OPEN ACCESS

2nd World Sustainability Forum
1-30 November 2012

www. wsforum.org

Article, Review, Communication (Type of Paper)

SURVEY OF HOUSEHOLD ENERGY USE IN A RENTAL HIGH-RISE MULTI-UNIT RESIDENTIAL BUILDING (MURB)

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Received: / Accepted: / Published:

Abstract: This paper discusses occupant's household energy use, behaviour and satisfaction in one of Toronto's rental multi-unit residential buildings (MURBs). First, the survey indicated that male respondents were found to own and use their appliances/electrical devices more than female respondents. A similar trend were also found for respondents with a longer residency in the building and older-aged respondents as well. Second, a comparison analysis found that that the surveyed respondents are well below the national average on ownership and usage of appliances and electrical devices. Lastly, the survey found that the respondents were dissatisfied with the summer temperatures of their apartment unit compared to the winter temperatures. A correlation analyses showed that seasonal temperature satisfaction is strongly correlated with respondent's thermal comfort; for example, satisfaction of the apartment unit temperatures during the summer and how the temperature enhances their thermal comfort was found to have a $r= 0.86$, $p<0.01$.

Keywords: Households energy use, multi-unit residential building, rental housing

1. Introduction

The residential sector is responsible for 17% of Canada's total secondary energy use [1]. Within the residential sector, 24% of Canada's energy use is contributed by multi-unit residential buildings (MURBs) [2]. Residential energy use, also referred to as domestic or household energy use, is a function of structure and intensity of energy use in a home [3]. According to Natural Resources Canada, approximately 63% of the residential energy is due to space heating, 17% for water heating,

14% for appliances, 4% for lighting, and 2% for space cooling [1]. Throughout this paper, household energy use is defined as the contribution of "affected by heating demand, use of energy-intensive appliances, occupancy work patterns, standards of living, comfort expectations, energy use behaviour, types of frequency of use of appliances and cultural habits" [3].

There have been several surveys conducted investigating the factors of household energy use [4-8]. Some factors that influence energy use are demographics (e.g. age, income, sex), energy behaviour, types of appliances, use of appliances and comfort. Yohanis (2011) defines energy behaviour as "actions taken by the householder in their use of energy in their homes" [9]. Furthermore, there are three aspects that address energy behaviour: usage (duration and use of the appliance), maintenance (servicing or energy provided to operate the appliance), and purchase (type and characteristics of the appliance) [10].

Natural Resources Canada's Survey of Household Energy Use (SHEU 2007) is a comprehensive national evaluation that provides information on the types and use of appliances in a household. The appliances range from major (e.g. stoves, refrigerators, water heaters) to minor (e.g. television, computers, light fixtures). Similarly, the United States of America conducts a similar survey called Residential Energy Consumption Survey (RECS) [11]. In the United Kingdom, Yohanis (2011) conducted a survey of domestic appliances, which contained similar questions as SHEU 2007. It is also important to note that the national surveys also take into account very minor appliances such as telephone chargers, baby monitors, and clocks. These appliances are significant as they contribute greatly due to their standby power consumption [12].

Aydinalp et al. (2003) shows a strong relationship between socio-economic factors on household energy use using neural networking (R^2 = 0.909) [13]. There is a strong link between income, household size, ownership, number of adults and children; the larger they are, the greater the energy consumption. The information to develop the neural network was extracted from SHEU 2007. Neilsen et al. (2010) also addresses the impact of socio-demographics and its effect on attitudes, perceptions and energy behaviour [14]. The variables considered were gender, age, education, income of household and respondent, number of children and residency.

Yamagishi et al. (1993) and Humphreys (2005) show the impact of occupants' thermal comfort and indoor satisfaction in an office environment [15-16]. Yamagishi et al. (1993) found a change in occupants' evaluation (e.g. luminance, thermal comfort, and noise level) when moving from an existing building to a newer building [14]. In another study conducted by Steemers and Manchanda (2010) demonstrated the relationship between an energy efficient building and occupant comfort and satisfaction [17]. They found that increasing the efficiency of their air conditioning system reduced reported occupant health conditions. An organization called the National Science Foundation (NSF) Industry/University Cooperative Research Center provides resources and sample surveys relating to residential indoor environment quality and occupant satisfaction [18]. Humphreys (2005) and the NSF contain similar questions such as scaled questions relating to environmental satisfaction and overall comfort.

Another important aspect to consider is tenant well-being and how it affects household energy use. As mentioned before, Steemers and Manchanda (2010) found a correlation between energy efficiency and reductions in reported health conditions, which increased levels of satisfaction. An organization called United Way Toronto conducted survey to more than 2000 tenants and found a relationship between low-income households living in high-rise housing [19]. Key findings were that households

living in poverty reside in high-rise buildings and as poverty increases so do poor housing conditions [18].

The purpose of this study is to further the research in household energy use and behaviour but specifically explore household energy use within rental MURBs. With more than one-third of Toronto's residents living in a MURB, this study addresses occupant behaviour and energy use in a rental MURB. Rental MURBs and high-rise condominiums produces about 40 percent of Toronto's residential greenhouse gas (GHG) emissions [20]. A potential of significant reductions in energy use and GHG emissions can result by examining how occupant's use their energy in these rental MURBs. The results in this paper are part of a larger project; the aim of this work investigates the following within a rental MURB: occupant demographic trends and household energy use, survey comparison to a Canadian national survey, and correlation between indoor environmental and thermal comfort.

2. Results and Discussion

In this section, the survey results are analyzed in four parts: first, general findings in the survey; second, compare to occupant predictor trends found in the literature - gender, age, residency and income; third, compare to national surveys such as SHEU 2007; lastly, descriptive statistics and correlation between indoor environment satisfaction and thermal comfort.

2.1. General Findings

A total of 49 surveys were completed. 80% of the surveys were completed by males, where a majority (59%) of the respondents are above the age of 46 years. Single-family households are most dominant (88%) in this rental MURB, where 45% of the respondents have lived in this rental MURB for more than 7 years. 49% of the respondents said that they spend 9 to 13 hours each day in their apartment unit (includes sleeping). 45% of the respondents had also said they have grown up in Africa. Lastly, 37% of the respondents have a total household income of $15,000 to $29,999 per year, which is below the national standard. It is important to note that all rental apartment units in this study are furnished with the same major appliances: small-sized refrigerator (241L/9ft), oven with stovetop (2.9 cu. ft.), and a fan coil unit.

The adoption of some energy behaviours were low such as the use of timer controls or purchasing of greener products. There are determinants, however, on occupant's behaviour and household energy consumption such as income and dwelling size. First, a majority of the survey respondents, in this paper, fall below the median after-tax income. According to Statistics Canada (2007), the total household income for Canadian families median is $61,800. The median after-tax income for unattached individuals (single-family households) is $24,200 [21], which 29% of the respondents fall below the median after-tax income. In the survey, it was found that 14 respondents between $0 and $14,999 (29%), 18 respondents between $15,000 to $29,999 (37%), 7 respondents between $30,000 to $49,999 (14%), no one over $50,000 and 10 respondents preferred not to say (20%). Low-income households are found to purchase less energy-efficient technologies (Guerin et al., 2000). Second, the dwelling size of the survey respondents is 230 ft^2 or 21.36 m^2. Guerin et al. (2000) found that with a larger dwelling size, the more energy is consumed. It was found that respondents did not own or use as much appliances and electrical devices compared to SHEU 2007. Despite this, further research can be done to see whether quantified energy consumption in the apartment units complements the survey results.

2.2. Occupant Predictors of Household Energy Use and Behaviour

This section explores whether general trends such as occupant characteristics found in literature are evident within the survey results. Guerin et al. (2000), Yun and Steemers (2011) and Guerra-Santin and Itard (2010) identify occupant predictors of household energy consumption behaviour and behaviour change [22-24]. Occupant predictors are classified as occupant's characteristics, attitudes and actions; for example, income, sex/gender, housing tenure and age. Guerin et al. (2000) provides a comprehensive literature review on these occupant predictors of household energy use since 1975. In this paper, three occupant characteristics - gender, age, income- are compared to the literature to see if the general trends are prevalent within the survey results. General trends found in literature are:

- Gender: Guerin et al. (2000) found that ecoconsciousness is more prevalent in women than men. This means that men have more potential consuming energy than women.
- Age: Guerin et al. (2000) found that households in the middle life-cycle consume more energy than younger or older families.
- Residency: residency is the number of years an occupant has been living within their home, also referred to as tenure. To date, there is little literature identifying a relationship between the number of years residing within a house to energy consumption behaviour. This study explores this relationship.

2.2.1 Gender and Household Energy Use

Appliance and electrical device ownership ratio was calculated by taking the total of 24 appliances and electrical devices that were accounted for in the survey to the survey response. It was found that males (0.28) have a higher appliance and electrical device ownership ratio than women (0.23). Figure 1 shows that a majority of the females (60%) do not own a computer compared to males (53.8%). Figure 2 shows that most women (30%) spend about 1 hour or less leaving the television on; whereas, most males (35.9%) leave the television on between 1 to 3 hours per day. For stove use, however, males were not found to use the stove as much as females (Figure 3).

In terms of light bulb use (lighting), close to a majority of the males (43.6%) use lighting 3 to 5 hours per day. Females were found to use light bulbs less than 3 hours per day during the summer. Similarly, during the summer, 90% of females use the light bulbs less than 3 hours per day; whereas, 30.8% of males use light bulbs from 3 to 5 hours per day (Figure 5).

