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Environmental Awareness and Household Energy Efficiency

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Executive Summary

The issue of environmental awareness, interpreted in many different ways – from operating in a sustainable manner, to reducing the size of the carbon footprint – has become increasingly prominent in recent years. The purpose of this paper is to investigate whether there are particular attributes associated with Canadian households that might be labelled as "environmentally aware", or "green". Specifically, data from the 2003 Survey of Household Energy Use (SHEU) are used to determine which, if any, characteristics – both of the house and of the household – are associated with energy efficiency. Particular attention is paid to attributes recorded in SHEU that might help identify households that could be considered to be environmentally aware. This analysis has potentially important policy implications in that to the extent that it is predominately these environmentally-aware households that are energy efficient, it would suggest that policies aimed at increasing energy efficiency in the residential sector would need to be directed more at increasing environmental awareness rather than simply increasing the availability of energy efficient products.

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1. Introduction

The concept of being environmentally aware can be interpreted in a number of different ways. In general terms, interpretations of this concept range from operating in a sustainable manner to reducing the size of one's carbon footprint. Whatever the precise interpretation that is used, there is little doubt that the concept has gained increased prominence in recent years. Its importance is reflected in product advertising that focuses more on environmental benefits, or at least a claimed lower degree of environmental harm, than on price, or on whether and to what extent the services that might be expected from the product are effectively provided. Apparently, at least some consumers must value these claimed environmental benefits, as these products are purchased even though their initial purchase cost often exceeds that of an apparently otherwise similar product that does not have, or claim to have, these attributes. Of course, purchase price is only one aspect of the cost of a product that requires energy – and/or other inputs such as water – to operate, and it is certainly possible that, at least in some cases, the present value of the total cost of purchasing and operating a product with claimed environmental benefits is less than that of a similar product without these benefits. Regardless of the outcome of such a comparison, it is likely that may consumers purchase products with claimed environmental benefits purely because they wish to be, or be seen to be, environmentally aware, that is, "doing their part" to help reduce the environmental implications of their actions.

There is a wide range of products that have or claim to have environmental benefits. Here, however, we limit our attention to a residential context, and in particular to the way in which households operate. Specifically, we focus on household appliances as well as other observed characteristics of residential buildings. Using data from the 2003 Canadian Survey of Household Energy Use (SHEU03), we investigate to what extent households appear to have availed themselves of these products with environmental benefits, and whether there are particular characteristics of Canadian households that are associated with the possession of these types of products. We also examine which, if any, characteristics – both of the house and of the household – are associated with energy efficiency. Particular attention is paid to attributes recorded in SHEU03 that might help identify households that could be considered to be environmentally aware, or "green". This analysis has potentially important policy implications in that to the extent that it is predominately these environmentally-aware households that are

energy efficient, it would suggest that policies aimed at increasing energy efficiency in the residential sector would need to be directed more at increasing environmental awareness rather than simply increasing the availability of energy efficient products.

The structure of the remainder of this paper is as follows. In Section 2 we examine energy-efficient appliance choices made by Canadian households, the penetration of various Energy Star appliances, and the prevalence of other forms of energy-saving behaviour in these households. In Section 3 the relationship between overall household energy efficiency and house characteristics is examined, while the relationship between energy efficiency and appliance choice is examined in Section 4. The results obtained using a regression-based approach to examining household energy efficiency and its relationship to various energy-efficient appliance choices and other household energy-saving behaviour are presented and analyzed in Section 5. Section 6 contains a brief summary and conclusions.

2. Appliance-Based Green Households

Although the concept of being "environmentally aware" or "green" covers many aspects of consumer behaviour, including transportation, recycling, composting, etc., we limit our attention here to a residential context, and in particular to energy use in residential buildings. Our analysis is based on data from the 2003 Survey of Household Energy Use (SHEU03) which surveyed over 4500 households across Canada (representing over 11 million households), excluding those residing in high-rise (five storeys or more) apartment buildings. In this survey, households were asked questions about their residence, energy consumption, appliance holdings, recent renovations, and some household characteristics. Within Canada, this is the first household survey to ask questions about energy-efficient appliances, and particularly those with the Energy Star designation.[1] Certain Energy Star designated products in specific product categories where levels and criteria can be harmonized – some products are not promoted because of climatic, language or regulatory concerns – began to be marketed and promoted in Canada in 2001 following an arrangement with the US EPA and US DOE.[2] Consequently, only appliances purchased in Canada within the 2001-2003 period could possibly have this designation.

Table 1 summarizes survey responses to questions concerning the presence of various Energy Star (ES) designated appliances in Canadian households. Column (1) of this table shows the proportion of Canadian households with an ES model of each appliance. Of course, not all households have all appliances – column (2) shows the proportion of households with each type of appliance, including both ES and non-ES models, in 2003. Presumably, all these households could have chosen to purchase a new ES model of these appliances but many decided not to do

[1] ENERGY STAR is a joint program of the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) that is designed to help save money and protect the environment through energy efficient products and practices. Introduced by the US EPA in 1992 as a voluntary labelling program designed to identify and promote energy-efficient products to reduce greenhouse gas emissions, Energy Star labelling was expanded in 1995 from computers and monitors to additional office equipment products and residential heating and cooling equipment. In 1996, EPA partnered with the US DOE for particular product categories, resulting in the Energy Star label appearing on major appliances, office equipment, lighting, and home electronics, and labelling has since been extended to cover new homes and commercial and industrial buildings. (http://www.energystar.gov/index.cfm?c=about.ab_history)

[2] "ENERGY STAR: News from Canada", Presentation at the International ENERGY STAR Meeting Washington, D.C. March 14, 2005, A. Wilkins and K. Delves, Office of Energy Efficiency, Natural Resources Canada. http://www.energystar.gov/ia/partners/downloads/international/2005_Canada.pdf

so. Therefore, for each appliance column (3) shows the proportion of households who own that appliance that have an ES model. Finally, since, as noted above, only appliances purchased in Canada between 2001 and 2003 could have the ES designation, column (4) shows the proportion of households with ES models relative to households that purchased a model of that appliance within the last three years.

Table 1: Proportion of Households with Specific Energy Star (ES) Appliances

Appliance	ES/Total	Use Appliance	ES/Use Appliance	ES/Possible ES
	(1)	(2)	(3)	(4)
Main refrigerator	15.4%	99.9%	15.4%	64.5%
Main freezer	5.5%	61.0%	9.0%	63.8%
Dishwasher	9.6%	55.1%	17.4%	65.1%
Washing machine	15.0%	88.3%	17.0%	69.4%
Television	13.4%	98.8%	13.6%	44.5%
VCR	12.4%	82.9%	15.0%	44.1%
DVD	21.9%	53.4%	41.0%	45.1%
Stereo	9.4%	86.2%	10.9%	34.4%
Furnace	5.7%	57.0%	10.0%	63.9%
Central AC	3.8%	26.7%	14.2%i	56.5%

As can be seen in column (1) of Table 1, except for DVD players, less than 16% of Canadian households possessed an ES model of any particular appliance in 2003. In general, market penetration of ES models was greatest for DVD players, refrigerators, washing machines, televisions, and VCRs, and is lowest (in terms of the appliances listed here) for central air conditioning, freezers, and furnaces. Of course, this does not take account of the fact that not all households have each appliance – as the penetration rates for each appliance in column (2) show – but even when this factor is accounted for in column (3), except for DVD players, less than 20% of households that have each particular appliance have an ES model of that appliance, and for freezers and furnaces this proportion is 10% or less.

