1-1-2013

# Survey And Articifical Neural Network Analysis On Occupant's Household Energy Use In A High-Rise Multi-Unit Residential Building In Toronto, Canada

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# SURVEY AND ARTIFICIAL NEURAL NETWORK ANALYSIS ON OCCUPANT'S HOUSEHOLD ENERGY USE IN A HIGH-RISE MULTI-UNIT RESIDENTIAL BUIILDING IN TORONTO, CANADA

By

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Honours Bachelor of Science

University of Toronto, 2010

A thesis

Presented to Ryerson University

In partial fulfillment of the requirements for the degree of

Master of Applied Science

In the program of

Environmental Applied Science and Management

Toronto, Ontario, Canada, 2013

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**Abstract**

Examining occupant's household energy use is a crucial step in achieving significant reductions in energy consumption. The purpose of this thesis is to collect information on ownership of appliances and electronics to evaluate their use, energy consumption, and behaviour with respect to energy in a Toronto high-rise multi-unit residential building (MURB). In this thesis, a survey was developed and implemented in a Toronto high-rise MURB. The survey data, energy consumption data from October 2010 to September 2012, and weather conditions were analyzed and used to develop an artificial neural network (ANN) model.

The detailed analysis of survey data resulted in the development of relationships between occupant's demographics and energy consumption. By creating an ANN model, results showed that the implementation of the survey may have reduced occupant's energy consumption in the high-rise MURB.

**Acknowledgments**

I would like to thank my supervisors, Dr. Alan S. Fung and Vera Straka, for all of their support and guidance throughout the course of my thesis. Dr. Alan S. Fung has been a great mentor and had invaluable comments. I would like to thank Vera Straka for her encouragement and review of my thesis throughout the way.

I would also like to thank Dr. Alan S. Fung and Vera Straka for allowing me to be part of Ryerson's Initiative: Tower Renewal Program. This initiative would not be possible without our sponsors: Canada Mortgage and Housing Corporation (CMHC), Ontario Ministry of Municipal Affairs and Housing (MAH), City of Toronto, Enbridge Gas Distribution Inc., and MITACS.

I would also like to thank Sylvain Prez and Damien Le Net for their assistance.

Finally, I would like to thank my family, friends, and loved ones for their continued support and encouragement during my Master's thesis.

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# Chapter 1 Introduction

## 1.1 Introduction

There has been a significant amount of studies on household energy consumption, particularly in the matter of residential building design and materials. Energy behaviour and usage, however, is a relatively new topic (Yohanis, 2012). Household energy consumption is an important issue, especially in Canada, where 17% of Canada's total energy use is due to the residential sector. Furthermore, from 1990 to 2008, Canada's residential sector increased its secondary energy[1] consumption by 14% and greenhouse gas emissions by 9% (Natural Resources Canada, 2011a). With increases in greenhouse gases and energy consumption, environmental effects are at risk such as climate change and loss of biodiversity (Abrahamse *et al.*, 2005). Reducing household energy consumption, therefore, would be beneficial for Canadians in order to reduce greenhouse gas emissions and their threat to the environment.

During the 1960s to 1970s, high-rise multi-unit residential buildings (MURBs) became one of the predominant forms of housing in Toronto. MURBs are responsible for 24% of the overall energy consumption within the residential sector (Liu, 2007). These buildings are energy inefficient due to their concrete frames, outdated building envelope and features - e.g., heating and cooling equipment, cladding, appliances, etc. (City of Toronto, 2011a). Another dimension of high-rise MURBs is occupant's household energy use. It is said that "buildings don't use energy: people do" (Janda, 2012). Thus, opportunities for significant reductions in energy consumption can be achieved by evaluating occupant's household energy use and behaviour within high-rise MURBs.

[1] Secondary energy is the energy used by the final consumers by sectors of the economy - transportation, residential, industrial, commercial, and agriculture.

## 1.2 Toronto Tower Renewal Program

One component of a municipal initiative, City of Toronto's *Tower Renewal Program,* is to reduce energy consumption in Toronto's MURBs. This initiative has many interested parties analyzing Toronto's high-rise residential buildings; interested parties include Canada Mortgage Housing Corporation (CMHC), Ontario Ministry of Municipal Affairs and Housing (MAH), City of Toronto, government agencies (e.g., TCHC and CMHC), University institutions (e.g., University of Toronto and Ryerson University) and NGOs (e.g., Toronto's Atmospheric Fund (TAF)). This study is to report to interested stakeholders on occupant's household energy use in a Toronto MURB pilot site.

The concept of Toronto's Tower Renewal Program was first introduced by E.R.A. Architects in 2004 and became a municipal initiative in 2008 (City of Toronto, 2011a). The focus of the program are on MURBs that were built between 1945 and 1984 with eight stories or more. The postwar boom created 1189 MURBs in Toronto. These apartment towers were typically built in mixed neighbourhoods, with concrete frames, and multiple elevators. Today, these buildings are energy inefficient, aging, lack maintenance, and typically house occupants of low socio-economic status (City of Toronto, 2011a; United Way Toronto, 2011).

Toronto's Tower Renewal Program was established to create pilot studies of various retrofits, programs and activities applied to Toronto's MURBs with a goal to explore their effectiveness and to develop strategies for various types of retrofits. Retrofits include mechanical, storm water retention, green roofs and renewable energy. With Toronto having the second highest high-rise building density in North America, the proposed project offers tremendous opportunities to (City of Toronto, 2011b):

- create a cleaner and healthier environment;

- create stronger communities;
- bring greater cultural awareness and activities;
- and enhance local economic activity.

In Canada, almost one-third of Canadians live in a MURB and this percentage is increasing (Liu, 2007). There are many issues related to MURB occupants and household energy use. First, high-rise rental MURBs typically house occupants of low socio-economic status (United Way Toronto, 2011). This restricts households to invest in energy efficient appliances or improvements. Second, occupants with the lack of knowledge or uninformed about residential energy consumption have shown to consume more energy than those tenants who are informed about energy consumption (Guerin *et al.*, 2000). Access to information and knowledge about tenant's household appliances and how much energy these appliances consume must be available in order to reduce energy consumption. Lastly, monthly rental costs includes utilities such as electricity and gas consumption. As a result, occupants would not care for the intensity level of their household energy use.

Household energy consumption is a function of structure and energy intensity of a home (Schipper *et al.*, 1982). Energy intensity is affected by behaviour, age and type of appliance, demographics and more (Yohanis, 2012). Determining all factors contributing to one's household energy consumption, however, is complex. Household energy consumption involves elements of technical, economic, social and psycho-social origin (Cayla *et al.*, 2011). Understanding and evaluating occupant's present household energy use and behaviour, therefore, is significant in order to develop energy reduction strategies such as tenant engagement and education. Artificial neural networking technique is an effective evaluation tool in determining causal relationships between many independent variables. In this case, neural networking may have the capabilities to develop a model in order to predict household's energy consumption based on multiple parameters. Currently, there has been no research done investigating household energy use in a Toronto MURB using neural networking (at an apartment unit level). In this thesis, the main objective is to fill this void.

## 1.3 Objectives of the Study

The main objective of this thesis is to investigate occupant's household energy use in a Toronto MURB. The investigation will comprise of evaluating the impact of various factors on household energy consumption in a Toronto rental high-rise multi-unit residential building (MURB). In addition, develop monthly profiles of the various factors and their impact on household energy consumption using a model.

This study is part of a larger and an on-going research project with Ryerson University. The data for this thesis were obtained by conducting a survey, access to a Toronto MURB unit's energy consumption data, and Toronto weather data.

The objectives of the thesis are the following:

1. Develop a methodology to conduct a survey of household energy use in a Toronto MURB. The survey will collect information on occupant's demographics, household energy use and behaviour. The survey data will be used towards the development of the artificial neural network dataset.
2. Develop a methodology to model occupant's household energy consumption within a Toronto MURB. The model will also predict monthly energy consumption of an occupant based on household energy use, behaviour, and demographics. Data to develop the model includes survey data, energy consumption data, and weather conditions.
3. Assess the accuracy of the model by comparing predicted outputs to metered data.

4. Investigate the impact of various factors, particularly demographics (e.g., age, gender, and income) on monthly household energy consumption.

## 1.4 Structure of the Thesis

This thesis is organized in the following chapters:

**Chapter 1: Introduction**

Introduction and objectives of the study.

**Chapter 2: Literature Review**

Literature review on surveys of household energy use and artificial neural networking (ANN).

**Chapter 3: Methodology - Survey of Household Energy Use**

Methods used to develop and collect surveys in order to obtain the necessary data (e.g., demographics, behaviour, appliance type and usage) for the development of the neural network model.

**Chapter 4 and 5: Methodology and Development of the Neural Network**

Methods used to develop the model using a neural networking technique. This section includes a flow chart illustrating the development of the model, information on the data sources, and procedure in order to predict the impact of various factors on household energy consumption. This chapter includes detail on data analysis, preprocessing, designing of the network, training, validation, testing, and queries.

**Chapter 6 and 7: Survey and ANN Results**

Results on the estimation of household energy consumption using the model, developed by the neural network approach. The impact of demographics (e.g., age, gender, and income) on household energy consumption is conducted using the model. In addition, monthly energy consumption profiles are developed to compare the seasonal variation between the demographics.

**Chapter 8: Achieving Energy Conservation for Low-Income Renters in Canada**

A literature review on barriers for low-income renters to conserve energy and possible solution to overcome these barriers such as tenant engagement strategies.

**Chapter 9: The Impact of the Survey on Household Energy Consumption using ANN**

This chapter includes two methods to assess the impact of the survey on energy consumption. One method is comparing the actual energy consumption between two years of energy data. The other method is creating an ANN model.

**Chapter 10: Conclusions and Recommendations**

This section will present general conclusions and recommendations for future research.

# Chapter 2 Literature Review

## 2.1 Overview

This chapter is divided into four sections: the first section is dedicated to a brief overview of energy consumption in Canada's residential sector. The second section presents background information on surveys of household energy use and research on Canadian high-rise MURBs. One section is dedicated to energy modeling and artificial neural networking, which gives a brief background on neural networking, its uses in energy modeling, and its modeling approach. The last section gives an overview of survey distribution and collection in order to obtain information on household energy use.

## 2.2 Background on Energy Consumption in Canada's Residential Sector

There are five housing types in Canada (dwelling percentages) - single detached (59%), double/row houses (16%), low-rise apartments (16%), high-rise (five or more storeys) apartments (8%), and mobile homes (1%) (Natural Resources Canada, 2010). Multi-unit residential buildings, according to Canada Mortgage Housing Corporation (CMHC) (1997), have four classifications: 1. low-rise (3 to 4 storeys) apartment buildings which may not have elevators; 2. mid-rise buildings (5 to 7 storeys); 3. high-rise buildings (7 to 30 storeys); and 4. few tall apartment towers (more than 30 storeys). Therefore, the classification of a low to high-rise "multi-unit residential building" depends on the number of storeys. This thesis focuses on high-rise MURBs - buildings between 7 to 30 storeys. Figure 2.1 illustrates the distribution of dwellings in Canada. A dwelling is a "set of living quarters that is structurally separate from the living quarters of other dwellings" (Natural Resources Canada, 2010). It is important to recognize that apartments are 24% of Canada's housing distribution (16% for low-rise and 8%

for high-rise apartments). In addition, MURBs have a high energy demand - almost a quarter of Canada's overall annual residential energy consumption (Liu, 2007).