Table 1 also shows that males (30.8%) set their heating and cooling equipment at very high temperatures (above 20˚C) during the winter. Females, on the other hand, do not use heating and cooling as much during the winter. During the summer, females (40%) use their heating and cooling equipment set between 16 and 20℃.

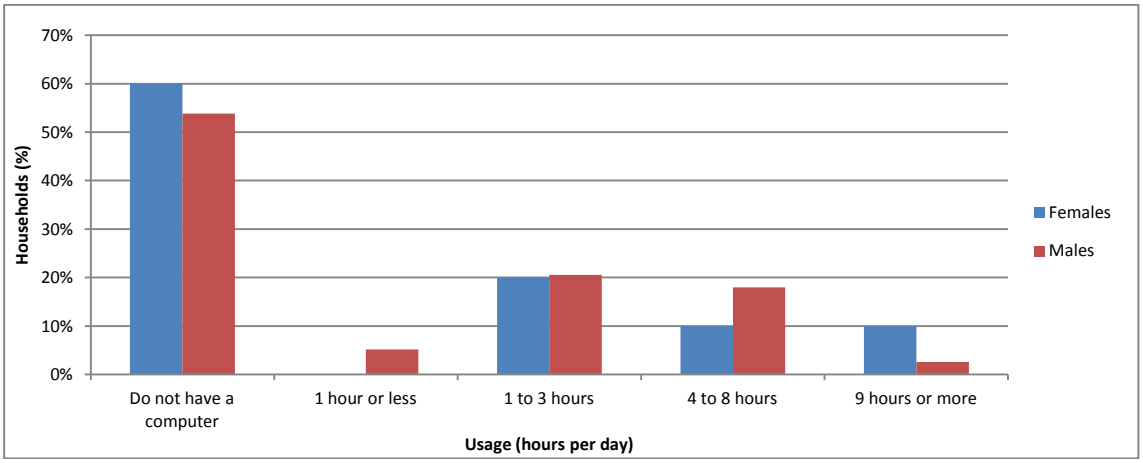

Figure 1: Computer usage per day - Gender distribution as a percentage of all the households surveyed.

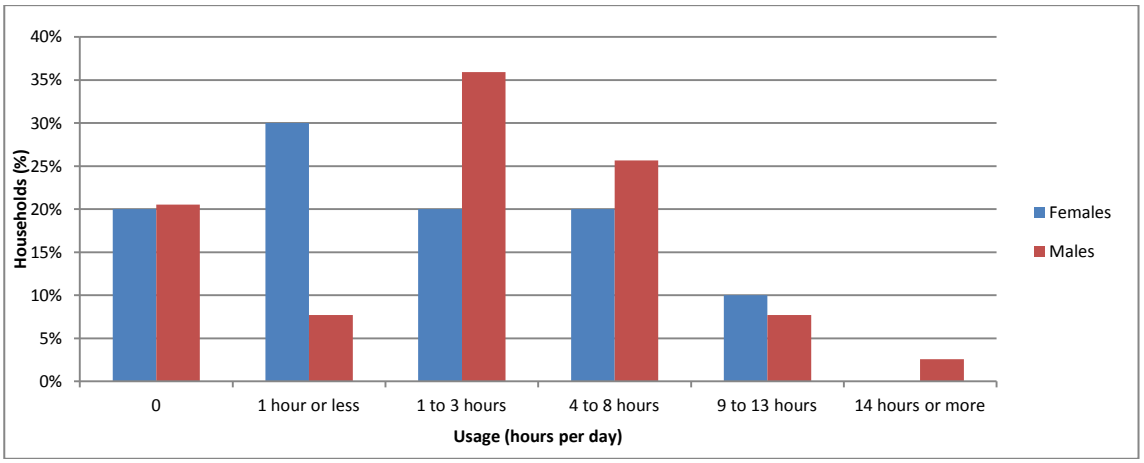

Figure 2: Hours per day the television is on - Gender distribution as a percentage of all the households surveyed.

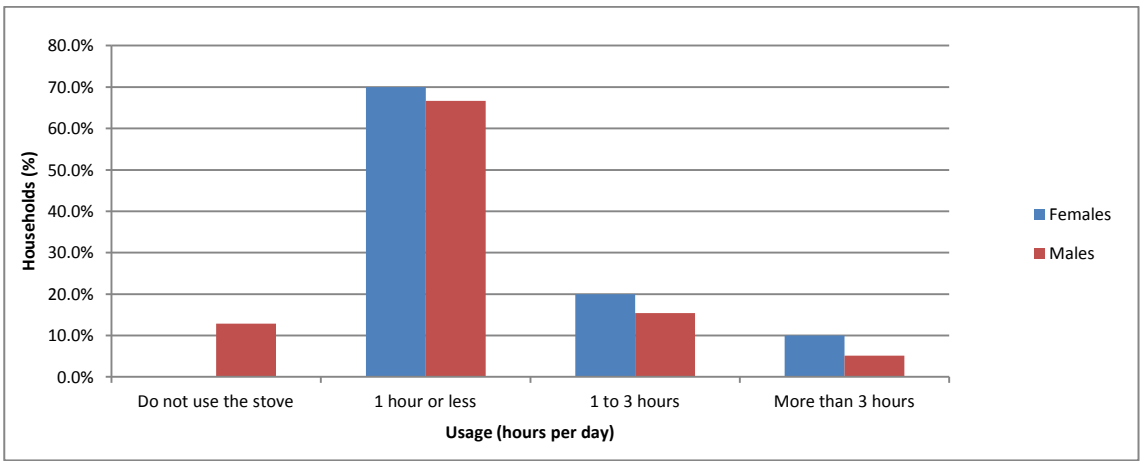

Figure 3: Stove usage per day - Gender distribution as a percentage of all the households surveyed.

Table 1: Householder's preferred temperature during winter and summer for heating and cooling equipment - Income distribution as a percentage of all households surveyed.

	Males		Females	
Temperature (°C)	Winter	Summer	Winter	Summer
Do not use heating or cooling equipment	35.9%	48.7%	40.0%	40.0%
0-16	12.8%	17.9%	20.0%	10.0%
16-20	17.9%	23.1%	20.0%	40.0%
>20	30.8%	7.7%	20.0%	10.0%
Other	2.6%	2.6%	0.0%	0.0%

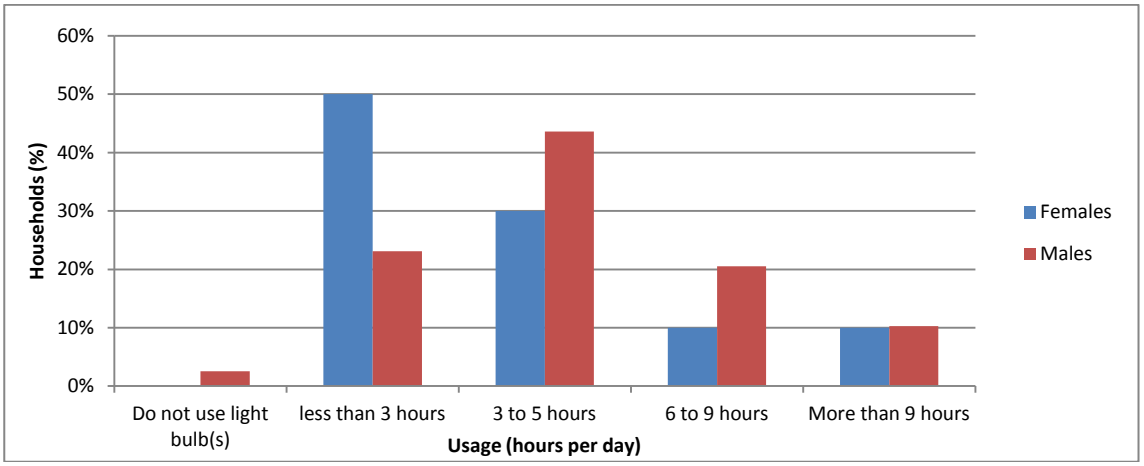

Figure 4: Light bulb usage in the winter per day - Gender distribution as a percentage of all the households surveyed.

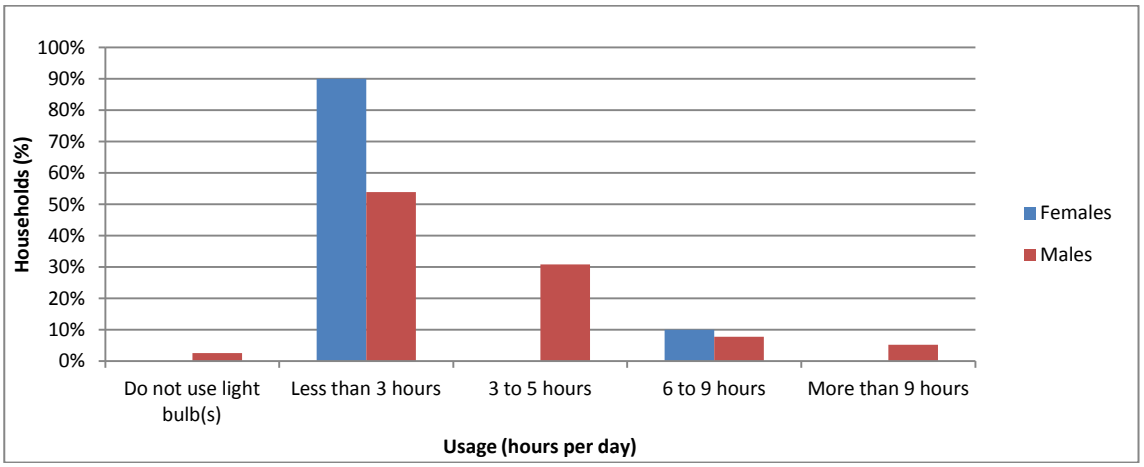

Figure 5: Light bulb usage in the summer per day - Gender distribution as a percentage of all the households surveyed.