When attention is limited to households that purchased the particular appliance within the last three years (column (4)), ES model penetration is seen to be considerably higher, ranging from 34% for stereo equipment to almost 70% for washing machines. Indeed, even central air

conditioning has an ES model penetration rate exceeding 56%, while for furnaces this rate is almost 64%. This suggests that as old appliances wear out and are replaced, households are more likely to choose ES models, so that the penetration of ES models of these appliances is likely to increase over time.

Table 2 shows the proportion of households with specified numbers of ES models of appliances. Over 58% of households have at least one ES model of an appliance, with almost 20% having more than two ES models of appliances. Consistent with the information in Table 1, this penetration of ES models is seen to be greatest (over 30%) for appliances designed for housework (washing machines, etc.) and for entertainment (DVD players, etc.), but remains relatively low (under 23%) for heating or cooling appliances. The relatively low proportion of households with no ES models of any appliance (41.8%) but higher proportions of households with no ES models of each of the three categories – housework, entertainment, and appliances – suggests that there is not a great deal of overlap in households decisions to purchase ES models of appliances in different categories. In other words, to a large extent, households that purchase an ES model of a housework appliance do not seem to be the same households that purchase an ES model of an entertainment appliance or of a heating or cooling appliance.

Table 2: Proportion of Households with Energy Star (ES) Appliances

Type of Appliance	Number of Energy Star Appliances			
	None	One	Two	More than Two
All	41.8%	24.4%	15.5%	18.3%
Housework	68.6%	21.0%	7.3%	3.1%
Entertainment	65.8%	18.3%	10.1%	5.8%
Heating or Cooling	77.6%	20.2%	2.2%	---

Even in the context of energy use for appliances in residential buildings, being an environmentally-aware household is not limited to purchasing ES models of household appliances. Many households may have been environmentally aware before ES designated products were available in Canada, while others may make appliance choices that take account of energy efficiency even though they do not purchase ES models. To reflect the possibility that there are indeed various shades of being green, Table 3 presents information of the proportion of

Canadian households that have adopted other energy-saving behaviour associated with appliance choice.

Table 3: Proportion of Households with Other Energy Saving Behaviour

Appliance/Activity	Proportion with the Specified Appliance/Activity relative to:	
	All Households	Subsample with Appliance
Front-loading washing machine	10.1%	11.5%
Use cold water for washing clothes	32.1%	36.3%
Moisture detector in clothes dryer	25.0%	30.1%
Dry dishes in dishwasher with heat off and/or door open	25.4%	46.1%
High efficiency furnace	20.2%	38.1%
Programmable Thermostat (PT) – one or more	29.8%	30.6%
PT that is programmed	23.0%	77.3%
Temperature of largest heating area varies	57.8%	
Water-saving showerhead	53.7%	
Use some Compact Fluorescent Lights (CFL)	31.8%	
Use some fluorescent lights	57.8%	
Use some halogen lights	47.8%	
Only use incandescent lights	20.2%	

As Table 3 shows, just over 10% of Canadian households use a front-loading washing machine, which is generally more energy efficient than a top-loading model. Almost one-third use cold water for washing clothes, while one-quarter have a clothes dryer that detects moisture which can prevent unnecessary energy use. Over 35% of Canadian households dry dishes in a dishwasher either with the heat off and the door closed or heat off and the door open, and this proportion increases to almost 50% if only those households with a dishwasher are considered. Over 20% have a high efficiency furnace – compared to under 6% for an ES model as shown in Table 1 – while for those with a furnace, the proportion with a high-efficiency model almost doubles to over 38%, compared to 10% for ES models. Approximately 30% of households have a programmable thermostat (PT) but only 23% of households have a PT that is actually programmed, comprising 77% of those who have a PT. Whether or not they have a PT, almost 60% of Canadian households vary the temperature in the largest heating area of their home between (at least two of) the day, evening, and nighttime periods. Over one-half of Canadian households use a water-saving showerhead, while around 58% use at least some fluorescent

lights, approximately 48% use some halogen lights, and just over 30% use some compact fluorescent lights (CFLs). In fact, only 20% of Canadian households use only incandescent bulbs in their lighting fixtures.

Based on this analysis, it appears that, at least in terms of appliance choice and usage, there are many Canadian households that could be categorized as environmentally aware, although the extent of this environmental awareness differs quite noticeably across households.[3] In the next sections we examine the extent to which this environmental awareness in appliance choice and other energy-saving behaviour is reflected in household energy efficiency.

[3] One caveat here is that the households who are surveyed may not have made the appliance choice. Some appliances may be provided with new homes, or inherited with old ones – especially furnaces, hot water systems, and possibly dishwashers and refrigerators. While SHEU03 contains some information on inherited appliances, it is not detailed enough to indicate whether the appliance currently in place was inherited. Therefore this issue is not considered further here.

3. Residential Greenness and Energy Efficiency

While information about the presence of energy-efficient appliances provides a measure of greenness, at least to some extent this only reflects overt greenness, that is, it indicates that the household is adopting aspects of energy-efficient behaviour with their choices of appliances, but not necessarily that they are actually saving energy through these, and other choices. To investigate this issue it is necessary to examine a measure of energy efficiency, and how this measure is affected by the household's decisions concerning the adoption of energy-efficient appliances. In this section we focus on energy efficiency and how it is related to various characteristics of the household. The relationship between energy efficiency and appliance choice is investigated in Section 4.

The energy efficiency measure that is considered here is energy use per square foot of heated area for each household. Total energy use is based on aggregate consumption of electricity, natural gas, heating oil, and propane, all measured in gigajoules. With the SHEU03 data it is possible to examine consumption of these energy sources separately, as well as – for electricity and natural gas – to focus on just the heating season or just the cooling season. However, a problem with disaggregating into the two seasons and different energy sources is that some uses of these energy sources are year-round (lighting, cooking, washing, etc.) while others are specific to the season (heating, air conditioning). Appropriate analysis that would account for these specificities would require incorporation of information about energy sources used for particular purposes, and controlling for these effects when examining energy efficiency. This issue is the subject of continuing research that is not reported here.