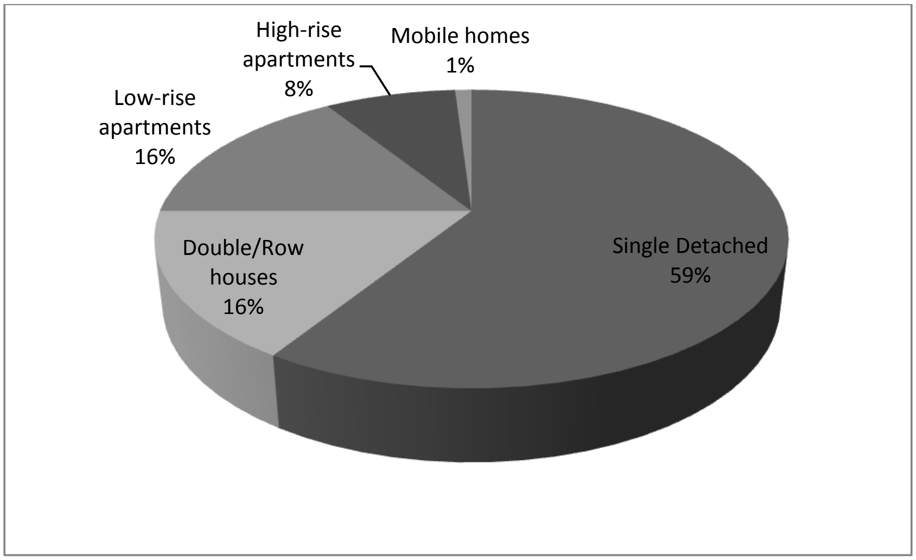



**Figure 2.1: Distribution of Dwelling Types in Canada, (Natural Resources Canada, 2010) - Survey of Household Energy Use (SHEU) 2007**

Residential energy consumption is due to varying factors such as usage type (e.g., space heating), location, or dwelling type. According to Natural Resources Canada (2010), 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 (Natural Resources Canada, 2011a). In addition, the average household in 2007 consumed approximately 29.4 x $10^3$ kWh. The average yearly household energy consumption, however, varies significantly between provinces and territories in Canada, where a majority of households are above 29.4 x $10^3$ kWh, such as Ontario with 29.7 x $10^3$ kWh per household (Natural Resources Canada, 2011a).

The yearly energy intensity by dwelling type varies as well; 258 kWh/$m^2$ for single detached houses, 203 kWh/$m^2$ for double/row houses, 147 kWh/$m^2$ for low-rise apartments, 128 kWh/$m^2$ high-rise apartments, and 292 kWh/$m^2$ for mobile homes (Natural Resources Canada, 2010). Figure 2 summarizes the energy intensity by dwelling type in Canada.

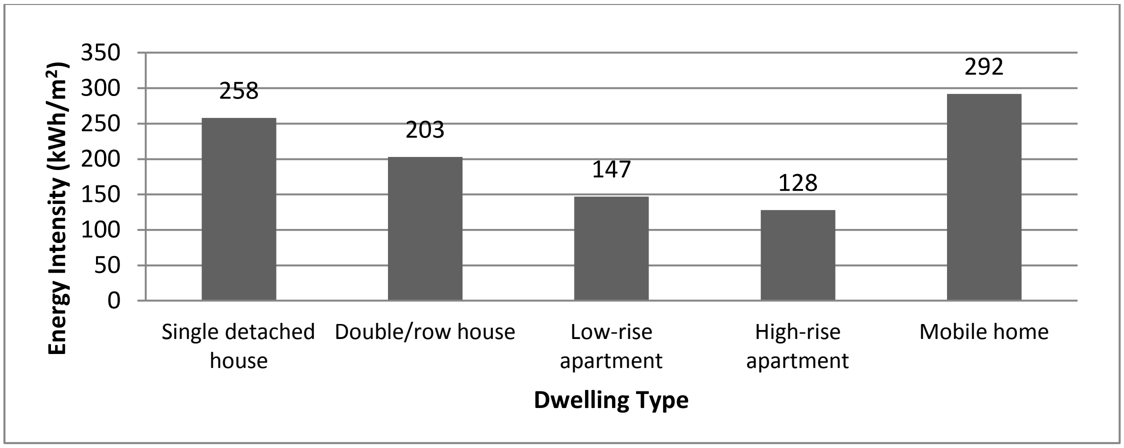



**Figure 2.2: Energy intensity by dwelling type (kWh/m$^2$) (Natural Resources Canada, 2010)**

Similar trends in energy intensity are found in Natural Resources Canada (2011a) study, where single detached housing consume the most energy (kWh/m$^2$) compared to other housing types. Single detached housing consume 229 kWh/m$^2$, single attached housing (e.g., double/row houses) consume 199 kWh/m$^2$, apartments (e.g., low and high-rise apartments) consume 197 kWh/m$^2$, and mobile homes consume 329 kWh/m$^2$.

## 2.3 Surveys of Household Energy Use

The most comprehensive and current household energy use survey in Canada is the Survey of Household Energy Use (SHEU 2007). This survey is conducted by Natural Resources Canada and Statistics Canada. SHEU 2007 is a national survey and provides detailed 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). Detailed information also includes the age of the appliances, duration of appliance usage, and the number of appliances. It is interesting to note that SHEU classifies the survey results in different housing types (e.g., single detached houses and high-rise apartments) and by the size of the household (e.g., number of people per household). High-rise apartments are defined as a dwelling unit containing more than five storeys. Furthermore, SHEU 2007 defines an apartment building as "a building originally designed to contain multiple dwelling units within it. Duplexes are not included in this definition" (Natural Resources Canada, 2010).

Natural Resources Canada's Office of Energy Efficiency - National Energy Use Database (NEUD) also addresses residential household energy use (Natural Resources Canada, 2011a). NEUD compares Canada's energy consumption and carbon emissions, quantitatively, within the residential sector from 1990 to 2009. The database includes the distribution of residential energy use by fuel type (e.g., electricity, heating oil, natural gas, and wood between households), trends between end-uses (e.g., space heating and cooling) and fuel type, trends in residential energy intensity and efficiency for all Canadian household types. NEUD's definition of "apartment", however, lacks detail; the broad definition of "apartment" includes both residential and non-residential buildings, ranging from low-rise to high-rise buildings. Therefore, this is not a suitable source when focusing strictly on residential energy use, especially looking at high-rise MURBs.

In the United States, a national survey called Residential Energy Consumption Survey (RECS) is conducted (EIA, 2012). The difference between SHEU 2007 and RECS is how they classify each housing type, specifically apartment buildings. RECS classifies an apartment building depending on the number of units within the apartment building; whereas, SHEU classifies an apartment building depending on the number of storeys. There is no uniform definition of high-rise apartment buildings or even apartment buildings, in general.

All three national surveys focus on three important points; first, all three surveys are at a national scale and focus on the energy intensity of a home. Numerous studies such as Aydinalp *et al.* (2003) and Marueljols and Young (2011) cite only SHEU versions due to the lack of data available on household energy use in Canada. Second, there is no consistent definition of apartment building, MURBs, or apartment building sub-categories (e.g., low, mid, high-rise) between surveys. Because of the inconsistent definition of high-rise MURBs, it would be difficult to compare survey results between apartment building types. Therefore, there is a need to investigate occupant's household energy use, at an occupant scale, in high-rise MURBs.

### 2.3.1 Theoretical Model of Household Energy Consumption

As mentioned before, household energy consumption involves many factors such as occupant's behaviour, age and type of appliances, demographics, income, gender, and more. The national surveys such as SHEU 2007 and NEUD lack other elements that contribute to occupant's household energy use (e.g., social aspects). Of course, incorporating all factors of one's household energy consumption is not an easy task; but the national surveys do not consider social or psycho-social aspects. Guerin *et al.* (2000) developed a theoretical model of household energy consumption that illustrates the interrelations of occupant behaviour on household energy use. This model is also known as the human ecosystem model; it examines the interconnectedness of four environments: natural environment, social environment, designed environment, and human organism. Figure 2.3 depicts the interactions between each "environment" and shows that all environments are connected.

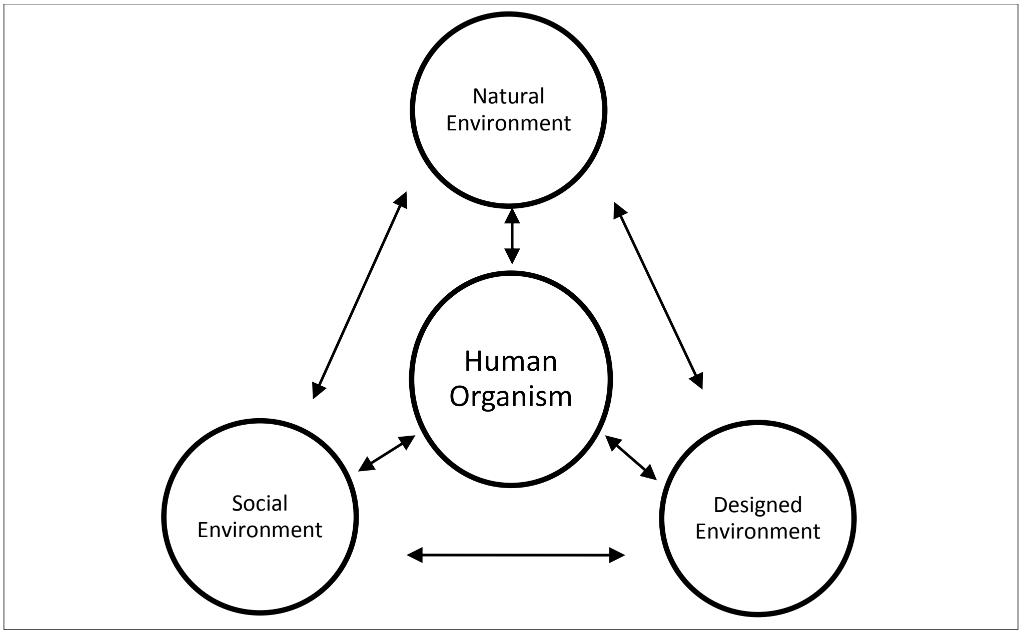



**Figure 2.3: The Human Ecosystem model developed by Guerin *et al.* (2000)**

According to Guerin *et al.* (2000), the environments are defined by the following: The natural environment includes physical components such as climate (e.g., heating and cooling degree days). The designed environment includes the structure of one's household such as the size of the house, number of appliances, and age of house. The social environment includes psychological and social behaviours of the occupants such as cultural norms, household activities, sense of comfort, and satisfaction. Lastly, human organism may be a single occupant or a number of people in a household and includes characteristics which describe them (e.g., age, gender and occupation). Energy behaviour are "actions taken by the householder in their use of energy in their homes" (Yohanis, 2011). 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) (Yohanis, 2011).

Many studies have investigated components of Guerin's human ecosystem model and how it affects energy behaviour and consumption; but little is known within the realm of occupant's household energy use in high-rise MURBs. In fact, some studies conduct surveys of household energy use and behaviour in order to measure the impact of tenant engagement, education or social programs. Abrahamse at al. (2007), for example, implemented a combination of interventions - tailored information, goal setting and tailored feedback - to examine whether change in energy-related behaviours and behavioural antecedents would occur. This was carried out by householders completing numerous questionnaires before, during, and after the interventions were implemented. The questionnaires included direct energy-related questions (e.g., thermostat settings, number of times doing the laundry, number of lights on in the household, and rating of whether appliances are on stand-by mode) and indirect energy-related questions (e.g., number of car trips per week, rating of whether household throw away food, and sharing of daily newspapers). The surveys showed that households exposed to the interventions saved more direct energy and adopted more energy-saving behaviours than the control group. Furthermore, those householders who were exposed to the interventions had greater knowledge of energy conservation than the control group.