2.2.2 Age and Household Energy Use

General observations found that older respondents use their appliances and lighting more per day than the younger respondents. The reason for this maybe because older individuals spend more time in their apartment unit compared to younger age groups (Figure 6). Table 2 shows the appliance and electrical device ownership for each age group; the highest ratio is between 46 to 60 years old (0.31) and the least from ages 31 to 45 years old (0.24).

Figure 7 shows that older adults have the television on for longer periods a time per day than any other age group. 46 to 60 years old, for example, 21% of the respondents leave the television on 9 to 13 hours per day. Younger adults (18 to 30 years old), on the other hand, a majority of them (60%) only have the television on for 1 to 3 hours per day.

In terms of computer usage, 18 to 30 years old use their computer 9 hours or more per day. Whereas, 86% of the older adults (over 60 years) do not own a computer (Figure 8). Furthermore, older adults are found to use the stove more hours per day than any other age group (Figure 9). Over 60 years old respondents, for instance, 13% of those respondents spend more than 3 hours per day using the stove compared to all the other age groups. A similar trend is found in lighting usage - older adults use lighting longer than younger age groups for both winter and summer (Figure 10 and 11). Table 2, however, shows either younger adults (18 to 30 years) or older adults (over 60 years) prefer high temperatures during the winter. Middle-aged respondents do not use or prefer to set their heating or cooling equipment during the winter or summer (e.g. fan coil unit).

Table 2: Appliance Ownership ratio between ages - ratio of all the households surveyed.

	Ratio
18 to 30 years	0.2833
31 to 45 years	0.2417
46 to 60 years	0.3125
Over 60 years	0.2722

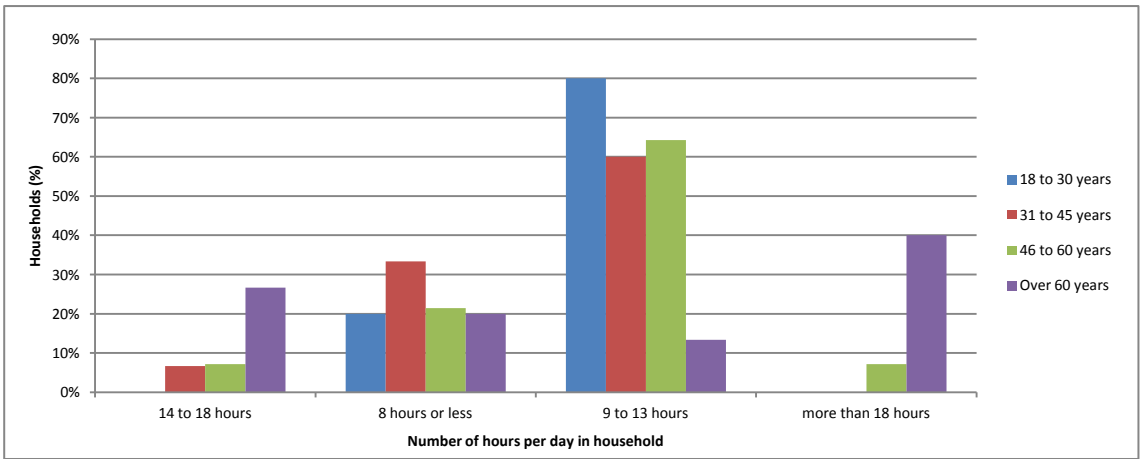

Figure 6: Hours per day in household - Age distribution as a percentage of all households surveyed.

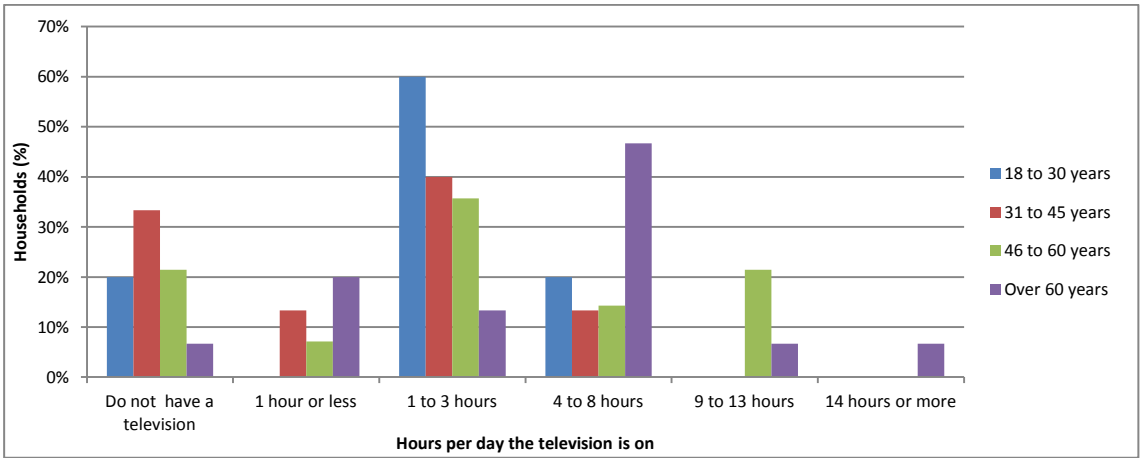

Figure 7: Hours per day the television is on - Age distribution as a percentage of all the households surveyed.

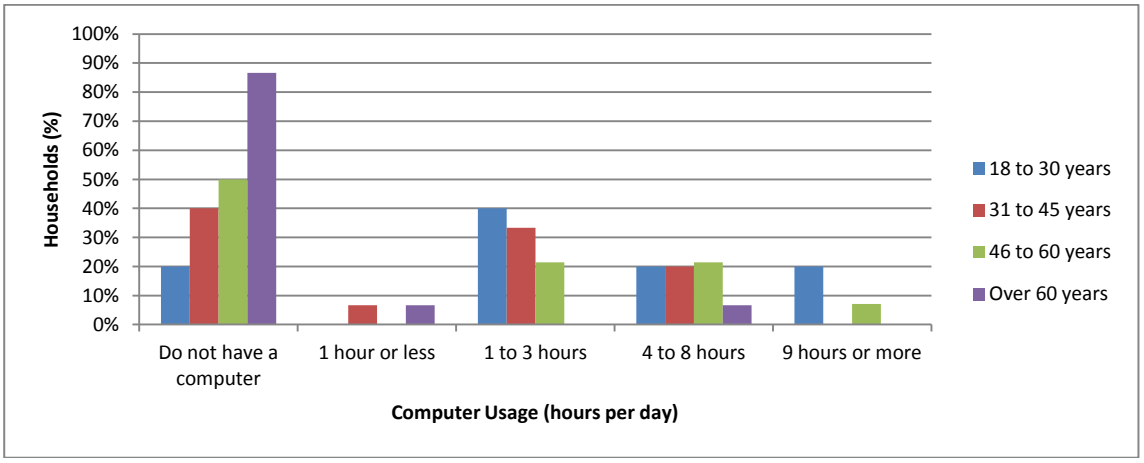

Figure 8: Computer usage per day - Age distribution as a percentage of all the households surveyed.

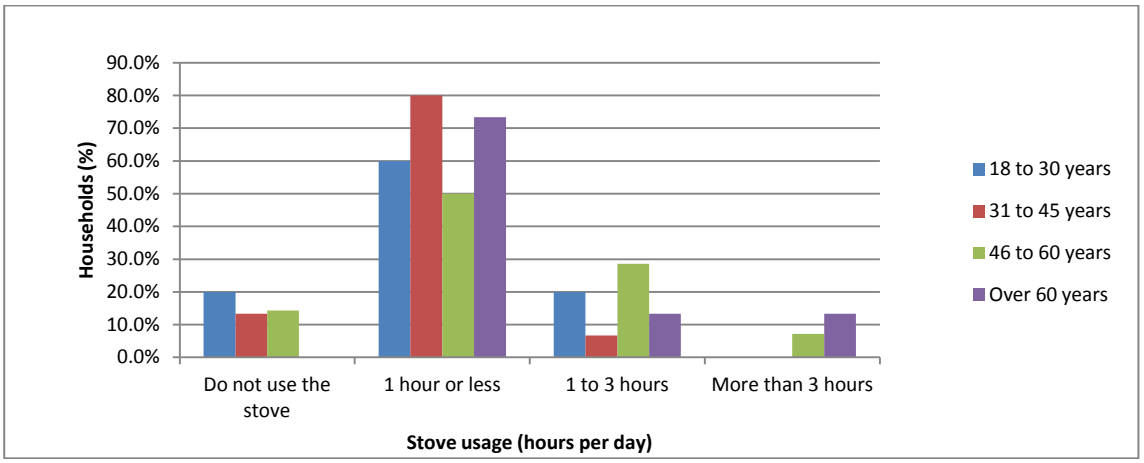

Figure 9: Stove usage per day - Age distribution as a percentage of all the households surveyed.

