when they are responsible for paying for the energy used. Similarly, tenants would be expected to be more likely to choose energy-efficient entertainment appliances or light bulbs when they are paying directly for the electricity used by these products.

Table 6 shows the average age of each type of major equipment chosen by the landlord. Shaded cells correspond to cases where there is evidence of an efficiency problem: where the landlord supplies a utility-paying tenant with equipment that is older. It appears that efficiency problems, when measured via appliance age, occur only in the LRA subset of the data, and only for heating and hot water systems. Contrary to expectations, other appliances are not older on average when the tenant pays the electricity bill. It is possible that high vacancy rates in some regions may be counteracting the agency-related efficiency impacts. It is always the case, however, that the average age of appliances in owned units is lower than in rental units.

**Table 6: Age of equipment in multi-family dwellings in years**

| *Age of major appliances* | Row, terrace, duplex or double house | | | Low-rise apartment | | |
|---|---|---|---|---|---|---|
| | Owned | Occupant pays | Landlord pays | Owned | Occupant pays | Landlord pays |
| Heating system | 12.6 | 16.7 | 19.5 | 12.6 | 16.2 | 15.6 |
| Hot water tank | 4.4 | 8.0 | 8.8 | 3.8 | 7.9 | 6.8 |
| Fridge | 6.0 | 6.2 | 8.2 | 6.6 | 7.8 | 10.9 |
| Stove (electric) | 6.4 | 9.2 | 11.1 | 8.6 | 10.0 | 13.2 |

*The average age is calculated based on the mid-points of reported age categories.

**Table 7: Number and type of appliances**

| | Row, terrace, duplexes or double house | | Low-rise apartment | |
|---|---|---|---|---|
| *Number of Energy Star appliances in the household* | Occupant pays | Landlord pays | Occupant pays | Landlord pays |
| Total number | 1.10 | 0.55 | 0.72 | 0.43 |
| Housework | 0.34 | 0.16 | 0.27 | 0.09 |
| Heating or cooling | 0.12 | 0.01 | 0.00 | 0.00 |
| Entertainment | 0.64 | 0.39 | 0.45 | 0.34 |
| *Ratio of Energy Star appliances in household* | | | | |
| Total number | .15 | .09 | .11 | .07 |
| Housework, cooling and heating | .11 | .04 | .08 | .03 |
| Entertainment | .18 | .12 | .14 | .11 |
| *Number of small appli ances in the household* | | | | |
| Small appliances / adult | 3.66 | 3.06 | 3.33 | 3.11 |

Another way of detecting evidence of efficiency problems is to look at the number of Energy Star® appliances or the ratio of Energy Star® to total appliances in a dwelling. This information is presented in Table 7. Landlords do not appear to choose a higher number of Energy Star® products when they pay for electricity usage. However, from the number and ratio of small Energy Star® appliances (TV, DVD player, VCR, satellite dishes and stereo systems) selected by the tenant, there is evidence of an efficiency problem. The number and ratio of Energy Star® appliances chosen by tenants are both lower when the landlord pays for electricity. However, the total number of small appliances per adult, which might be expected to be higher when a landlord pays the electricity bill, is on average lower for households whose electricity bills are paid by the landlord.

### *3.3.3 Energy-Saving Practices*

Agency problems are also expected to affect the general adoption of energy saving behaviour by a household. Table 8 shows that as far as temperature settings are concerned, households that do not pay for heat almost always opt for increased thermal comfort. Similarly, more households change temperature settings between day, evening and night hours when they pay for their own heat. Programmable thermostats are also programmed more often in households that are responsible for paying for their own heat.