Kurz *et al.* (2005) found that energy-saving labels led to a 23% reduction in water consumption. Attitude questionnaires found that feelings towards pro-conservation were strongly favoured relating to energy and water conservation. Using a Likert scale-based survey (1 to 5; 5 being pro-conservation), survey results found that many of the respondents would conserve energy once interventions were implemented (*mean score out of 5*= 4.10). Similarly, respondents would adopt water conservation behaviours (*mean score out of 5*= 4.40). The questionnaire also indicated that the interventions caused behaviour changes such as: 85.7% using less water in the garden; 68.8% not leaving the lights on; 62.3% reducing shower time; and 55.8% not leaving the fridge door open. Chapter 3 further discusses a survey of household energy use through the development of the survey for this thesis.

### 2.3.2 Occupant Predictors of Household Energy Use Behaviour

There is a relationship between household energy use behaviour and occupant characteristics; these are referred to as occupant predictors. Guerin *et al.* (2000), Guerra-Santin and Itard (2010) and Yun and Steemers (2011) have identified occupant predictors of household energy consumption behaviour. Occupant predictors are classified as occupant's characteristics, attitudes and actions that influences an occupant's household energy behaviour; for example, income, sex/gender, housing tenure and age. Guerin *et al.* (2000) provides a comprehensive literature review on these characteristics and how it effects occupant's household energy use and behaviour since 1975. Prominent occupant characteristics are gender, age, and income which are found to convey particular trends relating to energy use behaviour. Gender, for example, Guerin *et al.* (2000) found that ***ecoconsciousness*** is more prevalent in women than men. This means that men have more potential to consume energy than women. Another prominent occupant predictor in energy consumption is age. Guerin *et al.* (2000) found that households in the middle life-cycle consume more energy than younger or older families. Lastly, income is also an occupant predictor - as income increases, energy consumption increases (Guerin *et al.*, 2000).

### 2.3.3 Current Research on Canadian MURBs

Besides the two national surveys conducted in Canada, SHEU 2007 and NEUD, there has been a limited amount of research done on occupant's household energy use in Canadian MURBs. A majority of the research on Canadian MURBs, however, focuses on the energy intensity of the entire building quantitatively. A study conducted by Canada Mortgage and Housing Corporation (CMHC), for instance, analyzed the energy intensity of 40 apartment buildings across Canada. CMHC found that the average annual energy consumption of the 40 buildings is 279 equivalent kilowatt-hours per unit floor area (ekWh/$m^2$). The average annual energy consumption of residential high-rise is 317 kWh/m$^2$ (from 1961 to 1980) and 212 kWh/m$^2$ (high-rises built after 1981). This means buildings that were built from 1981 to present consume 33% less energy when compared to the older buildings (1961 to 1980). In addition, buildings that were more than six storeys were found to consume less energy per apartment unit, but 21% more energy per m$^2$ than six storey or lower buildings (Enermodal Engineering Limited, 2001). Thus, occupants residing in older buildings consume more energy (per m$^2$) than occupants in newer buildings. The energy intensity results from this study are much higher than Natural Resources Canada (2010) study. In addition, the sample size of this study is not large enough to represent Canada's apartment energy intensity.

Another study conducted by CMHC evaluated the indoor environment and energy consumption patterns of eight mid-rise apartment buildings throughout Canada (two buildings in Ottawa, two in Toronto, and four in Vancouver) (Scanada Consultants Limited, 1997). They found that mid-rise buildings ranged from 146 to 263 kWh/m$^2$ of floor area per year. Furthermore, compared to high-rise buildings, the mean value of energy consumption is almost the same. The energy consumption distribution of the buildings were the following: space heating (43.5% ± 8.8%), domestic hot water use (25.3% ± 2.6%), lighting (14.8% ± 4.8%), and miscellaneous energy use (15.8% ± 5.1%).

In Huang's thesis (2012), she developed a weather normalized energy benchmark for 45 gas-heated high-rise MURBs in Toronto. The normalized annual consumption for these buildings was found to range from 242 to 453 kWh/m$^2$. Within these 45 buildings, Huang (2012) found that 24 of the buildings had fluctuations in their normalized annual energy consumption, ranging from 45.6 kWh/m$^2$ increase to 103.7 kWh/m$^2$ decrease.

Based on Survey of Household Energy Use 2003, Maruejols and Young (2010) compared energy consumption (e.g., electricity, natural gas, and oil) between row, terrace, duplexes or double house to low-rise apartments. Low-rise apartments were found to consume 76.45% more energy overall and 29.48% more electricity per building (gigajoules of energy per square foot of heated area) than row, terrace, duplexes or double house. In a similar study, Maruejols and Young (2011) also found that split incentives impact some aspects of occupant behaviour. Households that do not pay for their heating utilities, were also found to be less sensitive to saving energy (e.g., turning off heating when no one is at home).

In a qualitative study called "Vertical Poverty", United Way Toronto (2011) conducted a survey to examine relationships between City of Toronto's high-rise housing and poverty. The survey involved a total of 2803 high-rise renters. Results found that low-income households are increasingly prevalent in high-rise buildings; from 1981 (34%) to 2006 (43%). Furthermore, there is a strong relationship between low-income households (poverty) and poor housing conditions such as in air quality, infestations of pests, and major repair problems. Although this study is not energy-related, it is important to note because it characterizes the environment within Toronto high-rise buildings.

### 2.3.4 Literature Gap

As mentioned, the most comprehensive and cited surveys to-date on household energy use in Canadian high-rise MURBs are SHEU 2007 and NEUD. These surveys, however, have inconsistencies in their classification of a MURB and lack other elements that can affect a household's energy use. While these two surveys are the most cited in other research, there is also a lack of information specifically related to high-rise MURBs at an occupant level.

Current research on Canadian MURBs assessed the energy intensity and building performance of the entire building. These quantitative studies focus on energy use at a larger scale, not at an occupant or level. Currently, there is no information on household energy use in high-rise Canadian MURBs at an occupant level nor any evaluation on occupant's energy use in Canadian high-rise MURBs. Therefore, there is a need to investigate household energy use within high-rise Canadian MURBs at an occupant level and evaluate occupant's interrelated effects on their household energy use.

## 2.4 Energy Use Modeling

The objective of this section is to review mathematical modeling to develop a model for household energy use in Canadian high-rise MURBs. This section deals with two energy mathematical modeling approaches - artificial neural networking and conditional demand analysis - in relation to energy modelling.

Mathematical modeling is a way of evaluating the interrelated effects of occupant's household energy use in high-rise MURBs. Mathematical modeling obtains observations and creates a function in order to represent and understand the observations (Heinz, 2011). According to Heinz (2011), the process of developing these mathematical models has the following steps:

1. Present the problem as simply as possible (e.g., data analysis).
2. Derive reasonable models.
3. Identify the optimal model that represents the observations.
4. Demonstrate the advantage of the model by deriving valuable conclusions.

As mentioned in Chapter 1, Canadian residential energy consumption is increasing. There increasing is associated with energy supply and global warming. As these conditions continue to increase, mathematical modelling facilitates the understanding of household energy use in the residential sector. Thus, evaluating household energy use in high-rise MURBs using mathematical modelling can help to explain the human impacts on residential energy consumption.

### 2.4.1 Overview of Energy Use Modeling

According to Swan and Ugursal (2009), energy consumption modeling is categorized in two ways: top-down and bottom-up. Top-down models predict various factors (e.g., energy consumption) to represent the entire residential sector. These models are at an aggregated level and typically represent energy consumption at a national scale (Kavgic *et al.*, 2010). Bottom-up models are at a smaller scale where the model estimates various factors, including energy consumption; however, it represents individual occupants and/or households. Swan and Ugursal (2009) provide a comprehensive overview of modeling techniques used for modeling residential sector energy consumption. Figure 2.4 is taken from Swan and Ugursal (2009) study that illustrates modeling techniques used in residential energy consumption modeling.

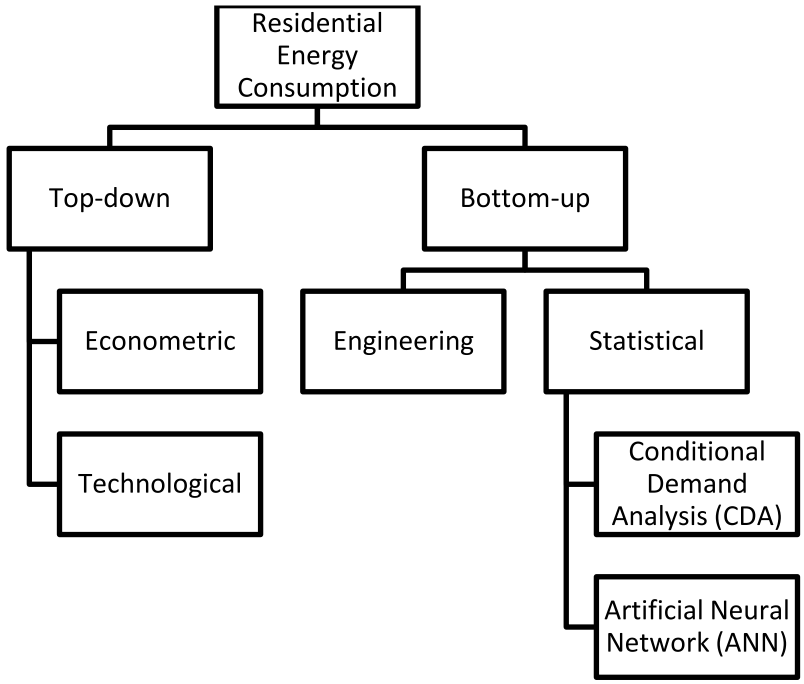



**Figure 2.4: Top-down and bottom-up modeling techniques used for residential sector energy consumption modeling (Swan and Ugursal, 2009).**

Top-down models include econometric and technological models. Econometric models include models based on price and income, and technological models include characteristic models representing the entire housing stock (Swan and Ugursal, 2009). The bottom-up model approach is made up of disaggregated data, such as individual household end-use data and, can be further categorized into two bottom-up model methods, statistical and engineering modelling (Figure 2.4). Engineering models account for energy consumption of end-uses dependant on explicit thermodynamic relationships, heat transfer, equipment use and power ratings (Swan and Ugursal, 2009). Statistical bottom-up modeling includes historical information and regression analysis. Statistical modeling can also characterize one's household energy use by end-uses and demographics (Swan and Ugursal, 2009).

Statistical bottom-up modeling techniques can develop energy consumption models deriving from various factors such as weather conditions, occupant's energy behaviours, occupant's demographics, and building characteristics. Two bottom-up modeling approaches used to evaluate Canadian's energy consumption using end-use, geographical, and demographical data are conditional demand analysis (CDA) and artificial neural network (ANN). There are many advantages of the bottom-up statistical modeling. First of all, bottom-up statistical modelling, CDA and ANN, is able to predict end-use energy consumption (Kavgic *et al.*, 2010). Secondly, these modeling techniques can include demographics, behaviour and socioeconomic elements (Aydinalp *et al.*, 2003). Lastly, a model can be created by using just energy billing and basic survey information (Kavgic *et al.*, 2010). Both methods require a large dataset in order to get energy consumption predictions, which is a disadvantage. These models depend on historical energy consumption data and information in order to correlate relationships between dependant and/or independent variables (Kavgic *et al.*, 2010). Boulaire *et al.* (2013) mentioned that acquiring for a large amount of data is significant to increase the confidence of the model's predictive capability. Data (e.g, survey data or energy consumption), however, is usually protected by privacy laws or can only be released by household's consent (Boulaire *et al.*, 2013). Hence, a disadvantage is modeling aggregated data to represent a small enough region while preserving household's privacy rights (Boulaire *et al.*, 2013).

CDA is a linear regression-based statistical technique. CDA is able to estimate the end-use energy consumption, at an end-use level, only by the basis of the household's total energy consumption. Thus, the household energy consumption is directly related to the variables inputted in the model, such as dwelling characteristics, behavioural patterns, and appliance usage. For instance, the regression-based equation for each month of billing data can be represented by Equation (1) (Parti and Parti, 1980):

(1)

As the formula shows, E is the monthly electrical energy consumption, C is the variable indicating the presence or usage of the appliance, *app*, V is a set of interaction variables with elements *i* (e.g., income and gender), and *c* is a coefficient (Parti and Parti, 1980).