Table 3: Householder's preferred temperature during winter and summer for heating and cooling equipment - Age distribution as a percentage of all households surveyed.

	18 to 30 years (N=5)		31 to 45 years (N=15)		46 to 60 years (N=14)		Over 60 years (N=15)	
Temperature (°C)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Do not use heating or cooling equipment.	20.0%	40.0%	60.0%	60.0%	35.7%	35.7%	20.0%	46.7%
0-16	0.0%	40.0%	6.7%	0.0%	21.4%	28.6%	13.3%	13.3%
16<x<20	20.0%	20.0%	26.7%	33.3%	21.4%	28.6%	13.3%	20.0%
>20	60.0%	0.0%	13.3%	6.7%	14.3%	7.1%	53.3%	20.0%
Other	0.0%	0.0%	0.0%	0.0%	7.1%	7.1%	0.0%	0.0%

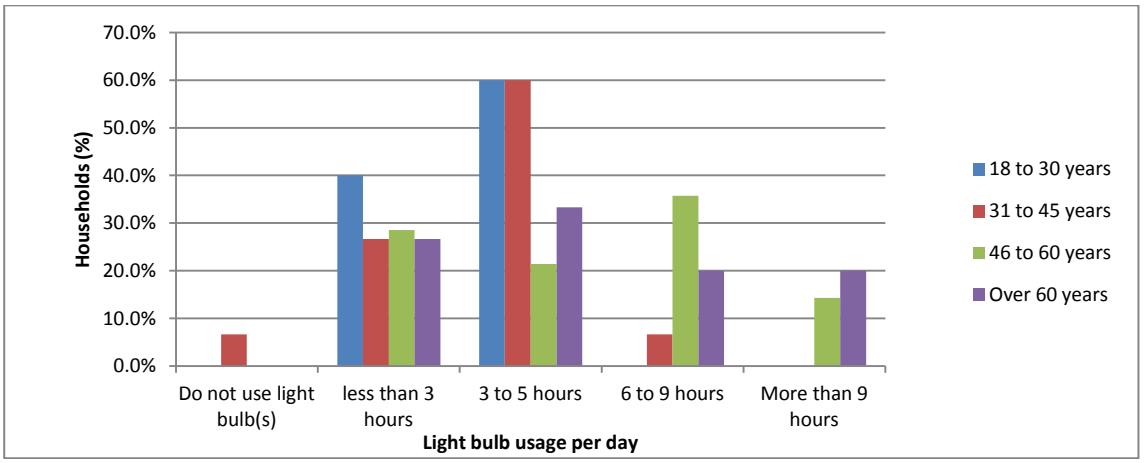

Figure 10: Light bulb usage in the winter per day - Age distribution as a percentage of all the households surveyed.

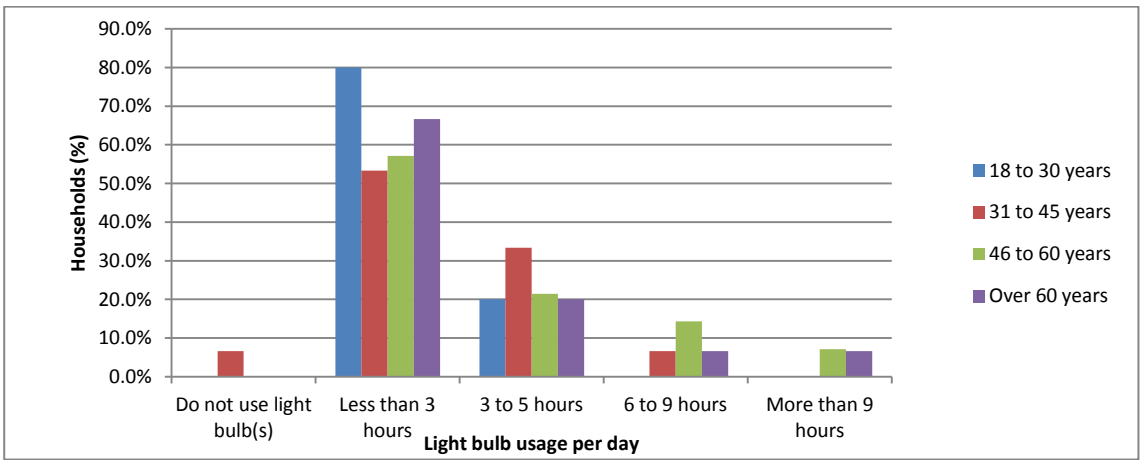

Figure 11: Light bulb usage in the summer per day - Age distribution as a percentage of all the households surveyed.

2.2.3 Residency and Household Energy Use

A majority of the respondents that live in the rental MURBs longer than 7 years are over 60 years old (Figure 12), receive higher incomes (Figure 13) than those who are newer residents, and older adults have a higher appliance ownership (0.29) ratio than those who are newer residents (0.21) (Table 4). Newer residents (33%) do not have a television; where as 36% of longer residency respondents have their television on for 4 to 8 hours per day (Figure 14). In terms of computer usage, residents living in their apartment units more than 7 years (72%) are most likely do not have a computer (Figure 15). Longer residency respondents, however, use the stove more than the newer residents - longer residency use their stove more than 3 hours per day (12%); whereas, newer residents do not use their stove more than 3 hours (Figure 16).

As a majority of the household energy use is from space heating, it is evident that longer residency respondents use more energy due to their demand and preferred temperatures (36.4% of the respondents) during the winter (Table 5). Longer residency respondents (63%) prefer a temperature above 20℃ for their heating equipment to be set. Another contributor of household energy use is lighting. Figure 17 and 18 shows that residents residing more than 7 years use their light bulbs on longer than newer residents. During the winter, 12% of the 7-year residents use their light bulbs more than 9 hours a day; whereas, none of the 1-year resident do not. A majority of the 0-1 year residents (65%) use their light bulbs 3 to 5 hours per day during the winter. Similarly, during the summer, 4% of the "more than 7 years" residents use their light bulbs more than 9 hours; whereas, a majority of the "0 to 1 year" residents (65%) use their light bulbs less than 3 hours per day.

Table 4: Appliance Ownership ratio between Residency - ratio of all the households surveyed.

Age groups	Ratio
0 to 1 year	0.21
2 to 4 years	0.27
5 to 7 years	0.28
More than 7 years	0.29

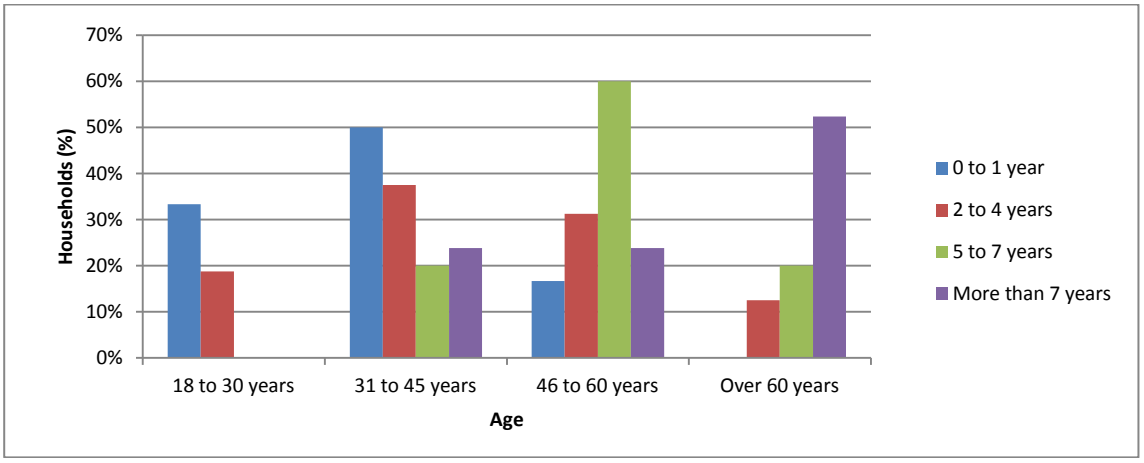

Figure 12: Age - Residency distribution as a percentage of all the households surveyed.

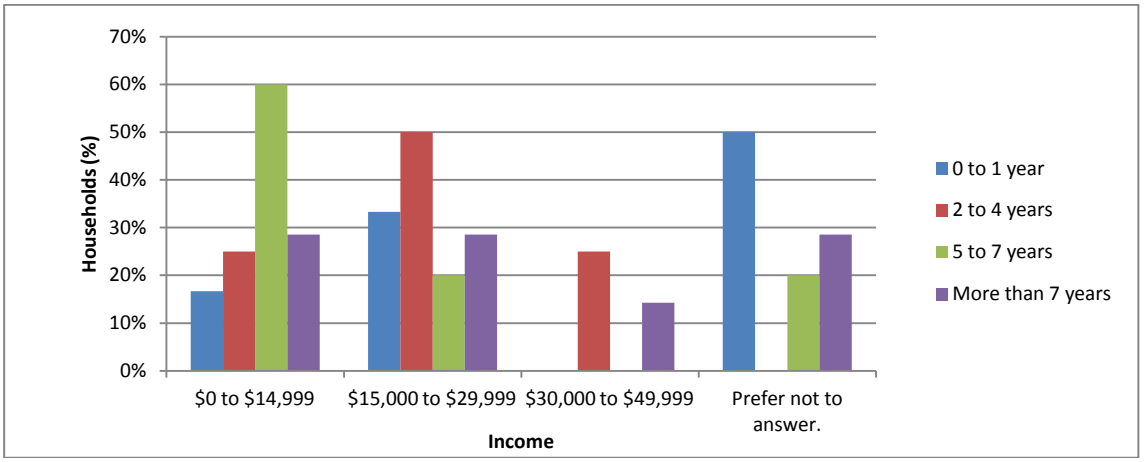

Figure 13: Income - Residency distribution as a percentage of all the households surveyed.