In terms of household area, the denominator of the energy efficiency measure that is used here, we focus on the heated area of the dwelling. This would appear to better reflect the area of the dwelling that is utilized by the household. It would also be possible using SHEU03 to use the total area of the building, but in view of the inclusion of low-rise apartments in the survey, this would necessitate their exclusion since building size and dwelling size for a particular household – to which the energy consumption data refer – would differ considerably for an apartment. Within SHEU03 the key variable used to determine heated area of the dwelling explicitly excludes the garage. For apartments, the garage in most cases would refer to indoor

parking, the heat for which would not be associated directly with the energy use measured for any particular household, so the exclusion of this area would be appropriate. However, for other dwellings, garages are often present, and in many cases are heated. Although respondents indicated if they had a heated garage, its size was not determined, except to the extent of the number of vehicles it could house.[4] Also, SHEU03 only asked about the heated area of basements, and not the heated area of other forms of foundation (crawl spaces, etc.), some of which were heated according to survey responses. As a result, in the analysis reported here, the heated area does not include garages and/or heated foundation areas other than basements, so that energy use per square foot figures will be overstated for some households. Dealing with this issue is also the subject of ongoing analysis. The size of the heated area ranges from 131 square feet to 9149 square feet – with an average of almost 1,850 square feet – for the sample of 4,551 respondents who, with the survey weights attached, collectively represent 11,169,389 households across Canada.

Measured as gigajoules of energy used per square foot, energy efficiency in Canadian households ranges from 0.0024 to 0.7758, with an average of 0.0786. As shown by the histogram of these energy efficiency measures in Figure 1, the distribution is positively skewed, with 50% of the energy efficiency values less than 0.063, and 95% less than 0.17. Figure 2 shows how energy efficiency varies across provinces. Average energy efficiency is best (lowest energy use per square foot) in New Brunswick and British Columbia, and is generally worst in the Prairie provinces (especially Saskatchewan) and some of the Atlantic provinces (Nova Scotia and Prince Edward Island) where the need for heating – as reflected in heating degree days (HDD) – is generally higher. Although the majority of the efficiency measures lie within a very small range for each province, Figure 2 shows that for most provinces there are a number of outliers.

[4] Some 305 of 3899 respondents who did not live in apartments indicated that they had a heated garage. However, heated area of these garages was only derived – either directly or by imputation – for 65 respondents, and so is omitted here.

Figure 1: Histogram of Energy Efficiency (gigajoules per square foot)

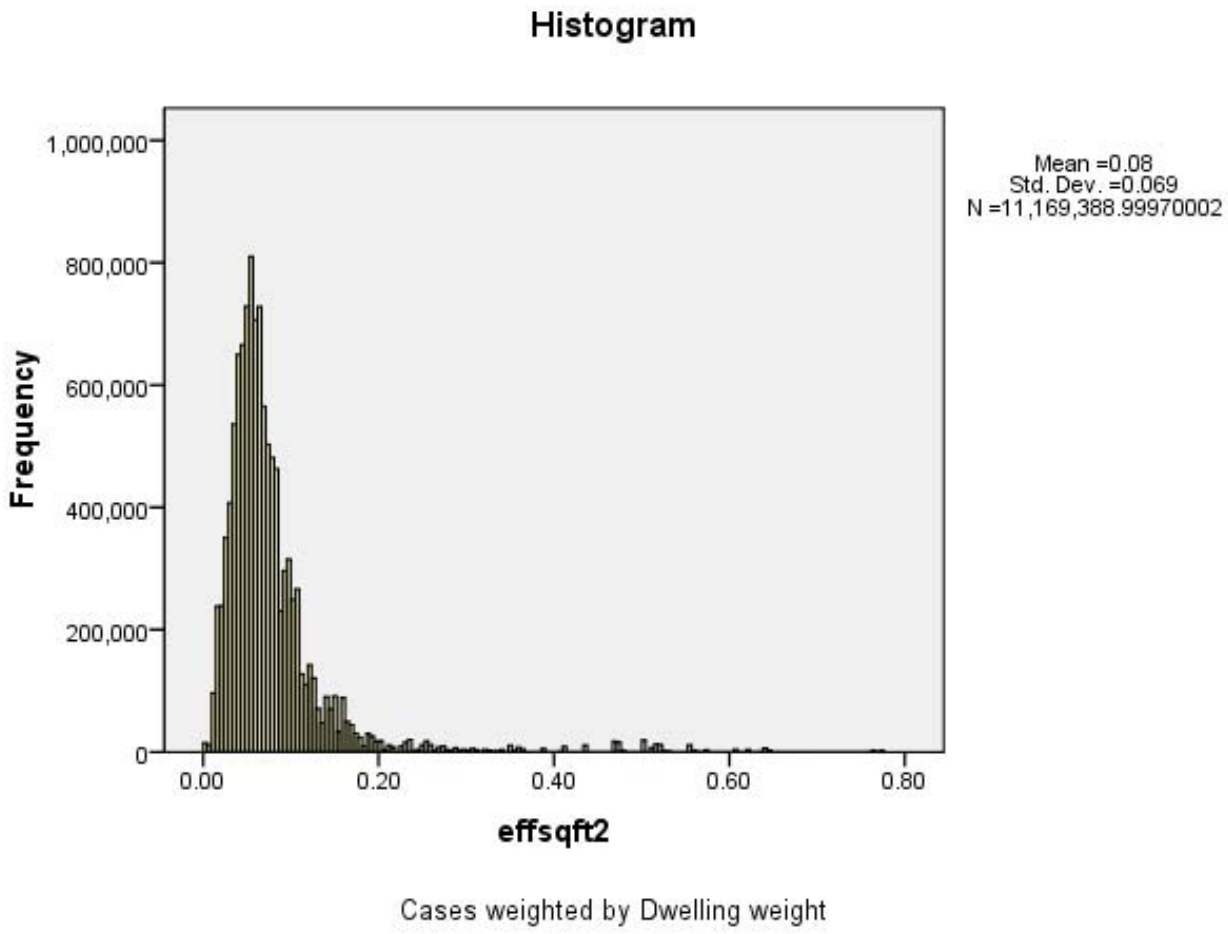
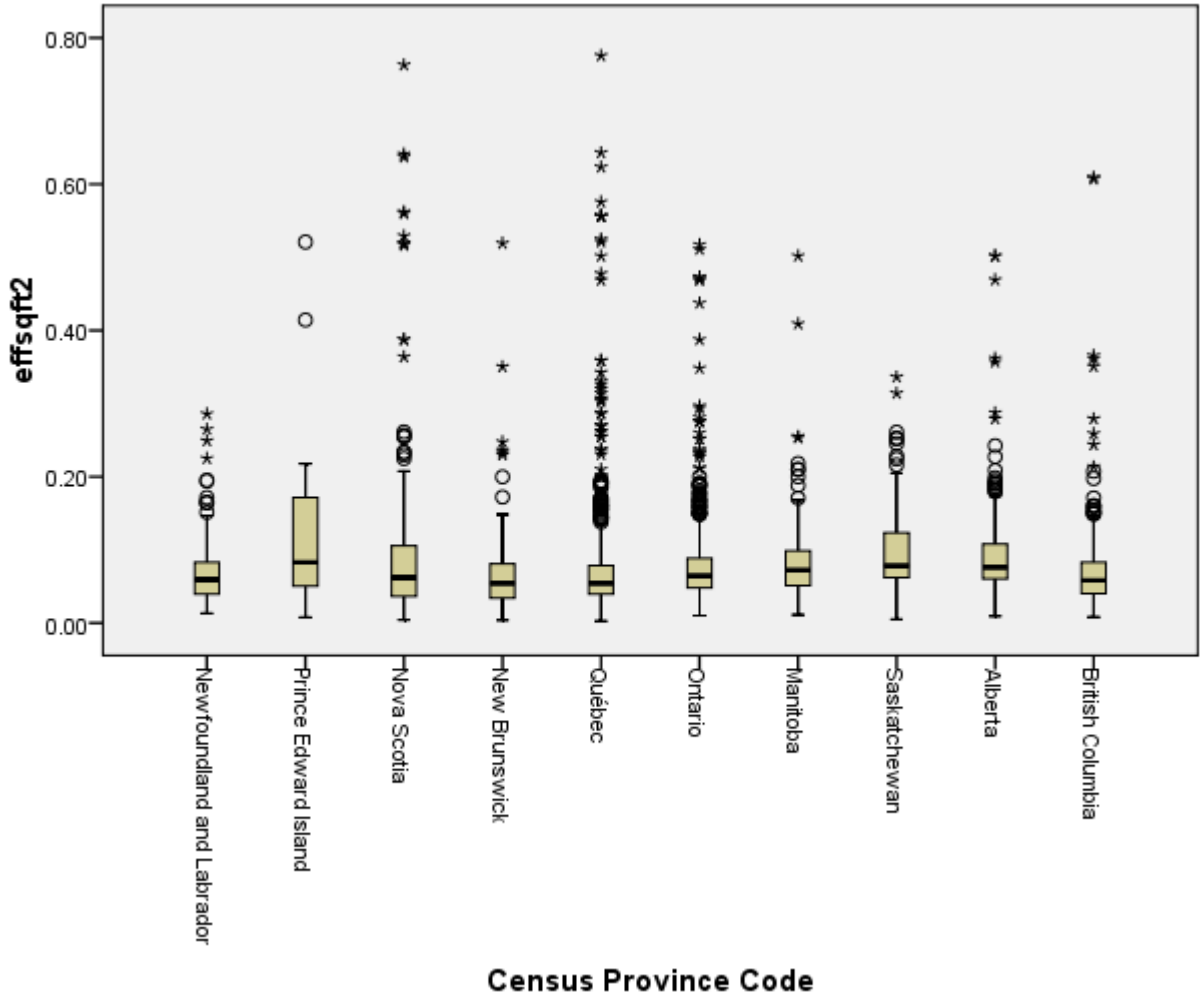