It is vital to mention that there are disadvantages by using the CDA approach. First, unreliable model predictions occur due to multicollinearity problems. Multicollinearity occurs when two or more predictor variables (e.g., appliance ownership dummy variables) are highly correlated. Thus, CDA approach may output negative loads for certain dummy variables due to high degrees of multicollinearity (Hsaio *et al.* 1995). Second, using the CDA approach has difficulties in predicting highly saturated appliances from the model such as refrigerators. This is problematic because a majority of households may own these major appliances (e.g., refrigerator), yet result in unreasonable estimates. Hsaio *et al.* (1995) explains that the problem with multicollinearity is the gap between the information requirements of the model and the sample data provided for the model. In order to reduce the gap, either the sample data must expand or reduce the information requirements of the model, or both (Hsaio *et al.*, 1995).

ANN differs from CDA, in which neural networking is based on simplified mathematical models of biological neural networks while CDA is a linear regression based model (Aydinalp, 2002). The ANN approach can be used to obtain numerous inputs, such as end-use variables, and to determine interconnected relationships between the inputs (through a series of parallel "neurons"). These parallel neurons are then applied to scaling factors, activation functions, and algorithms in order to determine causal relationships and minimize error between them.

In addition, ANN has other advantages, including neural networks' relation to arbitrary relationships between dependant and independent variables (Sargent, 2001). Further, ANN allows relationships between dependant variables and does not require explicit distributional assumptions like normality (Sargent, 2001). But there are disadvantages by using the ANN approach. First, ANN has the "black box" quality, having difficulty in understanding the problem (Sargent, 2001). Whereas, the CDA approach is able to modify and remove variables within the model in order to develop a more suitable model. Second, in order to perform ANN, computational resources are required and ANN software standards are not consistent between other ANN software (Sargent, 2001).

Sargent (2001) reviews an extensive amount of literature to compare the regression performance of ANN with statistical techniques. A total of 28 medical-related studies were reviewed. Results find that ANN outperforms regression in 36% of the cases, regression outperforms ANN in 14% of the cases and the two methods has similar performances in 50% of the cases. It is important to note that in larger sample sizes (sample size > 5000), regression methods outperforms ANN. In contrast, when applied to medium to large dataset (sample size > 200), ANN outperforms the regression technique. However, Sargent (2001) recommends further exploration of both methods and ANN should not replace statistical approaches.

### 2.4.2 Studies on Canadian Residential Energy Modeling using Bottom-Up Statistical Modeling

To date, the most comprehensive bottom-up statistical modeling research on Canadian residential energy use is Aydinalp's thesis on "*A New Approach for Modeling of Residential Energy Consumption*" (Aydinalp, 2002; Aydinalp *et al.*, 2003; Aydinalp *et al.*, 2004). Aydinalp (2002) conducted a comparison evaluation of Canada's residential energy consumption using both CDA and ANN. Furthermore, Aydinalp (2002) created three separate models for both CDA and ANN (a total of six models): appliances, lighting and cooling (ALC), domestic hot water (DHW), and space heating (SH). The purpose of Aydinalp's study is to develop two models, using 1993 SHEU data, and determine the energy prediction performance between CDA and ANN.

Aydinalp (2002) uses two sources of data for developing CDA and ANN models: the data from the 1993 Survey of Household Energy Use (SHEU) database and weather conditions for 1993 from Environment Canada. Similar to SHEU 2007, SHEU 1993 consists of detailed information about Canadian households, including house construction, space heating and cooling equipment, household appliance types and usage for 8767 households in Canada. Electricity billing data were also available for the entire year for 2050 households. In order to compare both models, $R^2$ (correlation coefficient) were used as their best prediction performance indicator.

All three models showed that ANN was a more effective modeling technique than CDA, Table 2.1 (Aydinalp, 2002; Aydinalp-Koksal and Ugursal, 2008). In the ALC model, the R-squared for CDA and ANN was 0.795 and 0.909, respectively; for the DHW model, the R-squared for CDA and ANN was 0.814 and 0.871, respectively; and finally, for the space heating model, the R-squared for CDA and ANN was 0.892 and 0.908, respectively.

**Table 2.1: Comparison of prediction performance ($R^2$) of the CDA and NN in Aydinalp's thesis (2002) and Aydinalp-Koksal and Ugursal (2008)**

| | $R^2$ |
|---|---|
| **ALC energy consumption** | |
| CDA | 0.795 |
| ANN | 0.909 |
| **DHW heating energy consumption** | |
| CDA | 0.814 |
| ANN | 0.871 |
| **SH energy consumption** | |
| CDA | 0.892 |
| ANN | 0.908 |

With a higher prediction performance than CDA (Table 1), the ANN model was used to estimate the impact of socio-economic factors and energy-saving measures on household energy consumption in Canada's residential sector. Aydinalp's research (2002) compares both modelling approaches (CDA and ANN) to Canadian's household energy consumption for ALC, DHW, and SH consumption (Table 2.2). Table 2.2 shows that in all three models, CDA undershoots estimates to that of the ANN model. Aydinalp (2002) argues that "due to the limited amount of variables that the CDA can accommodate, its capabilities to evaluate these effects deviated lower than the ANN model" (p. 167).

**Table 2.2: Comparison of CDA and ANN Predicted Weighted Average Consumption for ALC, DHW, and SH Models**

| | **Predicted Weighted Average Consumption** |
|---|---|
| **ALC model (kWh/year/household)** | |
| CDA | 8,387 |
| ANN | 8,791 |
| **DHW model (GJ/year/household)** | |
| CDA | 25.2 |
| ANN | 26 |
| **SH model (GJ/year/household)** | |
| CDA | 74.5 |
| ANN | 80 |

An assessment of the effects of socio-economic factors on household energy consumption (ALC, DHW, and SH) using neural networks is investigated (Aydinalp, 2002; Aydinalp *et al.*, 2003; Aydinalp *et al.*, 2004). General trends are found in all three cases. Firstly, as income increases, so does energy consumption. Secondly, owners consumed more energy than renters. Thirdly, dense populations (urban) consumed less energy than less dense areas. In the ALC model, Aydinalp (2002) found that single detached houses consumed more energy than single attached houses.

Farabakhsh *et al.* (1998) developed a comprehensive residential energy end-use model called Canadian Residential Energy End-Use Model (CREEM). The model is created by using high-resolution building performance simulation package, HOT2000. This model integrates the results of modelling from Canadian residential energy end-uses (Ugursal and Fung, 1996) and existing databases such as Statistics Canada (1993), Natural Resources Canada (1994) and Scanada (1992). The model compares residential sector energy consumption surveys to estimates from the model. Swan *et al.* (2013) further advances the CREEM model by creating a hybrid modelling approach which integrates neural network and engineering modelling methods to estimate residential end-use energy consumption. The study also includes a total of 16,952 unique Canadian households' thermal envelope descriptions, where originally CREEM was based on data collected from 8767 houses across Canada. The neural network is used to predict the ALC end-use energy consumption and DHW volume draw of Canadian household stock. In a similar study by Swan *et al.* (2011), estimations are made using the same CREEM model. It found that the national ALC energy consumption of Canadian single-detached and double/row houses contributed to 248 PJ and 201 PJ for DHW energy consumption, respectively.

Hsiao *et al.* (1995) provides an alternative methodology of integrating a Bayesian technique to CDA. This study builds on the work of Caves *et al.* (1987) and Bartels and Fiebig (1990), where Hsiao (1995) incorporates 49 households of end-use metered data and 347 households of energy billing and survey information from Ontario Hydro. The Bayesian technique involves forming a prior means and variation (distribution) from the end-use metered data and then combining it with the aggregated data, which is the household's energy bills and survey information.  The Bayesian methodology was then compared to that of the traditional CDA. Results show that the Bayesian technique outperforms the traditional CDA approach in a prediction perspective. However, the model created by the integration of the Bayesian method, however, requires a great deal of data in order to have accurate predictions.

### 2.4.3 Literature Gap

Nowadays, there is a need to model end-use energy consumption for occupants in Canadian high-rise MURBs. The literature review shows that Canadian studies related to energy modeling on household's energy use and behaviour have demonstrated the followings: first, Canadian housing stock has been modelled at national and provincial levels, and there is limited information on individuals living in high-rise MURBs; second, these studies are all at annual end-use consumption units, not at monthly or daily quantities. Thus, a model is needed in order to characterize occupant's household energy consumption in a high-rise MURB. The model is anticipated to predict their consumption based on various factors (e.g., demographics) at a monthly scale. This model would be useful to understand occupant's energy behaviours and the impact of social, demographic, and energy behaviour measures in a Canadian high-rise MURB setting.

## 2.5 Artificial Neural Networking (ANN)

### 2.5.1 Background

This section deals with background information on the artificial neural network modeling approach. This is followed by the use of ANN in energy modeling and other applications. Afterwards, a brief overview of ANN modelling approach is presented. The concept of ANN was initially introduced by McCulloch and Pitts in 1943 alongside their McCulloch-Pitts model. The ANN approach is inspired by networks of biological neurons, containing multiple layers of computing nodes (Dayhoff and DeLeo, 2001). The McCulloch-Pitts model (Figure 2.5) resembles a biological neuron. Figure 2.5 shows that a neuron receives a weighted sum of inputs; these weighted sums of inputs are then connected and outputs a value (Warner and Misra, 1996).

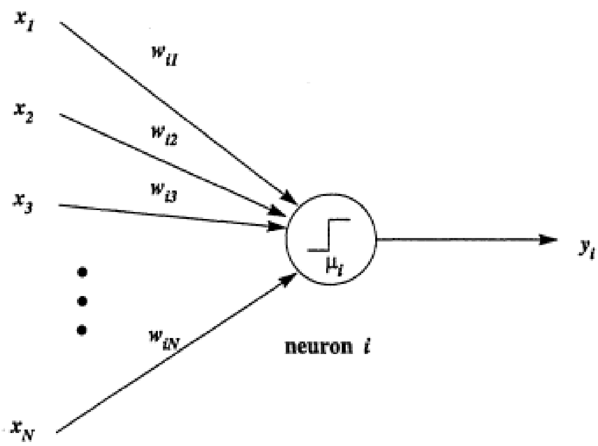



**Figure 2.5: Illustration of McCullock-Pitts Neuron (Warner and Misra, 1996)**

ANN is able to discover internal relationships between data. It is able to classify nonlinear relationships with incomplete and small datasets. Because of this, ANN has become a huge interest in all fields of study and has matured over the past 40 years (Dayhoff and DeLeo, 2001). To date, ANN is used for many applications, including national green energy use analysis (Ermis *et al.*, 2007), public awareness campaign assessments (Mohamoud and Alajmi, 2010), depression symptom analysis (Nair *et al.*, 1999), perceptions on building quality (Rebano-Edwards, 2007), energy dependency projections (Sozen, 2009), and forth on.

### 2.5.2 Other Studies on ANN and Energy Modeling

In Chapter 2.4, a review of literature on Canadian residential energy modeling using bottom-up statistical modeling has been presented. However, there have been other studies that have used ANN within the realm of residential energy modeling. For instance, Boulaire *et al.* (2013) developed a model by using spatial building and household characteristics from Census data in New South Wales, Austrailia. The regression-based model predicted daily electricity consumption at a district level. Results found that the model deviated -1.3% from actual energy consumption values. Afterwards, two scenarios were considered and applied to the model - the effect of energy consumption due to change in climate and population growth. Results found that warmer climates decrease electricity consumption. As population increased, the number of dwellings increased by 5% in districts with less than 200 dwellings, increased by 2% in districts between 200 and 400 dwellings, and 1% increased with dwellings over 400 dwellings.