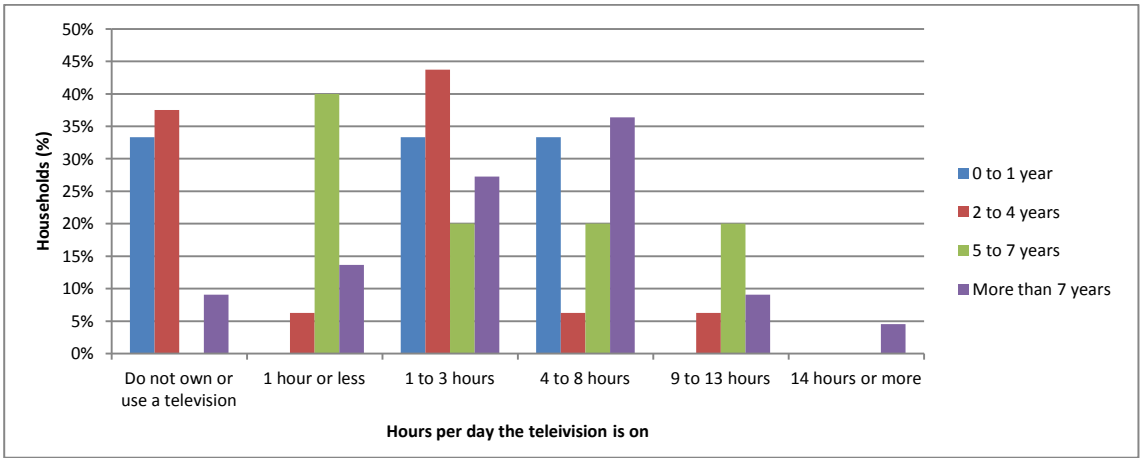

Figure 14: Hours per day the television is on - Residency distribution as a percentage of all the households surveyed.

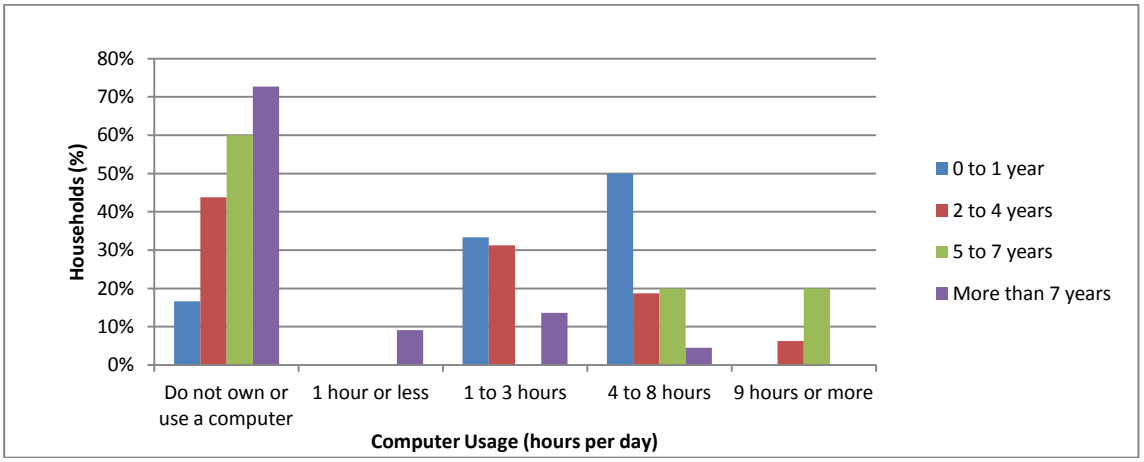

Figure 15: Computer usage per day - Residency distribution as a percentage of all the households surveyed.

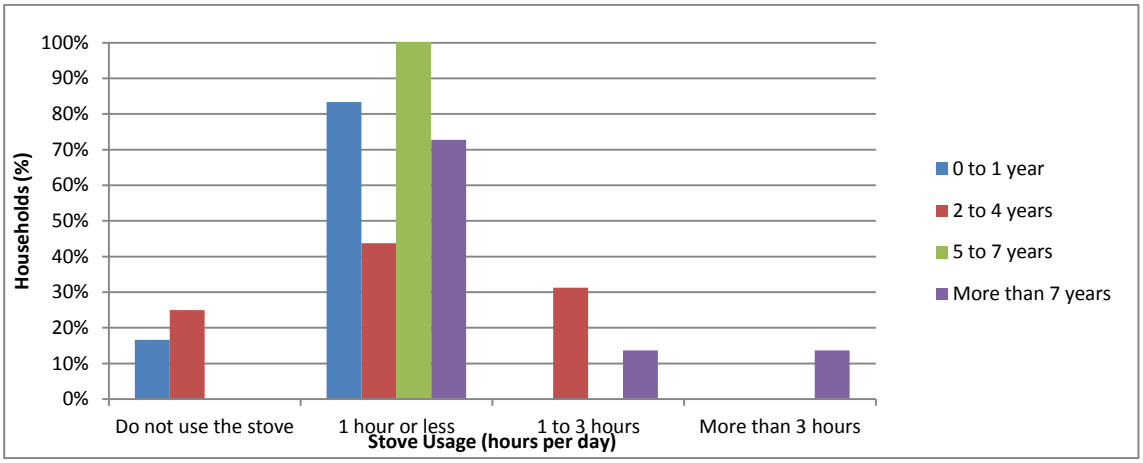

Figure 16: Stove usage per day - Residency distribution as a percentage of all the households surveyed.

Table 5: Householder's preferred temperature during winter and summer for heating and cooling equipment - - Residency distribution as a percentage of all households surveyed.

	0 to 1 year		2 to 4 years		5 to 7 years		More than 7 years	
Temperature (^{o}C)	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
0	50.0%	50.0%	37.5%	43.8%	40.0%	60.0%	31.8%	45.5%
0-16	16.7%	16.7%	12.5%	12.5%	0.0%	0.0%	18.2%	22.7%
16<x<20	16.7%	33.3%	12.5%	31.3%	60.0%	40.0%	4.5%	18.2%
>20	16.7%	0.0%	31.3%	6.3%	0.0%	0.0%	36.4%	13.6%
Other	0.0%	0.0%	6.3%	6.3%	0.0%	0.0%	0.0%	0.0%

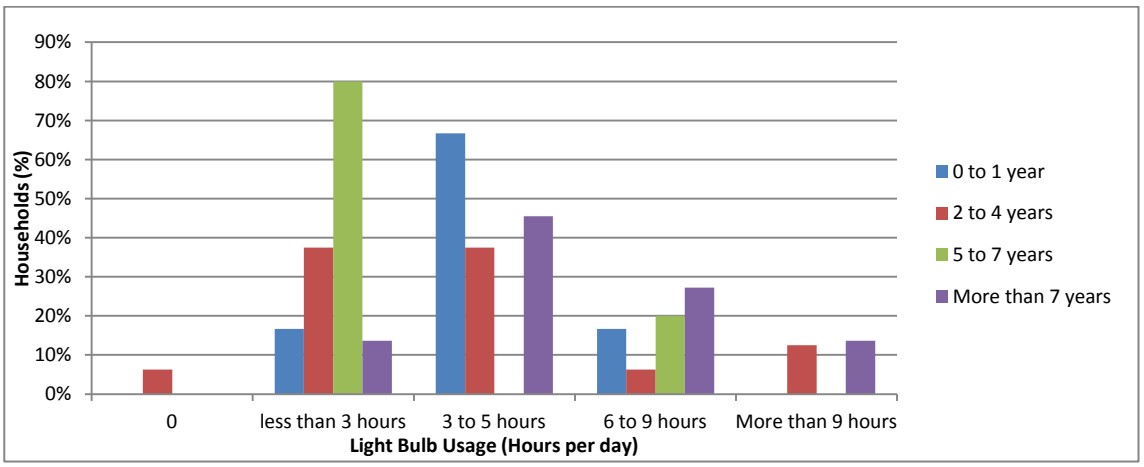

Figure 17: Light bulb usage in the winter per day - Residency distribution as a percentage of all the households surveyed.