Figure 2: Box Plot of Energy Efficiency per Square Foot by Province



In order to examine the relationship between household energy efficiency, which is a continuous variable, and energy-efficient appliance choice which is generally discrete, the energy use per square foot variable was divided into quartiles. While Canada-wide the proportion of households in each quartile is 25%, in view of the information in Figure 2, there are noticeable differences across provinces. For example, 43.2% of New Brunswick households are in the first quartile (most energy efficient), and only 20.3% in the fourth quartile (least energy efficient). In contrast, Saskatchewan has only 7.7% of households in the first quartile, while Alberta has 8.4% in this category. Over 42% of Saskatchewan households are in the highest energy use quartile (over 73% in the highest two quartiles), while 38% of Alberta households are

in this same category (almost 70% in the highest two quartiles).

Energy efficiency appears to be related to a number of house and household characteristics. Obviously, households with more members might be expected to use more energy, and possibly therefore to be less energy efficient. While there is some evidence of this effect, as shown in Table 4, it does not appear to be overly strong. Over 28% of single-person households are in the most energy-efficient group, and this proportion generally decreases as household size increases, with just over 19% for households with 5 or more persons falling in this category. Interestingly, this ranking is reversed for the least energy-efficient households (highest quartile), with one-third of one-person households being in this category but only 18% of households with five or more persons. Regardless of household size, a relatively similar proportion of households are in the lowest or second quartile according to energy used per square foot. Overall, while the largest households (four and five or more persons) are not disproportionally found in the highest quartile of energy use per square foot, they are over-represented (56% and almost 63%, respectively) in the middle two quartiles.

Table 4: Relationship between Household Size and Energy Efficiency

Household Size	Energy Use per Square Foot			
	Lowest Quartile	2nd Quartile	3rd Quartile	Highest Quartile
1	28.3%	19.9%	18.9%	33.0%
2	25.2%	24.7%	24.2%	25.9%
3	26.2%	26.9%	26.5%	20.5%
4	23.0%	26.8%	29.6%	20.7%
5 or more	19.2%	31.4%	31.3%	18.1%

Rather than household size, a more relevant characteristic for energy use and energy efficiency may be the age distribution of the household members. Examining the proportion of household members that are children (aged less than 18) – which ranges from 0 (for two-thirds of all households) to 0.83 – the most energy-efficient households (lowest quartile for energy use per square foot) have an average of 0.1385 while those in the second quartile have an average of 0.1619. Although households in the second highest quartile of energy use per square foot have an average proportion of 0.1782, in the highest quartile this average drops to 0.1275. Thus, there

is no clear trend of energy efficiency decreasing as the household has a greater proportion of younger members.

Energy efficiency may vary more with house size rather than household size or age composition. To investigate this possibility, house size (heated area) was divided into four categories – less than 1100 square feet (24.9% of the sample), 1100 to less than 1800 square feet (25.3%), 1800 to less than 2400 square feet (24.1%), and 2400 square feet or greater (25.7%). Table 5 shows how energy efficiency varies across these different dwelling sizes. Apart from the smallest houses in the lowest energy-use per square foot quartile, as house size increases, so too does energy efficiency – the proportion of households in each of the first two quartiles increases as house size increases, while the proportion in the highest quartile (least energy efficient) decreases with house size. For houses of 2400 square feet or more in size, over one-third are in the most energy efficient quartile, while less than 10% are in the least energy efficient quartile. In contrast, almost one-half of houses in the smallest size category are in the least energy-efficient quartile. Thus, it appears that generally energy-use per square foot decreases with dwelling size.

Table 5: Relationship between Dwelling Size (Heated Area) and Energy Efficiency

Dwelling Size (Heated Area)	Energy Use per Square Foot			
	Lowest Quartile	2nd Quartile	3rd Quartile	Highest Quartile
Less than 1100 sq. ft.	19.3%	13.4%	18.1%	49.2%
1100 – < 1800 sq. ft.	18.6%	24.1%	26.5%	30.8%
1800 – < 2400 sq. ft.	24.8%	29.4%	32.4%	13.4%
2400 sq. ft or more.	37.3%	33.0%	23.3%	6.5%

In view of this apparent relationship between energy efficiency and house size, we next turn to the relationship between energy use per square foot and the type of dwelling. As the values in Table 6 show, in terms of the proportion of each house type that is in the most energy efficient quartile, duplexes appear to be by far the most energy efficient, followed by low-rise apartments and single-detached houses, and row or terrace houses. However, apart from mobile homes, over 46% of all types of houses (and almost 60% for duplexes) are in either the lowest or second quartile in terms of energy use per square foot. Clearly, mobile homes are the least

energy efficient, having the smallest proportion in the lowest energy use per square foot quartile and the largest proportion (over 50%) in the highest quartile, while low-rise apartments are also over-represented (over 38%) in the least energy-efficient quartile.