Dombayci (2010) developed a neural network model to predict hourly heating energy consumption of a model home in Denizli-Turkey. During the development of the model, Dombayci (2010) only considered heating degree days (HDD) and cooling degree days (CDD) as weather conditions for the model. The model was trained by using heating energy consumption from 2004 to 2007, and it was then tested by using heating energy consumption data of the year 2008. The model was found to have a high correlation coefficient ($R^2$) of 0.9907 for training and 0.9880 for testing.

Mahoud and Alajmi (2010) used neural networking to measure the effects of a energy conservation public awareness campaign in Kuwait. This study is unique because it uses high resolution energy consumption data (hourly) and a large geographical region (country), which tests the neural network's capabilities. The model consisted of weather conditions and energy consumption data from 2004 to 2007. It was also found to have a $R^2$ = 0.884 and a 0.77% percent difference to the actual total energy consumption. The model was then used to forecast energy consumption by using weather data of summer 2007. After that, these predicted values were then compared to actual energy consumption. Ten large peak loads were identified and model predictions were found, ranging from actual energy consumptions of 299.1 MW to 368.4 MW for each peak in summer 2007, which is 3-4% difference from the actual energy consumptions.

### 2.5.3 Artificial Neural Networking Modeling Approach

A common ANN model approach called multi-layer perceptron (MLP). MLP consists of an input layer, one or more hidden layers, and an output layer. Each layer consists of neurons that are interconnected with each other and are assigned with various weights. The output neuron is established by the input layer passing through hidden layer(s). Each neuron receives signals from the neurons of the previous layer. Aydinalp's thesis (2002) presents a neural networks structure, shown in Figure 3.

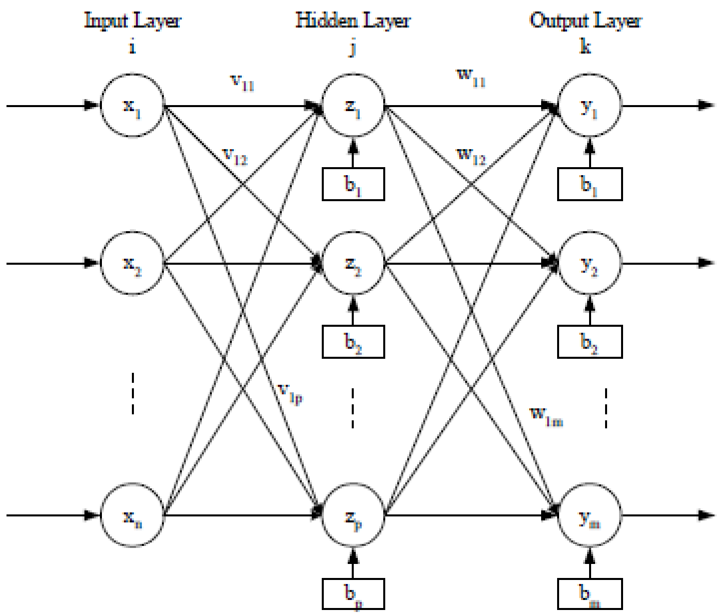



**Figure 2.6: MLP neural network structure with one hidden layer (Aydinalp, 2002)**

Poulad *et al.* (2010) presents seven major components of an artificial neural network. These components apply for all layers of the neural network - input layer, hidden layers, and output layer.

1. Weighting factors: Neurons interact with many inputs at the same time. Some inputs have greater significance than others. Thus, some inputs receive a greater weight than other inputs. These weighted inputs have a significant effect on the output.
2. Summation function consists of the sum of all the weighted inputs and results in a single number.

3. Transfer function: This function is an algorithmic process that transfers the results from the summation function or the weighted sum of the inputs to a working output.
4. Scaling and limiting: After the processing element's transfer function, the results may be scaled or limited.
5. Output function: The output reflects on the many neurons in the network, where each neuron consists of the many interactions between weighted inputs.
6. Error function and back-propagated value: The error function calculates the difference between the current output (from the model) to the desired output. In order to reduce the network's error, the error function transforms the output error to match the network's architecture. In some cases, the error is modified by squaring the error, cubing the error, or some use the error directly. Afterwards, the neuron's error is then typically generated into the learning function.
7. Learning function: This function is also referred to as an adaption function, which modifies the weights of the input connections in order to achieve a desired result. Examples of learning functions are back propagation algorithms, enhanced back propagation, and Quickprop.

### 2.5.4 Learning/Training Algorithms

According to Alyuda (2003), there is no single best training algorithm for neural networks; instead, it depends on the characteristics of the problem. Alyuda (2003) presents seven algorithms:

1. Quick Propagation (QP)
2. Conjugate Gradient Descent (CGD)
3. Quasi-Newton (QN)

4. Limited Memory Quasi-Newton (LMQN)
5. Levenberg-Marquardt (LM)
6. Incremental Back Propagation (IBP)
7. Batch Back Propagation (BBP)

It takes a great deal of experimenting in order to determine the best training algorithm for the network. There are simple guidelines that have been effective for practical purposes (Alyuda, 2003):

- CGD and QP are general-purpose training algorithms.
- If the network has a small number of weights (<300), LM algorithm is efficient.
- If the network has a moderate number of weights, QN and LMQN are efficient.
- If the network has a large number of weights, CGD is recommended.

IBP and BBP can be used for any size network. Back Propagation algorithms are the most popular algorithms during training of MLP.

### 2.5.5 Estimation by the ANN Model and Assessing its Performance

There are many steps in order to develop an ANN model. First, the whole dataset is divided into three datasets - training, validation, and testing. A majority of the dataset is used for training (more than two-thirds of the dataset), and the rest is split between the validation and testing sets (Alyuda, 2003).

After that, the datasets are preprocessed and scaled. Numeric inputs are left numerically. Categorical inputs can be scaled numerically or nominally. Activation functions are then used for both the hidden layers and the output layer. Activation functions are needed to introduce nonlinearity into the network (Aydinalp, 2002). Nonlinearity makes ANN MLPs more effective in discovering interconnected relationships between the inputs. The most common activation functions are logistic and tangent functions. Aydinalp (2002) concludes that activation and scaling intervals should be chosen after testing various combinations.

To determine the architecture of the network (number of hidden layers), there are no rules to establish the number of hidden layers for a particular application (Aydinalp, 2002). This is decided by a great deal of experimentation. The determination of the best architecture of the network can be done in two ways. First, the architecture can be done manually by selecting a number of hidden layers and comparing its performance to other architectures. The other way is to do an exhaustive search. An exhaustive search consists of seeking all possible architectures within the given inputs and hidden layers. This method is very time consuming; however, all possible architectures are presented.

During the training stage of developing the neural network model, weights are distributed randomly and learning algorithms are applied. During the training stage, a great deal of trial and error is required to find the best performing learning algorithm and least sum of square of errors (SSE). The training of the model stops until the least SSE or a high R-square ($R^2$) is achieved. R-squared is a statistical measure of how accurate the network's output (predicted) compares to the actual target values.  If the R-squared is equal to 1, it indicates that the model is a perfect fit (Alyuda, 2003). A validation set, a dataset not been introduced to the network, is used to strengthen the prediction performance of the network.

Finally, a third dataset called the testing dataset is introduced. The testing dataset is to further test the model's prediction performance. Similar to the validation set, the testing dataset is a dataset that has never been introduced to the model. The testing dataset is used after training and validation and then its network output is descaled to get its original units (Aydinalp, 2002).

## 2.6 Overview of Survey Distribution and Collection

This section provides a brief overview on survey distribution and collection. This is important because Chapter 3.5 deals with the development of the survey for the study site.

According to Statistics Canada (2003), data collection "is the process of gathering the required information for each selected unit in the survey". There are many methods, including:

1. Self-enumeration: This is when the respondent completes the survey without assistance (e.g., by mail or the Internet).
2. Personal interviews: the interviewer completes the survey with the respondent.
3. Telephone interviews: the interviewer assists the respondent over the telephone.
4. On-line (Internet) interviews: the interview is available on-line for the respondents to complete.

Table 2.3 shows the different methods of data collection with respect to cost, time and response rate (Statistics Canada, 2003):

**Table 2.3: Comparison of Self-Enumeration and Interview-Assisted survey methods with respect to cost, time, and response rate**

| | **Self-Enumeration** | **Interview-Assisted** | |
|---|---|---|---|
| | | **Personal** | **Telephone** |
| **Cost** | Low | High | Medium |
| **Time** | Longer | Average | Shorter |
| **Response Rate** | Low | High | Medium-High |

Statistics Canada (2003) outlines the advantages and disadvantages of the various survey data collection methods (Table 2.4).

**Table 2.4: Advantages and disadvantages of various survey data collection methods (Statistics, 2003)**

| Method | Method | Advantages | Disadvantages |
|---|---|---|---|
| Self-Enumeration | | •Easy to administer<br>•No interviewer is needed (no training needed)<br>•Reduces response error since respondents can consult their personal records or do it at home | •Data may be of poorer quality than other methods<br>•Questionnaire should be short<br>•Questionnaire must be well-designed and respondent-friendly |
| | •Paper-Based | •Printed reference material can reduce response errors<br>•Take less time to develop collection procedures | •Printing can be expensive<br>•No streaming in the questions - flip/skip questions (compared to computer-based survey)<br>•Requires more manual work |
| | •Computer-Based (Internet) | •Editing during collection can be automated, flip/skip options available (complex branching), and easy to monitor<br>•Easy to produce reports<br>•Better protection of confidentiality | •Need to test the computer application thoroughly<br>•Vulnerable to technical difficulties<br>•Respondents must have internet/computer access and know how to use the computer application |
| Interview-Assisted | | •Ensures that the correct unit and information is surveyed<br>•Interviewer can explain methods used, the project, survey, and ensure security and confidentiality<br>•Interviewer can improve data quality by explaining the survey and the concepts | •Need time to train and educate the interviewers<br>•Can increase response error - poorly trained interviewers and only providing socially correct answers |
| | •Personal Interviews (Person to Person) | •Provides a personalized and intimate environment compared to computer or telephone<br>•Instils confidence and identification to the respondents<br>•Can make direct observations | •One of the most expensive and time consuming method<br>•Difficult quality control of interviews compared to computer or telephone |
| | •Telephone Interviews | •Easily implemented for quality control<br>•Faster response<br>•More sensitive questions can be asked compared to in personal interviews | •May have the problems of confidentiality, if lines are shared or they may not want to give out personal information<br>•Cost for interviewers, telephone line, and office space for interviewers |

According to Cavusgil and Elvey-Kirk (1998), mail-in surveys or paper-based self-enumeration have many advantages such as, "…wider distribution, less distribution bias, better likelihood to reply, no interview bias, time-effective and cost savings". Kurz *et al.* (2005) used mail-in questionnaires that achieved a 56% response rate. The purpose of the questionnaire was to capture the household's attitude towards the importance of energy conservation. Similarly, Natural Resources Canada's SHEU, the surveys were collected through mail. Other survey distribution and collection methods applied are computer assisted personal interview. The sample size was 16,758 households.

Twenty out of the 163 households were interviewed (12% participation rate) (Gronhoj and Thogersen, 2011). The purpose of Gronhoj and Thogersen (2011) study was to examine the effects of feedback monitoring and household behaviours including consumption. It took about five months for the completion of the interviews, which consisted of their energy use behaviour and their willingness to continue conserving energy. United Way Toronto, a non-profit organization, conducted a study called "Vertical Poverty", investigating the growing concentration of poverty in Toronto and its concentration in high-rise buildings. This study used a similar approach in which 2,803 face-to-face interviews were conducted to investigate high-poverty issues within the high-rise buildings.