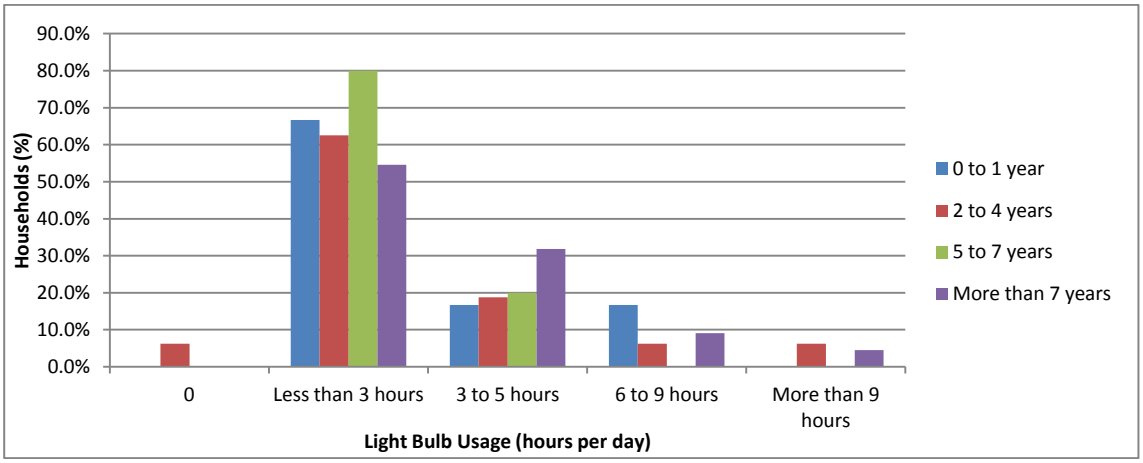

Figure18: Light bulbs turned on longer than 3 hours or more - Residency distribution as a percentage of all the households surveyed.

2.3. Comparison to SHEU 2007

The Survey of Household Energy Use 2007 (SHEU 2007) is a national survey conducted every four years to assess characteristics of household energy consumption throughout Canada. The information collected are dwelling characteristics, number of appliances and electrical devices, energy consumption and energy efficiency characteristics. This section highlights comparison between the rental MURBs survey respondents and the national survey, SHEU 2007.

2.3.1 Television

According to SHEU 2007, television sets "are the highest penetration rate of all the appliances" [25] and this is evident from the survey respondents, where a majority of the respondents own a television that is 5 years or less (55%). Similarly, in SHEU 2007, 55% of the most frequently used televisions are 5 years or less in Canada [25]. Figure 19 compares the age of televisions from the respondents to that of SHEU 2007. Penetration rate is the percentage of a sample population that use a given product during a specific time [25]. The sample population, in this case, are the survey respondents. Furthermore, there is a positive relationship between the number of members of a household and the number of television [25].

- 36% of the respondents own a regular (tube) television, 23% own a plasma television, and 41% of the respondents own a LCD/LED television.
    - In SHEU 2007, Canadians who own a television 64.5% of them own a regular (tube) television, 5.3% own a plasma television, and 13.6% own a LCD television.

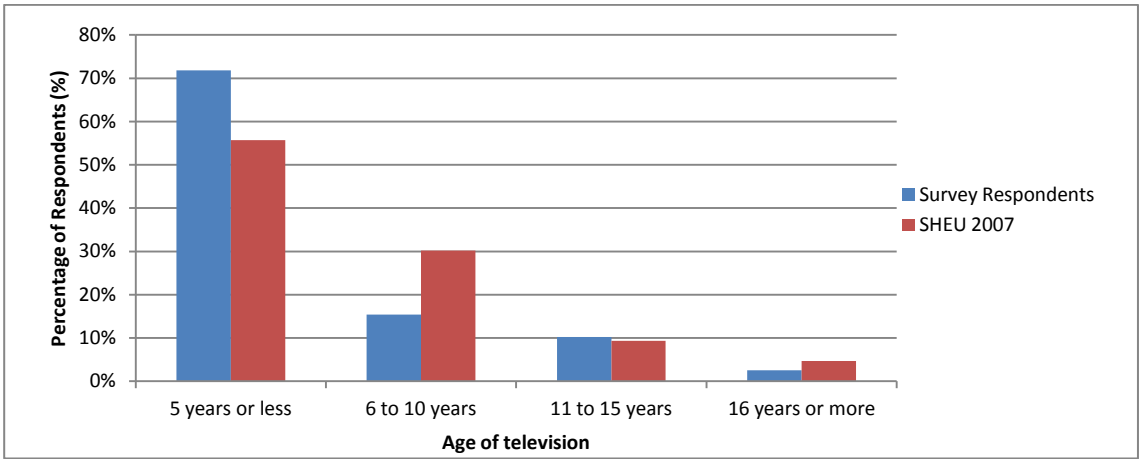

Figure 19: Age of Television - Comparison between SHEU 2007 and survey respondents.

2.3.2 Computer

A personal computer is either a desktop or laptop computer. Figure 20 compares the survey respondent's personal computer use to the Natural Resources Canada's Survey of Household Energy Use 2007. Figure 20 also shows that survey respondents do not have as many personal computers within their households compared to SHEU - A majority of the survey respondents do not have a computer; whereas, SHEU shows that a majority of Canadians have at least one personal computer. A similar trend is expressed between the survey respondents and SHEU 2007 - a majority of the computers are 5 years old or less (Figure 21).

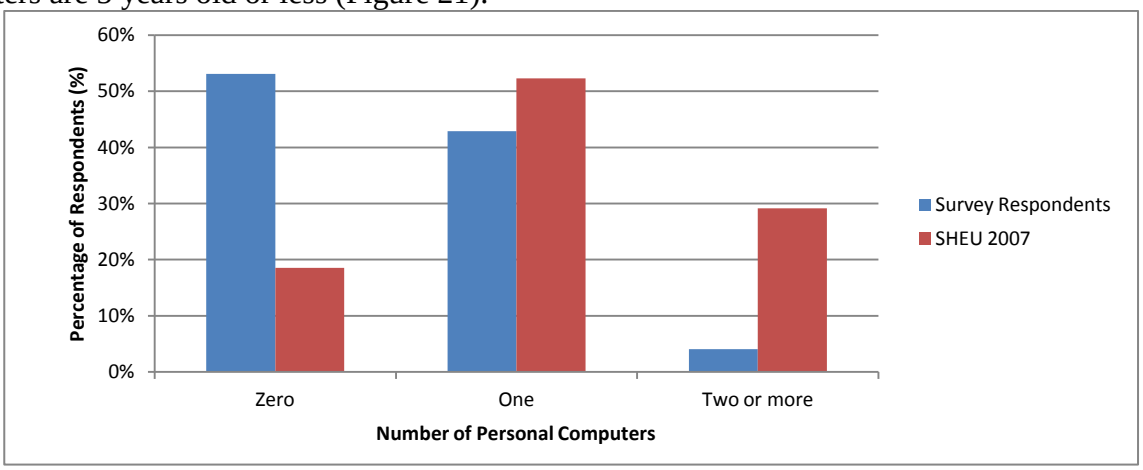

Figure 20: Comparison between SHEU 2007 and survey respondents - Number of personal computers.

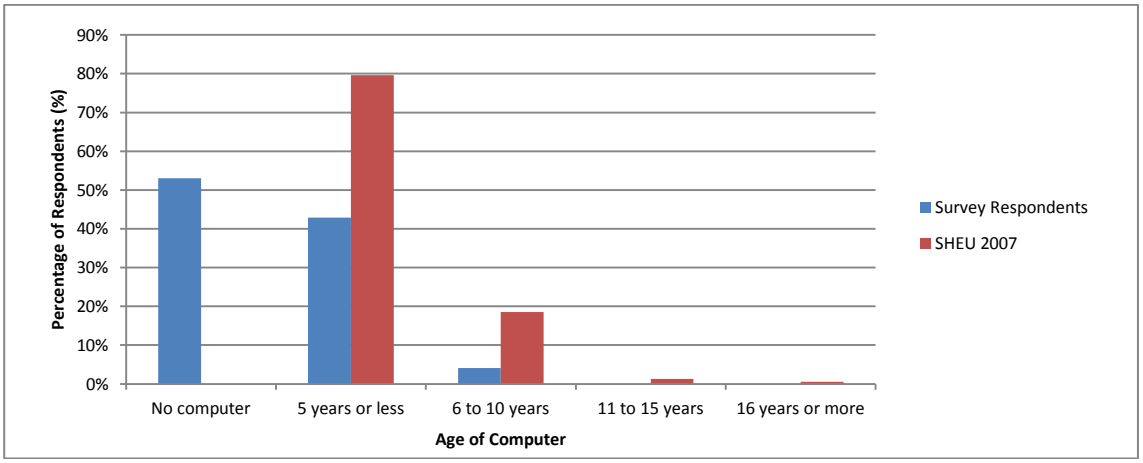

Figure 21: Comparison between SHEU 2007 and survey respondents - Age of Computer.

2.2.3 Lighting

Figure 22 illustrates the average number of each light bulb in an apartment unit - 2.4 CFLs and 1.6 incandescent light bulbs. In addition, the figure compares the number of light bulbs to the survey respondent's unit to the average number of light bulbs in a high-rise apartment unit [25]. It is evident that the survey respondents use less light bulbs than the typical high-rise apartment household. Surveyed occupants, however, do use more CFLs than the national average.

Figure 23 shows that the survey respondents significantly less incandescent light bulbs are turned on longer than 3 hours per day. Figure 24 shows that during the winter, a majority of the survey respondents turn their incandescent light bulbs 3 to 5 hours per day (40.8%); whereas SHEU 2007 respondents turn on their incandescent light bulbs longer - 6 to 9 hours (50.1%). Figure 25 shows that during the summer, a majority of the survey respondents turn their incandescent light bulbs less than 3 hours per day (61.2%); whereas SHEU 2007 respondents turn on their incandescent light bulbs longer - 3 to 5 hours (50.1%).