**Table 8: Temperature setting[7]**

| | Row, terrace, duplexes or double house | | Low-rise apartment | |
|---|---|---|---|---|
| *Temperature during heating season (in degrees celsius)* | Occupant pays | Landlord pays | Occupant pays | Landlord pays |
| Day | 19.65 | 21.05 | 19.36 | 20.44 |
| Evening | 20.23 | 21.11 | 19.97 | 20.76 |
| Night | 18.97 | 20.47 | 18.95 | 19.74 |
| *Share of households where…* | | | | |
| The temperature changes | 14.6% | 3.0% | 7.7% | 7.5% |
| Thermostat is programmed | 8.4% | 2.3% | 5.2% | 4.0% |

Table 9 shows that the share of households adopting non–environmentally friendly behavior is clearly higher in dwellings where the landlord pays at least one of the utility bills (electricity, natural gas or oil).[8] Although there was not always a clear pattern of efficiency or usage problems when examining the quantity of energy consumed or the choice of appliances, Tables 8 and 9 show clearer patterns in terms of the adoption of non-environmentally friendly practices depending on whether or not an occupant is responsible for paying for utilities.

[7] These numbers include only households who have control over the temperature setting in their dwellings (5.6% of households in multifamily dwellings in the sample do not have direct control of temperature settings)

[8] The results are similar if, rather than considering dwellings where the landlord pays "at least one the bill" we consider dwellings where the landlord pays for electricity or dwellings where the landlord pays for heat.

**Table 9: Adoption of non-environmentally friendly practices**

| *Share of households that…* | Row, terrace, duplexes or double house | | Low-rise apartment | |
|---|---|---|---|---|
| | Occupant pays* | Landlord pays** | Occupant pays* | Landlord pays** |
| Rinse dishes before using the dishwasher | 52% | 83% | 77% | 79% |
| Do not use water saving showerhead | 53% | 47% | 63% | 60% |
| Use hot or warm water for the washing machine | 47% | 77% | 35% | 66% |
| Dry the dishes with heat on when using dishwasher | 49% | 92% | 48% | 50% |
| Use only incandescent light bulbs | 35% | 36% | 38% | 42% |

Note: * indicates that the occupant pays all three bills;
** indicates that the landlord pays at least one of the bills

Agency problems may also have an impact on energy saving renovations and improvements made to rental dwellings. Table 10 shows the percentages of multi-family rental dwellings where various types of renovations were undertaken in 2003 according to the agent who pays the heating bill (upper panel) and according to the agent who pays for the electricity (lower panel). No consistent patterns emerge. In many cases, the share of dwellings that had renovations is higher when tenant pays for either heat or electricity than when the landlord pays.

**Table 10: Percentage of dwellings with renovations in 2003**

| | Row, terrace, duplexes or double house | | Low-rise apartment | |
|---|---|---|---|---|
| | Occupant pays | Landlord pays | Occupant pays | Landlord pays |
| *by agent paying heat* | | | | |
| roof structure or surface | 5.01% | 9.52% | 8.10% | 7.28% |
| exterior wall siding | 2.34% | 0.00% | 3.08% | 4.31% |
| insulation of roof or attic | 0.00% | 0.00% | 2.49% | 1.62% |
| insulation of basement or crawl space walls | 2.74% | 0.00% | 1.59% | 0.83% |
| insulation of any exterior walls | 2.58% | 0.00% | 1.28% | 0.32% |
| Foundation | 1.05% | 0.00% | 0.14% | 0.24% |
| heating equipment | 2.17% | 1.03% | 5.15% | 3.71% |
| ventilation or AC equipment | 0.00% | 1.03% | 2.71% | 1.91% |
| At least one improvement | 13.4% | 10.5% | 16.8% | 13.9% |
| *by agent paying electricity* | | | | |
| roof structure or surface | 6.03% | 7.49% | 7.77% | 7.37% |
| exterior wall siding | 2.16% | 0.00% | 2.91% | 5.99% |
| insulation of roof or attic | 0.00% | 0.00% | 1.86% | 2.92% |
| insulation of basement or crawl space walls | 2.52% | 0.00% | 1.26% | 1.29% |
| insulation of any exterior walls | 2.37% | 0.00% | 1.07% | 0.22% |
| foundation | 0.97% | 0.00% | 0.11% | 0.43% |
| heating equipment | 2.00% | 1.44% | 4.04% | 6.11% |
| ventilation or AC equipment | 0.00% | 1.44% | 1.78% | 3.44% |
| At least one improvement | 13.8% | 8.9% | 15.2% | 16.5% |