Table 6: Relationship between House Type and Energy Efficiency

House Type	Energy Use per Square Foot			
	Lowest Quartile	2nd Quartile	3rd Quartile	Highest Quartile
Single detached	24.6%	26.2%	27.3%	21.8%
Double	17.3%	29.1%	31.3%	22.3%
Row or terrace	22.3%	31.7%	28.0%	18.0%
Duplex	36.8%	22.5%	24.3%	16.3%
Low-rise apartment	28.4%	18.5%	15.0%	38.1%
Mobile	14.0%	17.3%	15.4%	53.3%

A number of other house or household characteristics may be associated with energy efficiency, some of which are displayed in Table 7. A greater proportion of rural households (38.6%) are in the most energy efficient quartile than is the case for urban households (22.2%), while the reverse is the case for the least energy efficient quartile (23% of rural households, 25.4% of urban households). Households that heat running water using electricity appear to be much more energy efficient than those that use natural gas or oil for this purpose. Finally, and perhaps somewhat surprisingly, households where the landlord rather than the occupant paid the electricity bills are more prominent in the group with the lowest energy use per square foot. However, over 50% of households where the occupant pays these bills are in the two most energy-efficient quartiles, compared to just over 40% when the landlord pays these bills. In fact, over 40% of households where the landlord pays the electricity bill are in the most energy-inefficient quartile. It is important to note, however, that only a very small proportion of the sample (less than 7%) do not pay their own electricity bills.

SHEU03 also contains information about various energy-saving renovations that were undertaken in 2003, as well as others that were proposed to be completed in 2004. In principle it would be useful to cross-tabulate household energy efficiency with this information on building retrofits to determine the extent to which household environmental awareness extends to aspects

of the building in which they reside. Unfortunately, there are severe limitations on this type of analysis due to the specific questions that are asked in SHEU03. In particular, it is not possible to control for households that have made energy-saving renovations to their residence prior to 2003. For example, a household that is green in the sense of their appliance choice may appear not to be in terms of their residence if they made no renovations in 2003 or plan none in 2004. Yet they may have made a series of renovations in 2002 which are not recorded in their responses to the SHEU03 questions. One way around this may be to focus on questions that ask if there are particular problems – such as drafts, condensation on windows, etc. – and then determine whether they dealt with them in 2003 or plan to deal with them in 2004. Unfortunately, in terms of renovations conducted in 2003, it is not possible to know if their responses to these questions about drafts, etc. refer to the situation before or after they made the renovations, although it may be reasonable to assume the former. Another issue concerns renters versus owners. It is difficult to know if landlords are responding to tenants' concerns when they undertake or plan renovations, and hence whether the energy awareness refers to the tenants or the landlords. This might not be a problem with major appliances such as furnaces, etc., that would likely also be chosen by the landlord, but may not apply to other household appliances. While it might be presumed that energy-aware people would choose relatively more energy-efficient accommodation, in many circumstances they may not have much choice in this matter. In view of the extent of the uncertainty associated with these issues, further analysis of the relationship between energy efficiency and energy-saving retrofits is left for future research.

Table 7: Relationship between Energy Efficiency and Other Characteristics

Characteristic	Energy Use per Square Foot			
	Lowest Quartile	2nd Quartile	3rd Quartile	Highest Quartile
Urban	22.2%	26.0%	26.5%	25.4%
Rural	38.6%	20.3%	18.1%	23.0%
Heat running water with:				
Electricity	37.1%	24.8%	20.4%	17.7%
Natural gas	12.4%	27.5%	31.5%	28.6%
Oil	18.4%	22.3%	23.4%	35.9%
Electricity bills paid by:				
Occupant	24.9%	25.7%	25.6%	23.8%
Landlord	27.0%	13.7%	18.0%	42.3%

4. Appliance Choice and Energy Efficiency

Next we examine how energy efficiency is related to the appliance choices made by households, and in particular the extent to which energy-efficient appliance choices are reflected in the overall energy efficiency of the household. To begin, we focus on Energy Star (ES) designated appliances. Table 8 shows the proportion of households that fall in each quartile of overall energy efficiency according to the total number of ES appliances that are present in the household. Somewhat counter-intuitively, a greater proportion of households with no ES appliances fall in the most energy-efficient quartile than is the case for households with one or more such appliances. In fact, in terms of this lowest quartile of energy use per square foot, those households with only a single ES appliance appear to be more energy efficient than those with a larger number of ES appliances. If we examine the highest quartile – the least energy-efficient households – those with no ES appliances have a larger proportion in this category than do households with any ES appliances, and households with more than two such appliances have a considerably smaller proportion in this group. Overall these results suggest that those households that appear to be energy efficient in terms of having ES appliances are not necessarily the most energy efficient households. Of course, it is important to note that no other factors have been held constant in this analysis, so it can only be regarded as suggestive rather than conclusive.

Table 8: Energy Star Appliances and Energy Efficiency

Total Number of ES Appliances	Energy Use per Square Foot			
	Lowest Quartile	2nd Quartile	3rd Quartile	Highest Quartile
0	28.2%	22.2%	22.1%	27.5%
1	24.6%	24.4%	23.9%	27.1%
2	23.5%	26.2%	26.1%	24.2%
More than 2	19.7%	31.3%	32.2%	16.8%

To investigate this issue further, similar analysis was conducted for the different types of ES appliances considered in Section 2 – housework, entertainment, and heating or cooling. The results for ES housework appliances, shown in the first panel of Table 9, are similar in some respects to those in Table 8. Households with more than two ES housework appliances have the

lowest representation in the most energy-efficient group. However, these households are predominately (54.2%) in the lowest two quartiles of energy use per square foot, which is greater representation than for households with a smaller number of ES housework appliances. In addition, only just over 11% of these households are in the least energy-efficient group.

Table 9: Specific Types of Energy Star Appliances and Energy Efficiency

Number of ES Appliances	Energy Use per Square Foot			
	Lowest Quartile	2nd Quartile	3rd Quartile	Highest Quartile
Housework:				
0	25.5%	23.5%	23.2%	27.7%
1	24.7%	27.8%	28.0%	19.5%
2	26.4%	24.2%	28.8%	20.6%
More than 2	14.2%	40.0%	34.7%	11.2%
Entertainment:				
0	26.2%	23.9%	23.5%	26.5%
1	24.4%	23.5%	26.2%	25.8%
2	24.1%	29.9%	26.5%	19.5%
More than 2	15.6%	34.0%	36.0%	14.5%
Heating or Cooling:				
0	27.9%	23.6%	23.4%	25.0%
1	14.4%	30.7%	29.3%	25.6%
2	21.6%	20.5%	40.6%	17.3%

In terms of ES entertainment appliances, as shown in the second panel of Table 9, there does not appear to be any distinct relationship between the number of these types of appliances present in the household and their overall energy efficiency. Households with none of these appliances are better represented in the most energy efficient quartile, but this is offset by higher representation in the second energy-efficiency quartile by those with at least two ES entertainment appliances. Less than 15% of households with more than two of these appliances are in the least energy-efficient category, which is a smaller representation than for households with fewer or none of these appliances. In fact, representation in this least energy-efficient category increases as the number of ES entertainment appliances decreases.