A study conducted by Abrahamse *et al.* (2007) sent out 6,000 invitations, asking residents to complete an on-line survey. As the results showed 874 request cards were received and 314 respondents (35.9% response rate) took part in the first measurement involving household energy use and behaviour. The problem with on-line surveys is that respondents must have access to the Internet and also a computer. This may also be difficult if you do not own a computer or are not competent in using a computer. Hence, choosing a data collection and distribution method is dependent on targeted respondents and other variables such as cost, time, and response rate. It is important to note that effective survey methods are found by sending request cards and mail-in surveys. Whereas, interview-assisted interviews were not as effective.

### 2.6.1 Underlying Motivators for Survey Response

Cavusgil and Elvey-Kirk (1998) outlines six underlying motivators of mail survey response behaviours - net individual benefit, societal outcome, commitment, novelty, convenience, and expertise. Cavusgil and Elvey-Kirk (1998) suggest that employing these underlying motivators influences survey response behaviour; it can increase response rates. Table 2.5 outlines the operations that can be carried out in order to increase mail survey response behaviour. For instance, providing a monetary incentive for completing the survey may motivate tenants to respond. Table 2.5 shows the potential operations/motivators in order to increase survey response rates within the survey population. The underlying motivators are ordered from most effective (e.g., net individual benefit) to least effective (e.g., expertise) in the table below. Thus, it would be beneficial to adopt appeal, personalization, or incentive measures to draw individuals to complete a survey.

**Table 2.5: Underlying motivators and operations to influence mail survey response behaviour (Cavusgil and Elvey-Kirk, 1998)**

| Underlying Motivators | Operations/Activities (to carry out underlying motivators) |
|---|---|
| 1. Net individual benefit | Appeal<br>Personalization<br>Incentive |
| 2. Societal outcome | Source<br>Promised Anonymity |
| 3. Commitment | Pre-notification<br>Cut-off Date Notification<br>Follow-up |
| 4. Novelty | Envelope Type<br>Cover Letter Form or postscript<br>Questionnaire (format, colour...) |
| 5. Convenience | Postage<br>Home vs. work address |
| 6. Expertise | Identify the "Informed Population" |

# Chapter 3 Methodology - Survey of Household Energy Use

## 3.1 The Approach

This chapter presents the methodology used in the study of household energy use in a Toronto MURB. In order to conduct a survey of household energy use in a Toronto MURB, the following tasks were undertaken:

1. Gathered Information on the study site, Toronto MURB.
2. Developed a survey on household energy use.
3. Developed a plan regarding survey distribution and collection.
4. Sought Ryerson University's Research Ethics Approval.
5. Collected survey results and analysis.

## 3.2 Study Site, Toronto MURB

The study site is owned and operated by a not-for-profit organization. Through a federal program, the organization aims to create affordable housing for primary single persons of modest incomes. In recent years, the organization decided to carry out sustainable retrofits such as geothermal and solar thermal domestic hot water heating, sub-metering, and so forth. The study site, Toronto MURB, shares similar characteristics to a majority of Toronto's MURBs. First, the households are typically low-income households; second, it is located in Toronto and classified with high density residential structures built between 1945 and 1984. Lastly, tenants do not pay for their energy consumption because it is included in tenant's monthly rent.

The building consists of sub-metered apartment units that track energy consumption data (electrical) per apartment unit. The sub-meter take account of entire plug loads and fan-coil unit (source of heating) consumption. Each apartment unit does not have any source of cooling other than what is supplied in the fan coil unit. This thesis only focuses on the electrical draw from the units; it does not include heating and cooling loads from the boiler.

This Toronto MURB is currently home to low income households; who are new to Canada, individuals with disability, or individuals having difficulties finding housing elsewhere. The not-for-profit organization believes in building a strong community and sheltering those in need of housing. Table 3.1 shows information about the study site, Toronto MURB, at a building and apartment unit level.

**Table 3.1: Building and apartment unit characteristics of study site, Toronto MURB**

| Building Characteristics | |
|---|---|
| Name of Building | Toronto MURB |
| Date of Construction | 1976 |
| Number of households | 136 households |
| Room Types | 2 x one-bedroom units<br>134 x bachelor units |
| Number of storeys | 11 storeys |
| Building Layout | Basement - Program space and mechanical rooms<br>First Floor - Gathering room, main lobby, housing administration and washrooms<br>Second to eleventh floor - Residential apartment units<br>Eleventh floor - Laundry facility |
| **Apartment Unit Characteristics** | |
| Apartment Unit Area | Bachelor units: 21.37 $m^2$<br>One-bedroom units: 65.03 $m^2$ |
| Apartment Unit Layout | Entrance hallway, washroom, kitchen and room |
| Heating and Cooling Equipment Provided | Electrical fan coil[2)] |
| Major Appliances | Stove with oven combo[3)]<br>Refrigerator[4)] |
| Appliances and Electrical Devices | May vary between occupants. |
| Lighting (15 W CFLs) | Entrance: 1 x one-light bulb light fixture<br>Bathroom: 1x two-light bulb light fixture<br>Main room: 1 x one-light bulb light fixture<br>Other light fixtures such as lamps may vary between occupants. |

[2)] Enviro-Tec by Johnson Controls - Series B Vertical Floor FCU, Model VFE; Voltage 115, Tap High, HP 1/30, Hand LH (Johnson Controls, 2012).

[3)] Frigidaire CMEF212E Freestanding Range, Multiflex brand, with an annual energy consumption of 416 kWh/year (Natural Resources Canada, 2011b), freestanding conventional cook top, single non-self cleaning oven, 0 L on the lower oven space, 54.8 L upper oven space and a width of 24 inches.

[4)] Type:LG-GM-3135SC, Top Mount, with an annual energy consumption of 370 kWh/year (Natural Resources Canada, 2011b), not an energy star product, automatic defrost mechanism, top freezer location, capacity (L/cubic ft):Total 254.7/9 ft, size 4 category on EnerGuide Label, no door ice service, refrigerator volume of 193.855 L (6.85$ft^3$), freezer volume of 60.845 L (2.15 $ft^3$).

## 3.3 Survey Development

The objective of the set of questions was to capture as much information related to occupant's household energy use in the Toronto MURB as possible. Prior to survey design and development, information was already gathered on occupant's apartment unit and building characteristics by interviewing the property manager, apartment unit inspection, and assessment of the building drawings (Chapter 3.2). Thus, a great deal of information on the occupants was already known. This allowed for exclusion of some questions. For example, all apartment units contain the same type of refrigerator, stove, and oven.

The development of the survey went through much iteration before the final draft was completed. Revisions and edits were made by the property manager, and Ryerson University graduates as well as professors. The final draft of the survey is found in Appendix A.

The survey included questions of the following topics:

- General information

General information includes gender, age, country grown up in, number of years living in the Toronto MURB, number of people living in their household, number of hours spent in their apartment unit (includes sleeping), and income. These parameters were selected based on previous surveys such as United Way Toronto's Vertical Poverty (2011) survey and SHEU 2007.

- Electrical devices

Electrical devices include television (usage, type, and age), cable use, computer (usage, type, and age), internet use, and a checklist of appliances that the occupant may own. Major appliances such as refrigerator and oven/stove tops were already known to the investigators. The selection of minor appliances was taken from SHEU 2007. Any other appliances not listed in the survey can be reported in the "other" section.

- Heating and cooling

The heating and cooling section includes temperature setting of their heating/cooling equipment (e.g., fan coil unit) during the winter and summer. Any other alternatives to adjusting apartment unit temperature (e.g., open/close windows) were specified in a checklist format.

- Energy behaviour (frequency turning off lights/television and purchasing)

Energy behaviour was measured by using a Likert scaling system, similar to Kurz *et al.* (2005) study: 1 being "always" performing the behaviour to 5 being "never" performing the behaviour. The selected behaviours are dependent on television use, lighting use, computer use, and purchasing of green appliances.

- Lighting (number and type of bulbs and fixtures)

Lighting was measured by using similar questions in SHEU 2007. These questions include number of compact fluorescent and incandescent light bulbs, number of light bulbs turned on longer than 3 hours, number of hours the light bulbs are turned on during the winter/summer seasons, and numbers of light fixtures (e.g., lamps and floor lamps) in their apartment unit.

- Water usage (showering, bathing, hygienic activities)

Water usage was measured to examine whether they ran their faucet during hygienic activities and washing their dishes. The water usage section also included the number of times they flush their toilet in a day and how many showers/baths they take in a week.

- Household activities (oven, stove, and microwave use)

Household activities include the use of stove, oven and microwave. These household activities were measured by using similar questions in SHEU 2007 but at a daily scale, rather than a weekly scale.

- Indoor environment satisfaction and thermal comfort (satisfaction on temperature, noise, appliances)

Indoor environment satisfaction and thermal comfort was measured using a Likert scaling system; 1 being very satisfied to 7 being very dissatisfied. These questions derived from Center for the Built Environment (CBE) (Center of the Built Environment, 2012).

- Your neighbourhood

This section deals with social aspects of living in the Toronto MURB. This was measured by inquiring about occupant's feelings about living in the Toronto MURB and in what ways it has changed their life (e.g., financially, security, and well-being). In addition, a question of occupant's sense of belonging derived from United Way Toronto's Vertical Poverty (2011) survey.

## 3.4 Survey Distribution and Collection

The survey population are Toronto MURB tenants, living in the Toronto MURB between April 16 and May 4, 2012. There were 136 households in total. The sample units were households - one survey respondent represents a household. Prior to survey distribution, notification posters were posted in high traffic areas (e.g., lobby and hallways) of the Toronto MURB for one-month (March 16 to April 16). Surveys were distributed by employing three survey methods:

1. Paper-based self-enumeration (mail-in surveys): surveys were sent to household's mailbox on April 9. A drop box was available in the main lobby. The drop box was then removed on May 4.
2. Interview-assisted surveys: five "drop-in" interview sessions were held in the main lobby of the Toronto MURB (April 18, 20, 23, 25 and May 2) from 5:30pm to 7:30pm.

Assistance to complete the survey was available by ways of interacting with one of Ryerson's graduate students.

3. On-line survey: Tenants had the opportunity to complete the survey on-line via Fluidsurveys (http://fluidsurveys.com/). The on-line survey became available from April 1 to May 31, 2012.

### 3.4.1 Increase Survey Response Behaviour

Many tactics were used to increase survey response rate. These tactics were determined by referring to Cavusgil and Elvey-Kirk study (1998) on the underlying motivators for mail-in survey response behaviour. The operations/activities that were carried out to increase participation are:

- Pre-notification of the survey distribution and collection by posters and newsletter notifications
- A cut-off date notification
- An incentive was given out ($5.00 cash) for completing the survey
- Tenants would receive their incentive in their mailbox
- Surveys were sent in their mailbox and were also available to be picked up in the main lobby during interview-assisted sessions
- Surveys were packaged in personalized envelopes that provided information about the research study, confidentiality, reminder about the incentive and a pen
- The survey packages were in colour with an attractive title page
- Posters and invitations notified tenants of the percentage of surveys completed. All posters were printed on "eye-catching" colours (e.g., green paper).

- Survey collection: A drop box and on-line survey was available 24 hours/day and 7 days/week from April 9 to May 4. Interview-assisted sessions were also held on April 18, 20, 23, 25 and May 2.

## 3.5 Research Ethics Approval

As of March 5, 2012, Ryerson University Research Ethics Board approved the project in order to conduct the survey of household energy use in the study site of this thesis, Toronto MURB. This thesis involves interaction with human subjects and requires compliance with Ryerson University's policies and protocol (See Appendix B for Research Ethics Approval documents). The Ethics application process requires detailed information on data that is obtained in the survey, how you will be collecting the information, compensation, method of recruiting, number of participants involved, and potential risks to exposure.

Prior to completing the survey, households were given a consent form informing them about the project and its confidentiality. Households were aware that Ryerson University is an independent entity responsible for conducting the research, that the property management was not involved in the study, and that all information is confidential and will not be shared with any other entities.