Even though there is no strong evidence of differences in renovation rates between dwellings where landlords and where tenants pay for utilities, there are some pronounced differences between owned and rented dwellings. As seen in Table 11, the share of dwellings that have undergone renovations is much higher in owned dwellings than in those in the rental market. These results suggest that the split incentive affecting improvements is not only financial (who pays the bill) but also resides in other aspects of home renovation. Barriers such as difficulties in renovating when tenants are occupying the dwelling, access to investment loans for small landlords, and access to government incentive programs may play a role in the relatively low rate of renovations of rental dwellings.

**Table 11: Percentage of dwellings with renovations in 2003: owned and rented dwellings**

| | Row, terrace, duplexes or double house | | Low-rise apartment | |
|---|---|---|---|---|
| | Owned | Rented | Owned | Rented |
| roof structure or surface | 2.64% | 6.22% | 2.77% | 7.73% |
| exterior wall siding | 1.24% | 1.71% | 0.65% | 3.64% |
| insulation of roof or attic | 2.17% | 0.00% | 0.71% | 2.10% |
| insulation of basement or crawl space walls | 2.64% | 2.00% | 5.02% | 1.24% |
| insulation of any exterior walls | 2.42% | 1.89% | 3.95% | 0.84% |
| Foundation | 0.98% | 0.77% | 0.94% | 0.19% |
| heating equipment | 4.30% | 1.86% | 1.58% | 4.50% |
| ventilation or AC equipment | 2.73% | 0.28% | 1.34% | 2.35% |
| At least one improvement | 11.54% | 9.80% | 14.95% | 15.54% |

## 4 Econometric Models[9]

In this section we construct econometric models that control for other factors when examining the determinants of energy usage and appliance choice in Canadian multi-family dwellings. As in Section 3, we start by looking at energy use and then proceed with an examination of a variety of related decisions.

The dependent variable in our energy regression is energy (or electricity) intensity, measured as (the natural logarithm (*ln*) of) total energy (gigajoules of electricity, natural gas, oil, propane) or electricity use per square foot of heated dwelling area. Explanatory variables include a number of physical characteristics of the dwelling including equipment, the type of energy used for space and water

[9] This section contains preliminary results. Model diagnostic testing has not yet been completed.

heating, and the building age. Also included are a set of socio-economic variables such as household size and composition, and income. Furthermore we control for whether the unit is owner-occupied, and whether it is the landlord or the tenant who pays for the utilities in a rental dwelling. In all regressions, a set of provincial dummies is included as well as heating degree days for the city in which the dwelling is located. To conserve space, only variables with significant coefficients are included in the tables of results. As noted earlier, many of the energy use observations are imputed. Imputation rates for energy variables are shown in the Appendix.

Price data for natural gas and oil are not used (due to missing values), but the price of electricity is included, essentially because electricity is the main source of residential energy expenditure. An interaction term between the 'landlord pays' dummy and the *price* variable is included to capture the fact that the price effect is expected to be different for those who face a zero marginal cost of energy use. An additional interaction term between the 'owner-occupied' dummy and price is included to allow for the possibility that home owners may respond differently to price changes than renters.

For appliances, the number of small (entertainment) appliances per adult is taken into consideration, while for major (housework, heating and cooling) appliances the total number of devices in the dwelling is used. Entertainment appliances include TV, DVD player, VCR recorder, satellite and stereo system. Housework appliances include the number of fridges, cooking stoves and freezers. The Energy Star® ratios represent the share of Energy Star® models among the appliances in each category. The major appliances are those chosen by the landlord (housework, heating and cooling) while small appliances are those chose by the occupant (entertainment). Many of the results are consistent with general expectations. For overall energy use, compared with the base case of a building constructed during the 1920s, buildings constructed in more recent years tend to use energy less intensely. The same does not hold true for electricity. This is consistent with better weatherization for newer houses which will tend to affect heating costs. Households with 'extra' appliances such as freezers, dishwashers and air conditioning tend to use electricity more intensely. And, as hypothesized, households for whom heating (electricity) is paid by a landlord use energy (electricity) more intensely.