The results in the third panel of Table 9 show that households with one or two ES heating or cooling appliances have much lower representation (14.4% and 21.6%, respectively) in the

most energy-efficient group than do households with none of these appliances (27.9%). While those households with one ES heating or cooling appliance have higher representation in the second quartile, there is still a greater proportion of households with none of these appliances (51.5%) in the lower two (most energy efficient) quartiles than for other types of households. Of course there are a number of possible explanations for this finding. For example, households without air conditioning (AC) are likely to use less energy than those that do have AC, while those that have ES AC appliances are likely to use less energy than those with other types of AC appliances. Alternatively, there may be rebound effects, so that those using more energy-efficient appliances simply use them more intensively. In order to analyze these types of issues, it is necessary to control for the effects of other factors when examining whether households with ES appliances are more energy-efficient overall. While this is considered subsequently, the conclusion that can be drawn from the above analysis is that simply having more ES appliances is not in itself sufficient for a household to be green, in the sense of being among those households that use the least amount of energy per square foot of heated area.

Of course, as noted in Section 2, there are a number of other forms of energy-saving behaviour that households can adopt in addition to, or instead of, ES appliances. To conclude this section the relationship between adoption of these forms of energy-saving behaviour and overall energy efficiency is examined. The appliances/activities that are considered here are the same as those shown in Table 3 except that, in view of the finding concerning energy efficiency and ES heating and cooling appliances, we also examine the effect of the household having central air conditioning. The findings of this analysis are presented in Table 10. In this table, energy-saving behaviour is seen to be energy efficient if it results in a relatively large proportion of households in the lowest quartile or possibly in the lowest two quartiles, and a smaller proportion in the highest quartile.

Table 10: Other Energy Saving Behaviour and Energy Efficiency

Appliance/Activity	Energy Use per Square Foot			
	Lowest Quartile	2nd Quartile	3rd Quartile	Highest Quartile
Front-loading washing machine	26.7%	28.4%	30.7%	14.2%
Use cold water for washing clothes	29.2%	27.8%	23.4%	19.6%
Moisture detector in clothes dryer	22.3%	29.9%	26.8%	21.0%
Dry dishes in dishwasher with heat off and/or door open	26.3%	28.2%	25.2%	20.2%
High efficiency furnace	15.2%	31.2%	30.0%	23.6%
Programmable Thermostat (PT) – one or more	21.7%	29.9%	28.6%	19.8%
PT that is programmed	20.5%	31.7%	29.6%	18.2%
Temperature of largest heating area varies	25.2%	26.8%	25.3%	22.7%
Water-saving showerhead	25.2%	27.7%	25.0%	22.0%
Use some Compact Fluorescent Lights (CFL)	22.7%	27.7%	26.3%	23.2%
Use some fluorescent lights	23.5%	27.5%	25.7%	23.4%
Use some halogen lights	25.6%	25.7%	26.2%	22.5%
Only use incandescent lights	26.6%	19.1%	22.7%	31.6%
Have central air conditioning	18.5%	30.4%	31.6%	19.6%

The values in the first column of Table 10 reveal some unexpected findings. For example, only 15.2% of households with a high-efficiency furnace are in the most energy efficient group, while 26.6% of households that only use incandescent lights are also in the most energy-efficient group. As anticipated earlier, only 18.5% of households with AC are in the lowest quartile of energy use per square foot. In terms of energy-saving behaviour, over 29% of households that use cold water for washing clothes, and 26.3% of households that dry dishes in the dishwasher with the heat off or door open are in the most energy-efficient quartile. Except for high-efficiency furnaces, use of only incandescent lights, or central air conditioning, for all the appliances or activities that are listed in Table 10 over 50% of households are in the lowest two energy-use per square foot quartiles, with the largest proportions associated with front-loading washing machines, use of cold water for washing clothes, and drying dishes with the door open or heat off. Less than 15% of households with front-loading washing machines are in the least energy-efficient category, while over 30% of those who only use incandescent lights are in this category. Other appliances or activities that are associated with a relatively small proportion of households in the most energy-inefficient group include using cold water for washing clothes, having a programmable thermostat – especially one that is programmed – and, perhaps surprisingly, having central air conditioning.

It is difficult to summarize these findings succinctly. Some appliances that would typically be viewed as associated with energy savings sometimes appear to be used by households that are overall energy efficient, but in other cases they are used by households that are not energy efficient. In contrast, activities typically not associated with energy savings – such as having only incandescent lights – are more often observed in energy-efficient households than would be expected, although a large proportion of such households are also found in the most energy-inefficient category. These types of findings appear to reinforce those found earlier in terms of the relationship between households with ES appliances and overall household energy efficiency. The main problem appears to be that other factors are not held constant when examining the relationship between some aspect of household energy-saving behaviour and overall household energy efficiency. Results of a regression-based approach that allows the effects of other factors to be held constant are discussed in the following section. Nevertheless, what is clear from the analysis so far is that the simple act of using energy-efficient appliances, or of adopting some forms of energy-efficient behaviour, is not sufficient in itself for a household to be energy efficient. Indeed, the results here suggest that use of energy-efficient behaviours and appliances is not even a necessary condition for a household to be energy efficient, since many of the most energy-efficient households do not have or have not adopted the energy-efficient appliances and behaviours considered here. An interesting implication of this is that presumably green households that have not yet done so could become even more energy efficient if they were to adopt more of these energy-efficient behaviours and appliances.

5. A Regression-Based Approach to Household Energy Efficiency

In order to hold constant the effects of other factors while examining whether various household energy-efficient appliance choices, as well as other household energy-savings behaviour, have a significant effect on household energy efficiency, a regression model is estimated using the data from SHEU03 as described previously. The dependent variable in this model is energy efficiency, EFF, measured as energy consumption per square foot of heated area in the dwelling. The basic form of the model is as follows:

$$EFF_i = f(\textit{appliance choices}, \textit{energy} - \textit{savings behaviour}, \textit{control factors})$$

where *appliance choices* refer to ES appliances present in the household, *energy-savings behaviour* refers to the appliances and activities listed in Tables 3 and 10, and *control factors* refer to such variables as location (province), prices of electricity and natural gas, weather (heating degree days), etc.