## 3.6 Collect Survey Results and Analysis

All survey responses were inputted into a data pool by using Microsoft Excel. After that, the analysis was then performed using IBM Statistical Package for Social Science (SPSS). One of the functions of SPSS is to analyze survey data. Frequency tables were created for all survey results. Further analysis was carried out by using Alyuda NeuroIntelligence Version 2.2 to assess the effect of occupant characteristics (e.g., age, gender, income, residency, and hours spent in their household) on their household energy use consumption. The methodology of this analysis will be discussed further in next chapter.

# Chapter 4 Methodology of the ANN Model

## 4.1 Overview

Chapter 2.5 has shown that the neural network approach can:

1. effectively model and estimate occupant's household use for Canadian households
2. outperform other statistical bottom-up methods such as CDA
3. determine causal relationships between variables

In this thesis, the multi-layer perceptron (MLP) artificial neural network approach is used. MLP is a variation of ANN, using different architectures and algorithms; MLP uses error back propagation algorithm during training phase (Aydinalp *et al.*, 2003). The name of the software is Alyuda NeuroIntelligence 2.2, created by Alyuda Research Inc. (Alyuda, 2003). Alyuda NeuroIntelligence 2.2 software uses MLP and has shown to be effective software as it is found in many publications. Alyuda NeuroIntelligence 2.2 software is used for many applications such as financial predictions (Agryou, 2006; Anwar, 2009), civil engineering problems (Li *et al.*, 2011), heat transfer (Poulad *et al.*, 2010), and construction and building material analysis (Prasad *et al.*, 2009).

First, the research methodology of the ANN model is presented by ways of the Alyuda NeuroIntelligence 2.2 software. Then, in the following chapter, the development of the ANN model is presented. The following section begins with the information on the sources of data used to develop the NN model. It also describes the methodology of the training, validation and testing of the dataset. The networks are used to predict monthly household's electrical energy consumption. The development of the model is shown in Figure 4.1.

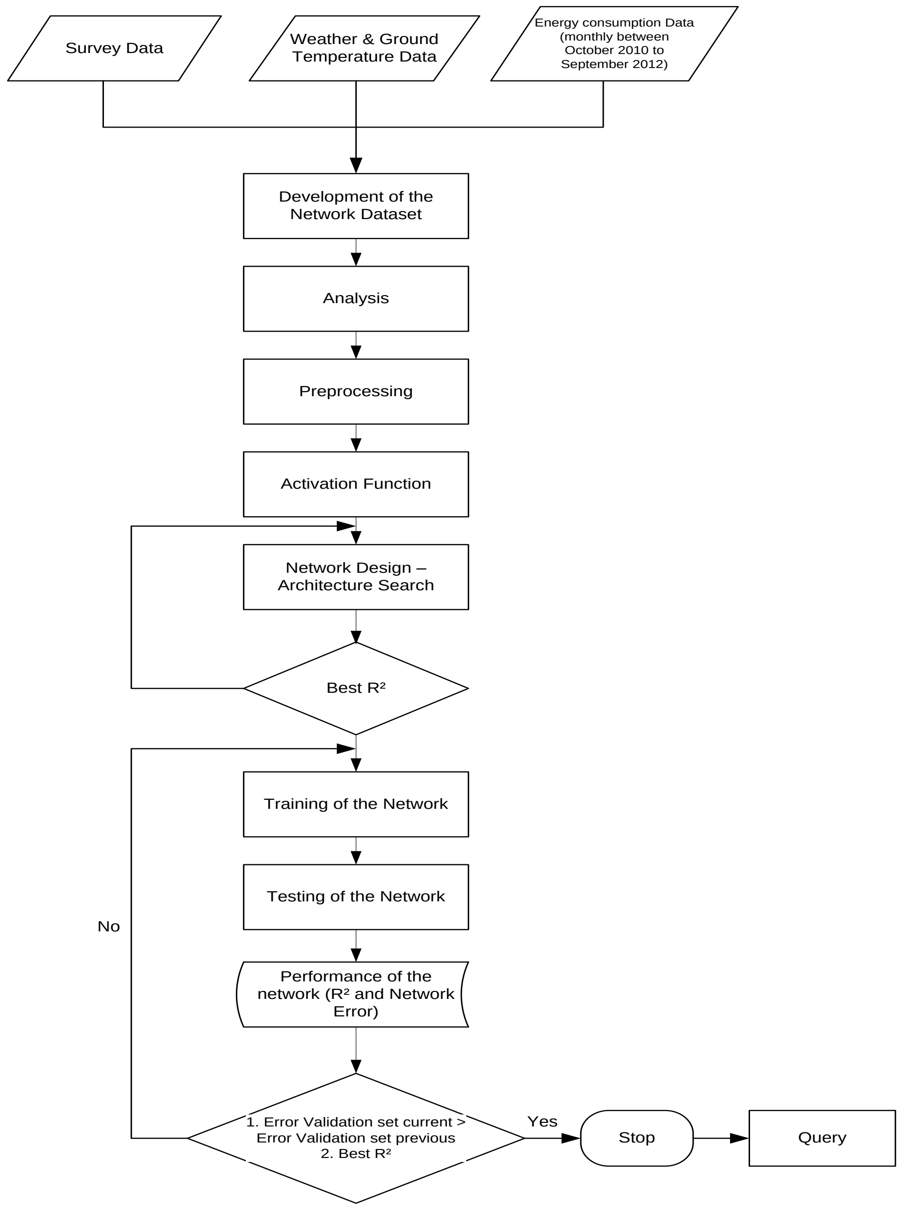



**Figure 4.1: Flowchart of the methodology for the development of the NN Model**

## 4.2 Sources of Data

Three sources of data were used for the development of the input units of the ANN models: the survey data of household energy use in the Toronto high-rise MURB (Roque *et al.*, 2012), monthly energy consumption of each unit, and the weather conditions (Environment Canada, 2012).

### 4.2.1 Monthly Energy Consumption Data

With the completion of 49 surveys, the following 49 households also had energy billing data. However, only 48 of the households had properly operating sub-metering units, as suggested by the Property Manager of the Toronto MURB. A complete monthly energy consumption for the 136 units in the Toronto MURB was obtained from October 1, 2010 to September 30, 2012 (24 months). This energy consumption is the amount of electricity used by each apartment unit in a month (kWh/month/household). Appendix C presents the energy consumption data from October 2010 to September 2012. In addition, Appendix C also presents an analysis of the energy consumption.

### 4.2.2 Survey Data of Household Energy Use

The data pool was based on 48 surveys, completed by occupants living in a Toronto MURB (Roque *et al.*, 2012). The survey consisted of a total of 51 questions related to occupant's space heating/cooling equipment, household appliances, and socio-economic characteristics. With approval from Research Ethics and the Toronto MURB occupants, the survey was conducted for duration of one month. Chapter 6 presents the survey results (data) of household energy use.

### 4.2.3 Weather Data

The weather conditions data were obtained from the National Climate Data and Information Archive (Environment Canada, 2012). The weather data obtained include monthly mean temperature (°C), monthly total of precipitation (mm), mean direction (10's deg) of gust, and mean speed of gust (km/h).

## 4.3 Development of the Network Datasets

A total of 48 surveys and their corresponding energy consumption data were linked to create the entire dataset. The total energy consumption data consisted of 24 months of energy consumption for each apartment unit (kWh/month/household). In total, 1152 cases were made - 24 months of energy billing data and 48 completed surveys. These cases were then partitioned into three parts at random: 1. 65% for training the network - 750 cases; 19% for validating the network - 218 cases; and 16% for testing the network - 184 cases.

## 4.4 Development of Input and Output Units

The input data for the neural network dataset were obtained by using the information from the survey in Chapter 3. The inputs for the networks describe:

- Date - month and year
- Apartment unit orientation
- Socio-demographic factors: gender, age, country the occupant had grown up, number of years living in the building, number of people in the household, number of hours spent in their apartment unit per day (includes sleeping), and income
- Weather conditions: mean temperature, total precipitation, extreme direction of maximum gust, and extreme speed of maximum gust
- Ownership, type, and usage of appliances, lighting, heating and cooling equipment
- Purchasing of green appliances/electrical devices
- Satisfaction of appliances in apartment unit (e.g., stove and refrigerator)

The number of inputs differs between networks. Multiple preprocessing attempts were conducted in order to find a suitable dataset and architecture for the model. This was done by training the model and comparing the predictor $R^2$ performance values.

When the dataset was developed, it was loaded into the ANN software. The data were then analyzed for any missing and incorrectly entered data, and/or outliers. All data inputs, whether numerical or categorical, were numerically scaled (and encoded) between -1 and +1. This means that columns with N distinct categories (values) were encoded into one numeric column, with one integer value assigned for each category. Orientation column with values "East" and "West", for example, will be represented as -1 (East) and +1 (West).

The output for the networks is household energy consumption per month (kWh/month/household).

## 4.5 Activation Function and Network Design

To design the network, network architecture (number of hidden layers and units in each layer) and network properties (error and activation functions) are needed. Network properties are defined automatically in the software but it is possible to change them manually, which in some cases improves network performance. In this study, an architecture search was launched with two (2) hidden layers and by changing the activation functions.

Logistic, hyperbolic tangent, and linear activation functions were used to develop the network design, shown in Table 4.1. All network designs and activation functions, shown in Table 4.1, were tested. An exhaustive search was applied to seek best performing network design and activation functions. The output error function used was sum of squared error (SSE).

**Table 4.1: Combinations of Activation Functions for the ANN Model**

| Network Name | Hidden Layer Activation Function | Output Layer Activation Function |
|---|---|---|
| A | Logistic | Logistic |
| B | Logistic | Hyperbolic Tangent |
| C | Logistic | Linear |
| D | Hyperbolic Tangent | Logistic |
| E | Hyperbolic Tangent | Hyperbolic Tangent |
| F | Hyperbolic Tangent | Linear |
| G | Linear | Logistic |
| H | Linear | Hyperbolic Tangent |
| I | Linear | Linear |

## 4.6 Training of the Artificial Neural Networks

Training of the artificial neural networks is an iterative, trial and error procedure. The following steps were conducted during the training phase of the network:

1. Training Algorithms - The following algorithms supported by NeuroIntelligence were applied to the training dataset: Quick Propagation (QP), Conjugate Gradient Descent (CGD), Limited Memory Quasi-Newton (LMQ-N), and Online Back Propagation (OBP).

All weights and biases were manually randomized between -1 and +1 (by default of the software) or at a suitable interval.

2. Training Algorithm's Parameters - The default of the parameters were set by the Alyuda software: Quick propagation coefficient = 1.75, and learning rate = 0.1

3. Stop Training Conditions - The termination criterion (when to stop training) used was as follows:

- after the number of iterations (1,000 iterations) or;
- when the network with the lowest validation error was achieved. This occurs when the validation error value stopped decreasing and started to increase.

4. Overtraining Control - To control the training of the network, the software was able to retain the best network (the network with the lowest validation error) and restore it after training is complete.

## 4.7 Testing of the Network

The performance of each network model was assessed numerically using both the coefficient of determination ($R^2$) and the validation error. The testing was conducted for all datasets: training, validation, and testing. If the coefficient did not reach the minimum values accepted (For validation and testing $R^2>0.75$, for all $R^2>0.85$) then the network was re-trained by choosing a different algorithm or by adjusting the weights.

In order to assess the ANN model prediction performance, Aydinalp *et al.* (2003) and Anstett and Kreider (1993) used fraction of variance, which is symbolized as $R^2$. As mentioned earlier, Alyuda NeuroIntelligence 2.2 is used to develop the ANN model and for simulation in this work. This software has a friendly user interface and a number of options for the different stages of analysis.

Once the networks are complete, the best network was used to predict the occupant's household energy consumption of the 48 apartment units in the Toronto MURB. The final network was used to assess the impact of demographics on occupant's household energy consumption. This was done by querying the best network.