Among the results that do not match with theory, the most striking is the positive effect of electricity price on energy intensity for all groups (owner-occupants, renters who pay their own utilities, and renters who do not pay their own utilities).

## Table 12: Energy Intensity Regressions

| | Total energy intensity | Electricity intensity |
|---|---|---|
| | coefficient (standard error) | coefficient (standard error) |
| Household size | | 7.81E-02 ( 0.1950E-01)*** |
| ln(heated area) | -0.51943 (0.4600E-01)*** | -0.59513 (0.4713E-01)*** |
| Urban dwelling | | 0.20352 (0.1162 )* |
| Owned | -1.1935 (0.5959 )** | |
| number of Energy Star® housework appliances | 0.15530 ( 0.8300E-01)* | |
| Energy Star® ratio - major appliances | -0.61764 ( 0.3422)* | 0.62022 (0.3484)* |
| Energy Star® ratio - small appliances | -0.52358 ( 0.2976)* | |
| landlord pays the electricity | | 2.8887 (1.034)*** |
| landlord pays the heat | 0.16301 (0.8867E-01)* | |
| water heating by electricity | | 0.69949 (0.1598 )*** |
| water heating by natural gas | | 0.35232 (0.1661)** |
| space heating uses electricity | -0.20689 ( 0.7759E-01)*** | 0.13564 (0.6636E-01)** |
| space heating uses natural gas | 0.29724 (0.8596E-01 )*** | -0.34743 (0.8826E-01)*** |
| space heating uses oil | 0.47062 (0.1132)*** | -0.27506 (0.1015)*** |
| dishwasher | | 0.92685E-01 (0.3852E-01)** |
| freezer | 0.10502 ( 0.4183E-01)** | 0.13625 (0.3696E-01)*** |
| ln(electricity price) | 1.2484 ( 0.3236)*** | 2.1758 ( 0.3147)*** |
| landlord pays * ln(electricity price) | | 0.95573 (0.3941 )** |
| owner-occupied * ln(electricity price) | -0.47296 (0.2266)** | |
| Air Conditioned | | 0.10669 ( 0.6239E-01)* |
| Age 9 (built after 1999) | -0.35958 ( 0.1208)*** | |
| Age 6 (built 1950 to1959) | -0.28838 (0.8715E-01)*** | |
| Age 5 (built 1940 to 1949) | -0.17868 (0.9269E-01)* | |
| Constant | 4.5276 ( 1.825)** | 4.0956 (1.753)** |
| | | |
| R square | 0.3802 | 0.5738 |
| Number of observations | 1061 | 1061 |
| Mean of dependant variable | -2.7485 | -3.5711 |

Notes: Heteroskedasticity consistent standard errors are used throughout;
***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Since many of the energy use values for multi-family dwelling units are imputed, results from regressions that examine other aspects of energy-related decisions (whose values are less likely to be imputed) may provide useful information regarding the impact of agency issues on energy-related behaviour. To this end, we consider a variety of models.