Details of the specific variables that are included in the estimated model are provided in Table 11. Control variables, listed at the top of this table, include the heated area of the dwelling and the square of this value to allow for a nonlinear relationship between energy efficiency and the size of the dwelling. Household size and the proportion of the household that is aged 18 years or less are also included here, along with dummy variables for whether the household owns their home, and whether it is located in a rural area. Dummy variables are also included for the province where the house is located (British Columbia is the default location), and the type of house (with single-detached dwellings being the default house type). Heating Degree Days (HDD) are also included, although weather effects may be captured by the provincial dummy variables, along with the price of electricity and natural gas, and dummy variables indicating whether the household obtains hot water using electricity or natural gas (with the use of other forms of energy for this purpose being the default case). Note that information on prices and HDD are not included in the SHEU03 database, and were matched to the records in this database using information on the first three digits of the postal code (FSA).

Table 11: Variables Included in Household Energy Efficiency Regression

Variable Name	Variable Description
EFF	Total energy consumption per square foot of heated area
MSTOTDWE	Heated area of dwelling, including basement
MSTOT2	Squared heated area of dwelling, including basement
HHSIZE	Number of persons in household
PROPLT18	Proportion of household members aged 18 or younger
RURAL	DV=1 if house is located in a rural area
OWN	DV=1 if household owns home
NFLD	DV=1 if house is in Newfoundland and Labrador
PEI	DV=1 if house is in Prince Edward Island
NS	DV=1 of house is in Nova Scotia
NB	DV=1 of house is in New Brunswick
QUE	DV=1 of house is in Quebec
ONT	DV=1 of house is in Ontario
MAN	DV=1 of house is in Manitoba
SASK	DV=1 of house is in Saskatchewan
AB	DV=1 of house is in Alberta
HDD	Heating Degree Days
DOUBLE	DV=1 if double housing
ROW_TERR	DV=1 if row or terrace housing
DUPLEX	DV=1 if house is a duplex
LOW_RISE	DV=1 if low-rise apartment or flat
MOB_HOME	DV=1 if mobile home
ELECHW	DV=1 if household uses electricity for heating water
GASHW	DV=1 if household uses natural gas for heating water
ELECPR	Price of electricity
MNGPR	Price of natural gas
ESTAR	Total number of Energy Star appliances
HA_ES	Number of housework type Energy Star appliances
EA_ES	Number of entertainment Energy Star appliances
THCA_ES	Number of heating and cooling Energy Star appliances
CFLDV	DV=1 if house has some compact fluorescent lights
HALOGEN	DV=1 if house has some halogen lights
FLUOR	DV=1 if house has some fluorescent lights
ONLY_INC	DV=1 if house only has incandescent lights
AC	DV=1 if there is central air conditioning
PTA	DV=1 if house has at least one programmable thermostat
PTUSED_A	DV=1 if house actually uses a programmable thermostat
DRYNOH	DV=1 if dishes are dried in dishwasher with no heat or door open
FRONTWSH	DV=1 if clothes washer is front loading
DRYMOIST	DV=1 if clothes dryer has a moisture detector
COLDWASH	DV=1 if clothes are washed in cold water
H20SAV	DV=1 if household has a water-saving showerhead
HIGHEFUR	DV=1 if household has a high-efficiency furnace
DIFFTEMP	DV=1 if temperature of largest heated area in house is varied

Most of the energy efficiency appliance choice variables and energy-saving behaviour indicator variables are those that have been discussed in previous sections of this paper. Since the effects on energy efficiency of different types of Energy Star (ES) appliances may differ, as an alternative to including just the total number of ES appliances in the specification, variables representing the number of ES appliances of each of three types – housework, entertainment, and heating and cooling – are included separately in an alternative specification.

Initial estimation of the model revealed that it was better specified with the dependent variable, the efficiency measure, in natural logarithmic form. In addition, since the residuals exhibited evidence of heteroskedasticity, estimated standard errors for the estimated coefficients were obtained using a heteroskedasticity-consistent covariance matrix estimator. The results obtained using this specification are reported in Table 12.

As the top panel of Table 12 shows, most of the control variables are significant at a 1% or 5% level. Energy efficiency increases significantly (energy use per square foot decreases) with increases in dwelling area, but the negative sign on MSTOT2 indicates that these increases are at a decreasing rate, and that eventually (beyond 5,200 square feet) efficiency will decrease with further increases in area. Significant decreases in energy efficiency occur as household size increases, and energy efficiency is higher in rural area. Surprisingly, energy efficiency is lower for home owners rather than renters. In terms of location, relative to homes in British Columbia, energy efficiency is not significantly higher in any other province, but is significantly lower in Ontario and Manitoba, and especially Saskatchewan and Alberta. As anticipated, HDD are not significant, with these effects likely captured by the province dummy variables, which are jointly significant. Relative to single detached dwellings, energy efficiency is significantly lower in mobile homes, but significantly higher in low-rise apartments, row or terrace housing, double housing and, less significantly, in duplexes. Finally, homes where electricity is used to heat water are more energy efficient, but prices of electricity and natural gas appear to have no significant effect on energy efficiency.

Table 12: Estimated Household Efficiency Regression Results

Variable	Estimated Coefficient	Estimated Standard Error	t-ratio	P-value
MSTOTDWE	-0.0006	0.0000	-19.9600	0.0000**
MSTOT2	0.0000	0.0000	11.3900	0.0000**
HHSIZE	0.0368	0.0082	4.5030	0.0000**
PROPLT18	-0.0484	0.0462	-1.0480	0.2950
RURAL	-0.1517	0.0223	-6.8030	0.0000**
OWN	0.0766	0.0273	2.8030	0.0050**
NFLD	0.1136	0.0901	1.2610	0.2070
PEI	0.1350	0.1432	0.9427	0.3460
NS	0.1692	0.0929	1.8220	0.0680†
NB	-0.0232	0.0568	-0.4085	0.6830
QUE	0.0935	0.0486	1.9250	0.0540†
ONT	0.1324	0.0638	2.0750	0.0380*
MAN	0.1423	0.0650	2.1870	0.0290*
SASK	0.3204	0.0678	4.7270	0.0000**
AB	0.2504	0.0644	3.8870	0.0000**
HDD	0.0000	0.0000	-0.0878	0.9300
DOUBLE	-0.0949	0.0344	-2.7570	0.0060**
ROW_TERR	-0.2404	0.0327	-7.3420	0.0000**
DUPLEX	-0.0866	0.0495	-1.7510	0.0800†
LOW_RISE	-0.2063	0.0413	-5.0000	0.0000**
MOB_HOME	0.0857	0.0437	1.9630	0.0500*
ELECHW	-0.2371	0.0360	-6.5770	0.0000**
GASHW	0.0386	0.0380	1.0160	0.3100
ELECPR	0.5597	1.6580	0.3375	0.7360
MNGPR	0.0012	0.0068	0.1770	0.8590
HA_ES	-0.0015	0.0091	-0.1621	0.8710
EA_ES	0.0098	0.0083	1.1840	0.2360
THCA_ES	-0.0880	0.0430	-2.0470	0.0410*
CFLDV	0.0014	0.0173	0.0818	0.9350
HALOGEN	0.0044	0.0184	0.2379	0.8120
FLUOR	0.0092	0.0202	0.4588	0.6460
ONLY_INC	-0.0042	0.0309	-0.1344	0.8930
AC	-0.0035	0.0223	-0.1576	0.8750
PTA	0.0058	0.0314	0.1834	0.8540
PTUSED_A	0.0375	0.0362	1.0380	0.2990
DRYNOH	-0.0145	0.0163	-0.8904	0.3730
FRONTWSH	-0.0320	0.0259	-1.2370	0.2160
DRYMOIST	0.0116	0.0174	0.6655	0.5060
COLDWASH	-0.0530	0.0167	-3.1780	0.0010**
H20SAV	-0.0287	0.0165	-1.7420	0.0820†
HIGHEFUR	0.1865	0.0503	3.7050	0.0000**
DIFFTEMP	-0.0481	0.0202	-2.3850	0.0170*
CONSTANT	-2.0738	0.1612	-12.8600	0.0000**

Note: **, *, and †, indicate significance at the 1%, 5%, and 10% level, respectively.