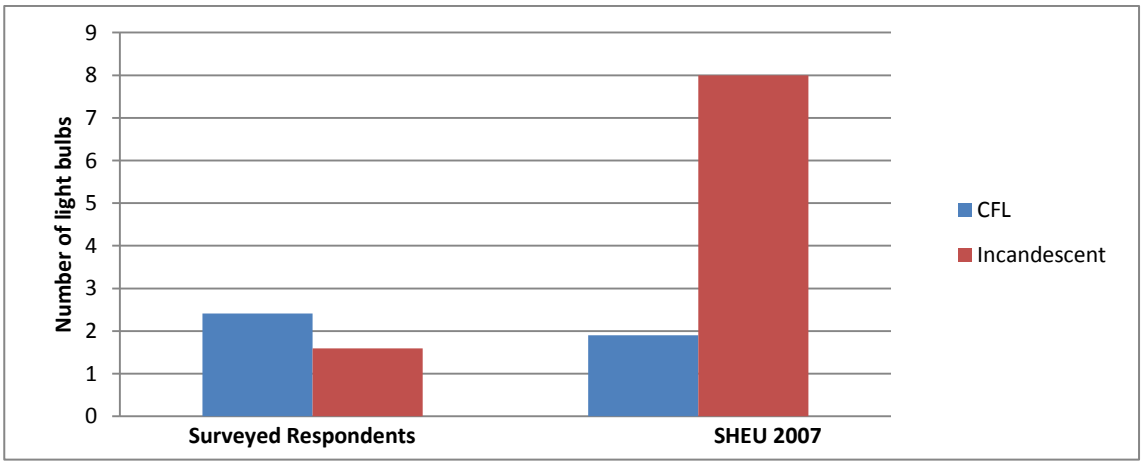

Figure 22: Average number of light bulbs per household - Comparison between SHEU 2007 and survey respondents

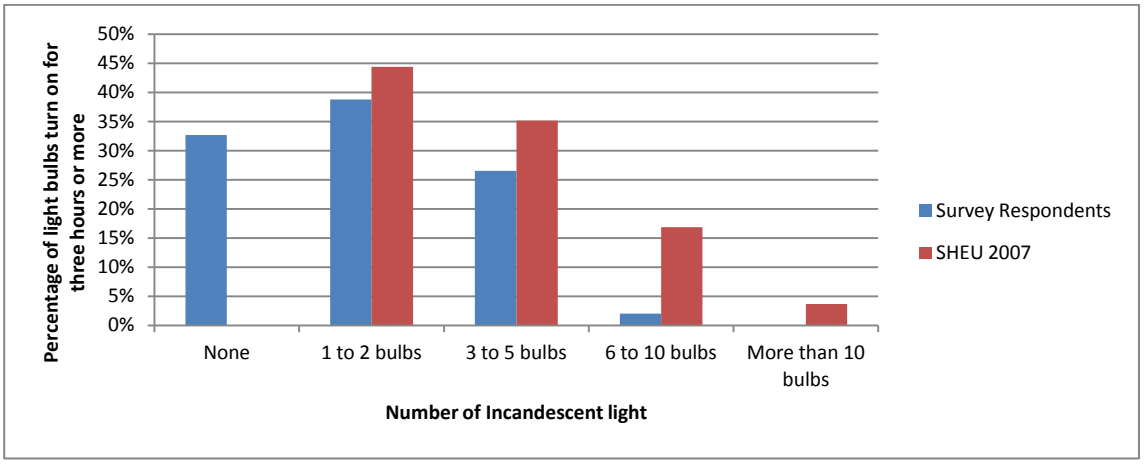

Figure 23: Number of incandescent light bulbs turned on longer than 3 hours per day - Comparison between SHEU 2007 and survey respondents

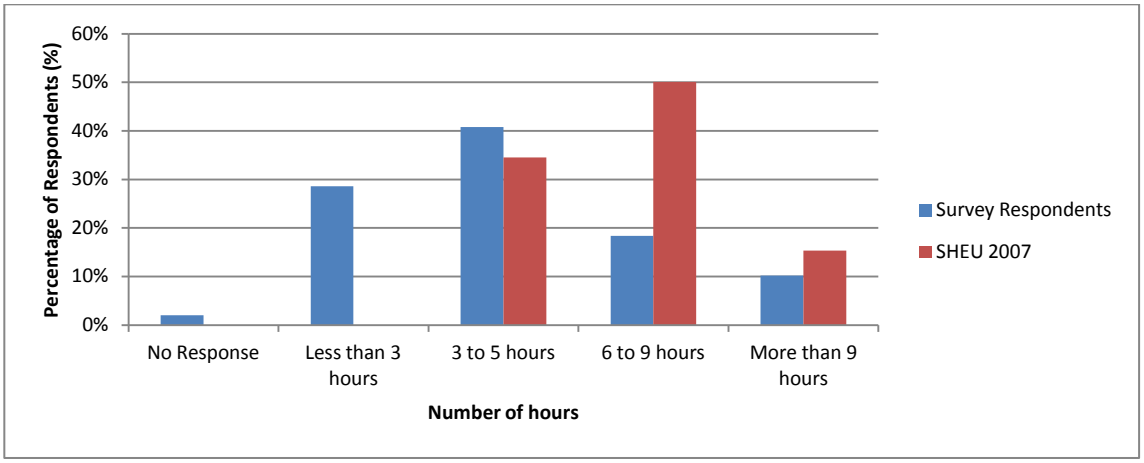

Figure 24: Number of hours incandescent light bulbs are turned on during an average day in the winter - Comparison between SHEU 2007 and survey respondents

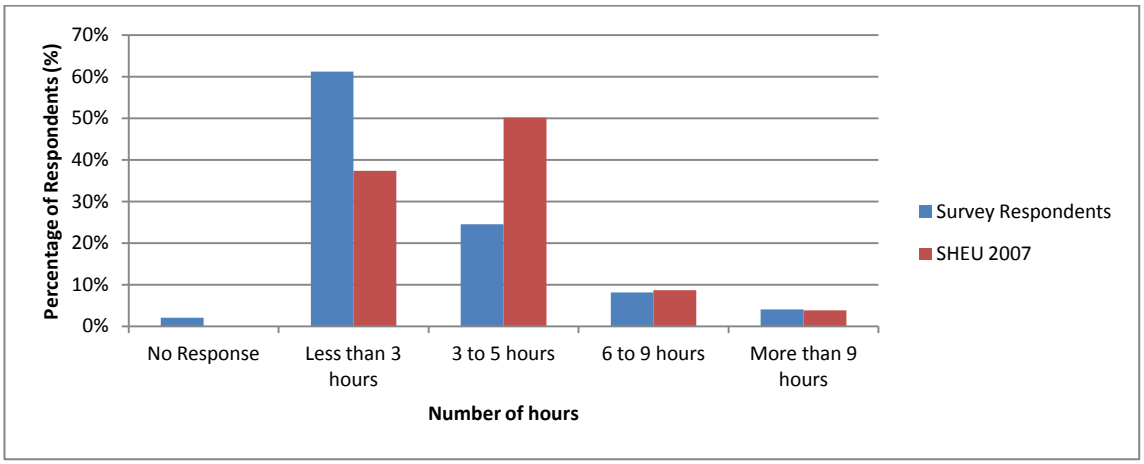

Figure 25: Number of hours incandescent light bulbs are turned on during an average day in the summer - comparison between SHEU 2007 and Survey Respondents

2.4. Indoor Environment Satisfaction and Thermal Comfort

Table 6 shows that the average survey respondent is overall satisfied with the indoor environment satisfaction of the rental MURB. Respondents are most satisfied with the cleanliness of the building (average = 1.71). Respondents, however, are somewhat dissatisfied with the temperature of their apartment units during the summer (average = 4.04).

Table 6: Occupant's average score on indoor environment satisfaction of their rental MURB.

How satisfied are you with...	Average score (1 being very satisfied; 7 being very dissatisfied)
...the amount of space available for individual daily activities?	3.45
...the apartment unit layout?	2.84
...the quality of water in your apartment?	2.18
...the appliances in your apartment (i.e. stove, refrigerator, etc.)?	2.02
...the cleanliness of the building?	1.71
...the maintenance of the building?	2.18
...the temperature of your apartment unit during the summer?	4.04
...the temperature of your apartment unit during the winter?	2.82
...the temperature of your apartment unit during the spring/fall?	2.67
...the air quality in your apartment (e.g. stuffy/stale air, odours, cleanliness, etc.)?	3.33
...the sound privacy between apartments?	2.84

The correlation between indoor environment satisfaction and thermal comfort is highly significant. First, there is a correlation between the cleanliness of the building satisfaction and maintenance satisfaction (Pearson $r = 0.747$, $P<0.01$). Second, there is a correlation between the temperature of their apartment unit during the summer and overall enhancement of occupant's thermal comfort (Pearson $r=0.86$, $P<0.01$). Similarly, there is a correlation between the temperature of their apartment unit during the winter and overall thermal comfort (Pearson $r=0.759$, $P<0.01$). Fourth, there is a strong correlation between the temperature of their apartment unit during the spring/fall and overall thermal comfort (Pearson $r=0.933$, $P<0.01$). Lastly, there is a correlation between the air quality in the apartment units and their overall thermal comfort (Pearson $r=0.810$, $P<0.01$). Wagner et al. (2007) conducted a study that looked at thermal comfort and the effects on occupant's satisfaction [26]. Wagner et al. (2007) revealed that occupant's who control their climate influences their overall satisfaction with thermal indoor conditions. This study also recognizes that indoor climate conditions are strongly correlated with an occupant's satisfaction; this study reconfirms this point.