### 4.1 Temperature Settings

**Table 13: Temperature Setting Regressions**

| | Day | Evening | Night |
|---|---|---|---|
| | coefficient (standard error) | coefficient (standard error) | coefficient (standard error) |
| Proportion of household under 18 years old | | | 0.90942 (0.5242)* |
| Urban dwelling | | | 0.70719 (0.3606)* |
| Energy Star® ratio - major appliances | -0.90154 ( 0.3472)** | | |
| Small appliances | -0.10914 (0.4210E-01)** | | -0.91914E-01 (0.4447E-01)** |
| Dishwasher | 0.31986 (0.1632)* | 0.30448 (0.1541)** | |
| Air Conditioned | | 0.38172 (0.2054)* | 0.60784 (0.2532)** |
| A landlord pays the electricity | | | |
| A landlord pays the heat | 0.85235 (0.2565)*** | 0.70164 (0.2254)*** | 0.60909 (0.2782)** |
| Programmable thermostat is programmed | -0.53050 (0.2265)** | | -0.88207 (0.2101)*** |
| Heating degree days (log) | 1.6748 (0.6113)*** | 1.2047 (0.5452)** | 1.2288 (0.6741)* |
| A9 (built after 1999) | -1.3523 (0.6751)** | | |
| A8 (built 1990 to 1999) | -1.1032 (0.5518)** | -1.0723 (0.5746)* | |
| A7 (built 1980 to 1989) | -1.089 (0.5464)** | -1.0206 ( 0.5696)* | |
| A3 (built 1940 to 1949) | -1.1196 ( 0.5843)* | -1.0325 (0.6259)* | |
| INCOME (40 to 60 thousand) | -0.54537 (0.2049)*** | | |
| INCOME (60 to 80 thousand) | -0.6009 (0.2296)*** | | |
| INCOME (80 to 100 thousand) | -0.57891 ( 0.2571)** | | |
| INCOME (100 thousand+) | -1.0872 (0.3827)*** | | -0.80833 (0.3700)** |
| Constant | | 9.5361 (5.520)* | |
| | | | |
| R square | 0.1201 | 0.0810 | 0.1418 |
| Number of observations | 1012 | 1012 | 1012 |
| Mean of dependant variable | 19.751 | 20.308 | 19.062 |

Notes: Heteroskedasticity consistent standard errors are used throughout;
***, **, * denote significance at 1%, 5%, and 10% levels, respectively.

Respondents to the SHEU 2003 survey provided information on space-heating thermostat temperature settings within the home for daytime, evening and nighttime hours. Many of the results from the temperature setting regressions are consistent with those found in the energy regressions. Residents of more recently constructed buildings, for example, use lower temperature settings, at least during the daytime and evening hours. This is likely due to better weatherization in these homes. As might be expected, those who live in colder regions tend to have higher temperature settings at all times of day. Furthermore, those households that might be most environmentally aware (in terms of programming a thermostat or using Energy Star® appliances) tend to have lower temperature settings. Households where children are present tend to keep the house warmer overnight. Compared to households in the lowest income group, those with higher incomes tend to have lower temperature settings during the day. It may be the case that those in higher income groups are less likely to be home during the day, and therefore more likely to turn down the heat during daytime hours. In terms of agency effects, regardless of the time of day, households who do not pay their own heating bills opt for additional thermal comfort at all times of the day.

## 4.2 Appliance Choice

Regardless of whether a unit is owner-occupied or rented, it will typically be the occupants of a dwelling who purchase small kitchen and entertainment appliances. It will generally be the owner (owner-occupant or landlord[10]), however, who purchases the heating, hot water and major kitchen appliances such as the refrigerator and stove. If there are major 'efficiency' problems, we would expect to see that in cases where the landlord pays the heat or electricity, less efficient appliances would be purchased. If there is a major 'usage' problem, we would expect to see tenants, who do not pay their own electricity, purchase less energy-efficient products (at least if they plan to be long-term residents of such a dwelling). As our measure of appliance efficiency, we consider the percentage of appliances in each category that are labeled as Energy Star® products. One drawback of this approach is that at the time of the survey, the Energy Star® program had only been in effect for 4 years. When controlling for other factors, either using the full sample of all multi-family dwellings or the subset of rental units, there was no evidence of any usage or efficiency problems. In fact, in the only case in which a 'landlord pays' dummy had a significant coefficient, the sign was contrary to expectations.

[10] The landlord may be acting as an agent for the building owner.