Turning to the results concerning energy-efficient appliances and other aspects of energy-saving behaviour, we note first that a test that the coefficients on the number of ES housework, entertainment, and heating and cooling appliances are all equal could only be rejected at a 10% level of significance. If just the single ESTAR variable is included, indicating the total number of ES appliances, it is not significant at any reasonable level. When these three variables are included separately, the only significant coefficient is on the number of heating and cooling ES appliances (significant at a 5% level), with the negative coefficient here indicating that energy efficiency increases when more of these appliances are present in the household. None of the lighting variables are significant either individually or jointly, and neither are the programmable thermostat variables or the dummy variable that indicates that the house has central air conditioning.

In terms of specific energy-saving activities, the most significant (at a 1% level) in terms of increasing overall household energy efficiency is using cold water to wash clothes. In addition, while having or using programmable thermostats did not significantly affect energy efficiency, allowing the temperature of the largest heating area to vary during a 24-hour period was found to have a significant (at a 5% level) positive effect on energy efficiency. The use of a water-saving showerhead also significantly increased energy efficiency at a 10% level of significance. However, and perhaps surprisingly, households with a high-efficiency furnace were found to have significantly reduced (at a 1% level) energy efficiency. Other energy-saving activities that were considered here – including using a front-loading washing machine, or a clothes dryer with a moisture detector, or leaving the door open or heat off when drying dishes in a dishwasher – were found to have no significant effect on overall household energy efficiency.

Overall, the regression results mainly appear to confirm the earlier findings from the data analysis. Having more ES appliances is not statistically significantly associated with increased overall energy efficiency except for ES heating and cooling appliances. Some energy-saving activities – those related to hot-water saving or to not maintaining a constant temperature in the house in a 24-hour period – are significantly associated with increased energy efficiency, but others are not, and some even appear to be associated with increased use of energy per square foot of dwelling area. Of course this latter finding, as well as the others concerning the ES

appliances, may reflect the non-random selection of households that adopt these types of appliances. For example, if a household is already energy-conscious, the additional energy savings that they might obtain from using an ES appliance rather than an alternative may be less than for a household that is otherwise not aware of their energy usage. Alternatively, households that adopt various energy-saving appliances may decide that in view of the energy savings achieved in one area they can afford to be less careful with energy use in others. These self-selection and rebound-type effects in this context remain as interesting topics for future research.

6. Summary and Conclusions

In this paper, data from SHEU03 are used to investigate Canadian household choices with respect to energy-efficient appliances and other energy-savings activities, and their relationship to overall household energy efficiency. Although Energy Star (ES) designated appliances have only been available in Canada since 2001, their penetration among households that – from 2001 to 2003 – purchased the types of appliances considered here, ranges from 34% (stereo) to almost 70% (washing machine). Based on this information, as well as responses to other survey questions concerning energy-saving behaviour, it appears that, at least in terms of appliance choice and usage, there are many Canadian households that could be categorized as environmentally aware, although the extent of this environmental awareness differs quite noticeably across different households.

An examination of the extent to which this environmental awareness in appliance choice and other energy-saving behaviour is reflected in household energy efficiency reveals some interesting and often apparently counter-intuitive findings. Larger household sizes appear to be under-represented in the group of the most energy-efficient households, while houses with a larger dwelling size are over-represented. Low-rise apartments and duplexes appear to be more energy efficient than single detached dwellings, and especially mobile homes, as are houses where water is heated using electricity. In terms of appliance choice, households that appear to have made energy-efficient choices, in terms of having ES appliances, are not necessarily the most energy efficient households. Of course there are a number of other forms of energy-saving behaviour that households can adopt in addition to, or instead of, ES appliances. Again the results are mixed, with some appliances that would typically be viewed as being associated with energy savings used by households that are among the most energy efficient overall, but in other cases they are used by households that are the least energy efficient. In contrast, activities typically not associated with energy savings – such as having only incandescent lights – are more often observed in energy-efficient households than would be expected, although a large proportion of households with only incandescent lights are also found in the least energy-efficient category. Apparently the simple act of using energy-efficient appliances, or of adopting some forms of energy-efficient behaviour, is neither sufficient in itself for a household to be energy efficient nor is it even necessary, since many of the most energy-efficient households do

not have or have not adopted the energy-efficient appliances and behaviours considered here.

One problem with examining the relationship between some aspect of household energy-saving behaviour and overall household energy efficiency is that the effects of other factors are not held constant and therefore these effects may be confounded. Results of a regression-based approach that allows the effects of other factors to be held constant reveal that energy efficiency increases significantly (energy use per square foot decreases) with increases in dwelling area – but at a decreasing rate – and as household size increases. Energy efficiency also varies by province, being significantly lower in Saskatchewan and Alberta, but higher in rural areas. Relative to single detached dwellings, energy efficiency is found to be significantly lower in mobile homes, but significantly higher in other forms of housing and also is higher in homes where electricity is used to heat water. In terms of energy-saving appliances and behaviour, houses with a larger total number of ES-designated appliances are not significantly more energy efficient, although energy efficiency significantly increases with the number of heating and cooling ES appliances. In addition, none of the lighting variables or programmable thermostat variables is found to be significantly associated with increased household energy efficiency. In terms of increasing overall household energy efficiency, the most significant energy-saving activities include using cold water to wash clothes, allowing the temperature of the largest heating area to vary during a 24-hour period, and the use of a water-saving showerhead. However, households with a high-efficiency furnace are found to have significantly reduced energy efficiency. Other energy-saving activities that were considered are found to have no significant effect on overall household energy efficiency.

Overall, the regression results mainly appear to confirm the earlier findings from the data analysis: some energy-saving activities are significantly associated with increased energy efficiency, but others are not, and some even appear to be associated with increased use of energy per square foot of dwelling area. Of course to some extent at least, some of these findings may reflect the non-random selection of households that adopt these types of appliances or energy-savings behaviour. Further research is required to disentangle the self-selection and rebound effects and to ultimately determine why adoption of energy-savings appliances and behaviour appears not to be reflected in overall household energy efficiency measures.

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