3. Experimental Section

The study consisted of conducting surveys to all tenants living within a rental MURB in Toronto. The survey has nine parts, a total of 51 questions. The questionnaire investigated the following: demographics (e.g. age, gender and residency), appliance characteristics and usage (e.g. minor appliances), heating and cooling equipment characteristics and usage, energy behaviour, lighting

characteristics and usage, water usage, indoor environment satisfaction and thermal comfort. The survey was distributed and collected between April and May 2012. The sample units are households - one survey respondent represents a household. Prior to survey distribution, notification posters were posted in high traffic areas (e.g. lobby and hallways) for 1-month. Surveys were distributed by employing three survey methods:

1. Paper-based self-enumeration (mail-in surveys): Surveys were sent to household's mailbox in April. A drop box was available in the main lobby. The drop box was then removed in May
2. Interview-assisted surveys: Five interview sessions were held in the main lobby in the evenings.
3. On-line survey: Tenants had the opportunity to complete the survey on-line. The on-line survey became unavailable at the end of May.

Some general observations during the interview-assisted surveys were: First, the average number of tenants per household were single-occupancy household; Second, the tenants that were interviewed were the "primary occupant" of the household; Lastly, a majority of the tenants were seniors.

All survey responses were inputted into Microsoft Excel. The analysis was then performed using Statistical Package for Social Science (SPSS). SPSS is a tool used to analyze survey data; it has many uses such as discovering the correlation between variables, frequencies and creating graphs. For this study, SPSS was used for frequency and correlation tables. Further analysis was carried out using Microsoft Excel to compare trends found in literature on occupant characteristics (e.g. age, gender, income, residency, and hours spent in their household) and its relationship to household energy use.

4. Conclusions

Household energy use is dependent on many factors - structure of the home, human behaviour, age of appliances, and the list goes on. This paper focused on investigating household energy use of occupants residing in a Toronto rental MURB. This paper had also compared results to a national survey, indoor environment satisfaction and thermal comfort. First, the results suggest that specific demographics (e.g. males, older-aged, or longer residency respondents) own or use their appliances compared to other occupant characteristics. Male respondents, for instance, were found to own more appliances than women. Second, indoor environment satisfaction can be improved by temperature adjustments within respondent's apartment units during the summer. Respondents were somewhat dissatisfied with the temperature of their apartment unit during the summer. Lastly, it was also found that survey respondents use and own significantly less appliances and electrical devices compared to an average household. For instance, survey respondents have more CFLs in their apartment unit compared to SHEU 2007; but the average household uses significantly more incandescent bulbs. Survey respondent's lighting usage during the winter or summer is also significantly less than the average household.

There are two main issues to consider relating to this study: first, rental housing is very unique in that, sometimes occupants do not have to pay for their energy consumption. Second, energy consumption can increase due to increase in the use of appliances or purchasing more appliances. Lastly, survey responses are sometimes not representative of the respondent's actual energy consumption. The concept of tenant engagement and education strategies, however, can promote

energy reduction opportunities for occupants in a rental setting. This study can further facilitate similar analysis by comparing the energy use and behaviour before and after implemented strategies. A similar analysis can also be conducted by assessing respondent's survey results to their actual energy consumption.

It is recommended to have a larger sample size to have a higher degree of accuracy to represent the survey population. More advanced statistical analysis can be done looking more in-depth on the occupant predictors of household energy consumption. The survey results from this project is part of a larger project. It will also serve as the basis of investigating other rental MURBs and analysis. Neural networking is able to find internal representations between raw data such as the survey results in this project [13]. The next steps of this project is to use the survey data and energy consumption to model household energy use within the rental MURB.

Acknowledgments

I would like to acknowledge and thank the supporters of this project: Mitacs, City of Toronto, Canadian Mortgage and Housing Corporation (CMHC), Ontario Ministry of Municipal Affairs and Housing (MAH), and Enbridge Gas Distribution Inc..

Conflict of Interest

The authors declare no conflict of interest.

References and Notes

1. Natural Resources Canada. (2011). *Energy Efficiency Trends in Canada: 1990 to 2008.* Retrieved 2012 January from Natural Resources Canada: http://oee.nrcan.gc.ca/publications/statistics/trends10/index.cfm
2. Liu, R. (2007). *Energy Consumption and Energy Intensity in Multi-Unit Residential Buildings (MURBs) in Canada.* Retrieved February 2011, from Canadian Building Energy End-Use Data and Analysis Centre: http://www.cbeedac.com/publications/documents/MURBsrp04.pdf
3. Yohanis, Y. G. (2012). Domestic energy use and householders' energy behaviour. *Journal of Energy Policy*. 41: pp. 654-665.
4. Abrahamse, W., Steg, L., Vlek, C., & Rothengatter, T. (2005). A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology* , 25: pp. 273-291.
5. Paco, A., Varejao, L. (2010). Factors affective energy saving behaviour: a prospective research. *Journal of Environmental Planning and Management*. 53 (8): pp.963-976.
6. Haldi, F., Robinson, D. (2011). The impact of occupants' behaviour on building energy demand. *Journal of Building Performance Simulation.* 4 (4): pp.323-338.
7. Cayla, J. Maizi, N., Marchand, C. (2011) The role of residency in energy consumption behaviour: Evidence from French household data. *Journal of Energy Policy*. 39: pp.7874-7883.
8. Bonino, D., Corno, F., De Russis, L. (2012). Home energy consumption feedback: A user survey. Journal of Energy and Buildings. 47: pp. 383-393.
9. Yohanis, Y. G. (2012). Domestic energy use and householders' energy behaviour. *Journal of Energy Policy*. 41: pp. 654-665.

10. Hitchcock, G. (1993). An integrated framework for energy use and behaviour in the domestic sector. *Journal of Energy and Buildings*. 20 (2): pp. 151-157.
11. U.S. Department of Energy (2012). Residential Energy Consumption Survey (RECS). Retrieved on January 2012 from weblink: http://www.eia.gov/consumption/residential/
12. Fung, A., Aulenback, A., Ferguson, A., Ugursal, V. (2003) Standby power requirements of household appliances in Canada. *Journal of Energy and Buildings*. 35: pp. 217-228.
13. Aydinalp, M., Ugursal, V., & Fung, A. (2003). Effects of socioeconomic factors on household appliance, lighting, and space cooling electricity consumption. *International Journal of Global Energy Issues* , 20 (3): pp. 302-315.
14. Neilsen, J. B., Gyrd-Hansen, D., Kristiansen, I., Nexoe, J. (2003). Impact of Socio-demographic Factors on Willingness Pay for the Reduction of a Future Health Risk. *Journal of Environmental Planning and Management*. 46(1): pp. 39-47.
15. Yamagishi, A., Tereda, K., Arakawa, M., Amano, K., Yamashita, Y., Okamura, K., Ishigaki, H., Kato, N., Tsuchikawa, T., Sik, C., Dan, W., Lin, Z, Horikoshi, T. (1993). Indoor Environmental Study and Post Occupancy Evaluation in an Office Environment. *Journal of Thermal Biology.* 18(5/6): pp. 533-540.
16. Humphreys, M. (2005). Quantifying occupant comfort: are combined indices of the indoor environment predictable? *Journal of Building Research and Information*. 33(4): pp.317-325.
17. Steemers, K., Manchanda, S. (2010) Energy efficient design and occupant well-being: Case studies in the UK and India. *Journal of Building and Environment*. 45: pp. 270-278.
18. National Science Foundation (NSF) - Center for the Building Environment. (2012). Retrieved on December 11, 2011, from http://www.cbe.berkeley.edu/index.htm
19. United Way Toronto. (2011). Vertical Poverty Retrieved November 12, 2011, from http://www.unitedwaytoronto.com/verticalpoverty/downloads/Report-PovertybyPostalCode2-VerticalPoverty-Final.pdf
20. TowerWise (2012). City of Toronto's Toronto Atmospheric Fund (TAF) website. Retrieved on March 2012 from weblink: http://www.towerwise.ca/about_towerwise.
21. Statistics Canada (2007). Income in Canada. Catalogue no. 75-202-X
22. Guerin, D. A., Yust, B. L., & Coopet, J. G. (2000). Occupant Predictors of Household Energy Behaviour and Consumption Change as Found in Energy Studies Since 1975. *Family and Consumer Sciences Research Journal*. 29 (1): pp.48-80.
23. Yun, G., Steemers, K. (2011). Behaviour, physical and socio-economic factors in household cooling energy consumption. *Journal of Applied Energy*. 88: pp. 2191-2200.
24. Guerra-Santin, O., Itard, L. (2010). Occupant's behaviour: determinants and effects on residential heating consumption. *Journal of Building Research and Information*. 38 (3): pp. 318-338.
25. Natural Resources Canada. (2010). *Office of Energy Efficiency*. Retrieved September 23, 2012, from Natural Resources Canada: http://oee.nrcan.gc.ca/Publications/statistics/sheu-summary07/pdf/sheu-summary07.pdf
26. Wagner, A., Gossauer, E., Moosmann, C., Gropp, Th., Leomhart, R. (2007). Thermal comfort and workplace occupant satisfaction - Results of field studies in German low energy office buildings. *Journal of Energy and Buildings*. 39: pp. 758-769.