### 4.3 Environmentally Unfriendly Behaviour of Tenants

A series of probit regressions was used to examine the determinants of whether or not a tenant was in the habit of undertaking the following 'environmentally unfriendly' behaviours:

(i) rinse dishes before using dishwasher (using subset of dwellings with a dishwasher);

(ii) dry dishes using 'heat' as compared to drying dishes by leaving the door open and the heat off (using subset of dwellings with a dishwasher);

(iii) no water-saving showerhead;

(iv) wash clothing not using cold water.

In none of the cases was either 'landlord pays electricity' or 'landlord pays heat' a significant factor. And, in fact, in only the second case was the probit model able to outperform a naïve model where the predicted outcome for all households is whatever outcome is most prevalent in the sample.

### 4.4 Renovations by Landlords

One of the main barriers to improving energy efficiency in rental dwellings is a lack of incentives for the landlord to invest in the dwelling, especially if the tenant is paying the utility bills. It would be expected that dwellings where the landlord pays the heat would be more likely to be renovated (as the landlord reaps the benefits from energy savings). To examine renovation behaviour, another set of probit regressions was undertaken. In particular, we examine the determinants of recent renovations and those planned for the year following the survey for both the full sample and the subsample of rented units. As the dependent variable we use a dummy variable that is equal to 1 if a renovation was made (planned) that would potentially affect the energy intensity of the dwelling.

Not surprisingly, only a small share of the dwellings had been improved or was slated for improvement. Of the four probit regressions, in only one was a 'landlord pays' variable found to be a significant factor in the decision to renovate. This occurred for planned renovations for the rental dwelling subset. If a landlord pays the heat, the probability of an energy-related renovation increases by 0.16 . Although this particular variable is significant and the prediction success outperforms a naïve model, the regression is not significant overall according to a likelihood ratio test (p-value = 0.13). Notwithstanding, if it is the case that renovations in any given year consist of a combination of those that had been planned and those that are undertaken on an emergency basis, it is not surprising that it is only in the case of planned renovations that there is any individually significant impact found in the data that can be attributed to agency effects.

## 5 Concluding Remarks

The multi-family dwelling portion of the Canadian residential sector presents challenges for energy efficiency efforts. This is partially due to the variety of ownership and tenancy relationships that can be found in this sector. The SHEU-2003 data allow us to examine a variety of aspects of energy use behaviour for residents of small-scale multi-family buildings (excluding high rise apartments). We find that households who own their dwelling unit tend to use total energy most efficiently (in terms of consumption per square foot of heated area), while those who rent and are not responsible for paying their own heating bills use energy the most intensely. While there is no significant difference in terms of the intensity of electricity use between owners and renters who pay their own electricity bills, those renters who have their electricity charges included in their rent use electricity more intensely. Since much of the energy usage data in SHEU-03 has been imputed, these results should be interpreted with caution.

The SHEU-03 data allow us to consider other aspects of behaviour. The increased use of energy by those who do not pay directly for their heat is verified in a series of regressions that look at the determinants of temperature settings. Regardless of the time of day, those who do not pay heating bills opt for additional thermal comfort. There is also (somewhat weaker) evidence that landlords who pay for heat tend to plan more energy-related renovations, possibly to offset the decisions of their tenants to turn up the heat. There is no corroborating evidence, however, for the findings of increased electricity use by households who do not pay electricity bills. In particular, a series of probit regressions for the determinants of 'unfriendly' environmental behaviour and appliance choice show no significant impact of whether or not they pay for their own electricity on these choices. It may be the case that the typical household has bought into energy conservation / awareness campaigns, and even at a zero marginal cost of electricity has learned to limit energy use. An alternative interpretation would suggest that households who pay their own electricity bills are not sensitive to bearing a positive marginal cost of using energy and they adopt similar behaviours to those who do not pay directly for the energy they use.

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## Appendix: Imputation of Energy Data for Rental Multi-family Dwellings in SHEU-2003

| **Fuel Source** | **Imputed for:** |
|---|---|
| Electricity: | 33.6% of sample |
| Natural Gas: | 74.9% of those who use Natural Gas |
| Oil: | 83.6% of those who use Oil |

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