# Chapter 5 Development of the ANN Model

## 5.1 Overview

This chapter presents the development of the ANN model. The ANN model will represent the survey respondents' household energy use in the Toronto MURB from October 2010 to September 2012. The first section will describe the development of the network dataset, which includes the inputs and outputs of the ANN model. The second section then describes the analysis and preprocessing of the network datasets. Afterwards, the selection of the architecture search and activation functions are established. The final sections present the training, testing and querying of the network.

## 5.2 Development of the Network Datasets

As presented in Chapter 4.4, the network dataset consists of 48 households and 24 months of energy consumption data. A total of 1152 cases were created by having 48 households for every month. The inputs for the network were obtained by survey responses, weather conditions, date, and building characteristics. The selection of the inputs for survey data was determined by the components which the sub-meters account for - all plug loads and fan coil unit consumption. The energy consumption data is the monthly sub-meter data, which measures the apartment unit's electrical draw.

In order to select the most suitable network dataset, many combinations were tested. During the development of the model, the number of inputs was modified to improve the results. Hence, two datasets were tested. Table 5.1 shows the tested datasets for the network. The purpose of the different datasets was to explore the best performing dataset during the architecture and activation search. The following sections explain the development of the inputs and outputs for the ANN model. The main difference between dataset #1 and #2 is the energy consumption behaviour ratio and electronic ratio in dataset #2. The energy consumption behaviour ratio and electronic ratio will be discussed in Chapter 5.2.5.

**Table 5.1: Tested input datasets for the ANN model**

| Dataset # | Number of Inputs | Description of the input |
|---|---|---|
| 1 | 62 | Date<br>Orientation (West or East) input<br>Seven demographic inputs<br>Four weather condition inputs<br>49 appliances/electrical devices (type, usage, and energy-related behaviour) inputs |
| 2 | 34 | Date - month and year (two) inputs<br>Orientation (West or East) input<br>Seven demographic inputs<br>Four weather condition inputs<br>Energy consumption behaviour ratio<br>Electronic ratio<br>18 appliances/electrical devices (type, usage, and energy-related behaviour) inputs |

### 5.2.1 Inputs for Date

The date was represented in two separated columns; one column being the month and the other being the year.

### 5.2.2 Inputs for Orientation

The orientation of the apartment units were either West or East. Therefore, West or East were represented by denoting "1" to West and "2" to East.

### 5.2.3 Inputs for Demographics

Seven demographical inputs were selected for the dataset: gender, age, country grew up, residency (number of years residing in the Toronto MURB), number of people per household, number of hours spent per day in their apartment unit per day (including sleeping), and income.

To indicate the options for each demographic input, a coding system was used. For example, the gender option was male ("1") or female ("2"). This system was carried out for the other demographic inputs, which include age, country grew up, residency, number of people per household, number of hours per day, and income. Table 5.2 shows the coding system used for each demographic input.

**Table 5.2: Coding system for demographics**

| Coding system | Description |
|---|---|
| **Gender** | |
| 1 | Male |
| 2 | Female |
| **Age** | |
| 1 | 18 to 30 years |
| 2 | 31 to 45 years |
| 3 | 46 to 60 years |
| 4 | Over 60 years |
| **Country Grew Up** | |
| 1 | Canada |
| 2 | USA |
| 3 | Europe |
| 4 | Africa |
| 5 | West Asia and Middle East |
| 6 | East Asia |
| 7 | South or Central America |
| **Residency** | |
| 1 | 0 to 1 year |
| 2 | 2 to 4 years |
| 3 | 5 to 7 years |
| 4 | More than 7 years |
| **Number of People per Household** | |
| 1 | 1 person |
| 2 | 2 person |
| **Number of hours spent in apartment unit per day (includes sleeping)** | |
| 1 | 8 hours or less |
| 2 | 9 to 13 hours |
| 3 | 14 to 18 hours |
| 4 | More than 18 hours |
| **Income** | |
| 1 | $0 to $14,999 |
| 2 | $15,000 to $29,999 |
| 3 | $30,000 to $49,999 |
| 4 | Prefer not to say. |

### 5.2.4 Inputs for Weather Conditions

All weather conditions were numerically represented in the dataset. The weather conditions include monthly mean temperature (°C), total monthly precipitation (mm), mean direction (10's deg) of gust, and mean speed of gust (km/h). Table 5.3 shows the weather condition inputs for the model.

**Table 5.3: Weather condition inputs for the model, taken from Environment Canada (2012)**

| Date | Mean Temp (°C) | Sum Total Precip (mm) | Mean Dir of Max Gust (10's deg) | Mean Spd of Max Gust (km/h) |
|---|---|---|---|---|
| Oct-10 | 10.2 | 57.2 | 18.16 | 31.29 |
| Nov-10 | 4.5 | 66.2 | 12.87 | 27.3 |
| Dec-10 | -3.8 | 36.8 | 21.45 | 34.87 |
| Jan-11 | -7 | 42 | 12.74 | 23.9 |
| Feb-11 | -5.4 | 47 | 16.96 | 36.32 |
| Mar-11 | -0.5 | 91.4 | 20.48 | 35.26 |
| Apr-11 | 6.9 | 96.6 | 16.17 | 40.7 |
| May-11 | 14.1 | 142 | 11.58 | 24.58 |
| Jun-11 | 19.1 | 59 | 17.38 | 29.83 |
| Jul-11 | 24.4 | 32.4 | 18.55 | 27.77 |
| Aug-11 | 21.9 | 72.2 | 13.7 | 23.26 |
| Sep-11 | 17.7 | 85 | 10.1 | 22.3 |
| Oct-11 | 10.5 | 119.2 | 8.42 | 21.29 |
| Nov-11 | 6.6 | 98 | 18.97 | 35.6 |
| Dec-11 | 0.8 | 52 | 13.35 | 22.42 |
| Jan-12 | -1.7 | 54.2 | 17.35 | 32.42 |
| Feb-12 | -0.3 | 26.6 | 16.62 | 28.67 |
| Mar-12 | 6.7 | 18 | 13.94 | 28.55 |
| Apr-12 | 7.3 | 43.8 | 23.03 | 35 |
| May-12 | 16.6 | 44.4 | 11.61 | 18.29 |
| Jun-12 | 20.6 | 76.4 | 14 | 24.37 |
| Jul-12 | 24.3 | 100 | 13.87 | 23.77 |
| Aug-12 | 21.6 | 52.4 | 7.52 | 11.23 |
| Sep-12 | 16.4 | 44 | 14.17 | 20.73 |

### 5.2.5 Inputs for Appliance/Electrical Device

There were a total of 62 inputs related to appliance/electrical device ownership, age, type, and usage. Similarity to the method used in Chapter 5.2.3, a coding system was used for each appliance/electrical device age, type, and usage-type options. For example, television age options were "I do not have a television", "5 years or less", "6 to 10 years", "11 to 15 years", or "16 years or more". The coding system denoted television age options using 0, 1, 2, 3, and 4, respectively.

For appliance/electrical device ownership-type options, binary variables "0" and "1" were used. Denoting ownership with "0" means that the household does not own the appliance/electrical device; whereas denoting "1" means that the household does own the appliance/electrical device. It is also important to note that any input denoted by "0" means that the occupant does not own or use the appliance/electrical device.

For numerical inputs (e.g., number of light bulbs, rating score, indoor environment satisfaction score, and temperature), they remained as numbers.

Table 5.4 to 5.15 shows the coding of the inputs used in the network dataset.

**Table 5.4: Coding system for television use options**

| Coding system | Television Use options |
|---|---|
| 0 | None |
| 1 | 1 hour or less |
| 2 | 1 to 3 hours |
| 3 | 4 to 8 hours |
| 4 | 9 to 13 hours |
| 5 | 14 hours or more |

**Table 5.5: Coding system for television type options**

| Coding system | Television Type options |
|---|---|
| 0 | None |
| 1 | LCD/LED |
| 2 | Plasma |
| 3 | Regular (tube) |

**Table 5.6: Coding system for cable box usage options**

| Coding system | Cable Box Usage options |
|---|---|
| 0 | I do not have cable |
| 1 | Always turn off |
| 2 | Leave on all the time |
| 3 | Sometimes turn it off |

**Table 5.7: Coding system for stove and oven usage options**

| Coding system | Stove and Oven Usage options |
|---|---|
| 0 | None |
| 1 | 1 hour or less |
| 2 | 1 to 3 hours |
| 3 | 3 hours or more |

**Table 5.8: Coding system for microwave usage options**

| Coding system | Microwave Usage options |
|---|---|
| 0 | None |
| 1 | Less than 3 minutes |
| 2 | 3 to 9 minutes |
| 3 | 9 to 15 minutes |
| 4 | more than 15 minutes |

**Table 5.9: Coding system for computer use options**

| Coding system | Computer Use options |
|---|---|
| 0 | None |
| 1 | 1 to 3 hours |
| 2 | 4 to 8 hours |
| 3 | 9 hours or more |

**Table 5.10: Coding system for computer age options**

| Coding system | Computer Age options |
|---|---|
| 0 | None |
| 1 | 5 years or less |
| 2 | 6 to 10 years |

**Table 5.11: Coding system for internet use options**

| Coding system | Internet Use options |
|---|---|
| 0 | I do not have Internet |
| 1 | 1 hour or less |
| 2 | 1 to 3 hours |
| 3 | 4 to 8 hours |
| 4 | 14 hours or more |

**Table 5.12: Coding system for appliance/electrical devices**

| Coding system range | Appliance/Electrical Devices |
|---|---|
| 0-1 | Cell phone, home phone, VHS player, DVD player, Gaming Console, Printer, Speakers, Clock, Radio/stereo, Slow Cooker, Rice Cooker, Iron, Vacuum Cleaner, Humidifier/Dehumidifier |

**Table 5.13: Inputs for heating and cooling equipment (temperatures)**

| Input | Heating and Cooling Equipment Temperature |
|---|---|
| Temperature (Degrees Celsius) | Response may vary. Answers: Degrees Celsius, Fahrenheit, Categorical temperature (low, medium, high) |

**Table 5.14: Inputs for energy behaviour**

| Range<br>1 being always; 5 being never | Energy Behaviour Inputs |
|---|---|
| 1-5 | Do you turn off the lights when not at home? |
| 1-5 | Do you turn off the lights when not in use? |
| 1-5 | Do you turn off electronics when you are not at home? |
| 1-5 | Do you turn off electronics when not in use? |
| 1-5 | Do you use timer controls to control your electrical devices? |
| 1-5 | Do you turn off (shut down) computer when not in use? |
| 1-5 | Do you turn off (shut down) computer when you are not at home? |
| 1-5 | Do you buy green appliances/devices (e.g., green saving light bulbs, ENERGY STAR™) |

**Table 5.15: Coding system for satisfaction with appliances in apartment unit**

| Coding system | How satisfied are you with the appliances in your apartment unit? |
|---|---|
| 1 | Very satisfied |
| 2 | |
| 3 | |
| 4 | Neutral |
| 5 | |
| 6 | |
| 7 | Very Dissatisfied |

A way to improve the results of the model is to select and adjust the model's inputs and interactions (Kavgic *et al*., 2010). This can be done by reducing the number of inputs to reduce the number of computations and time. Thus, a second dataset with 34 inputs was created. Initially, the dataset included 62 inputs. Reducing the number of inputs was done by combining inputs together. The number of inputs was reduced by creating two ratios: electronic ownership and energy behaviour.

Since the same electronics and electrical devices were asked in the survey, an electronic ratio was created. The electronic ratio is a relation between occupant's ownership of electronics to the total amount of electronics asked in the survey. The survey inquired about 22 electronics: cell phone charger, home phone, VHS player, DVD player, gaming console, printer, speakers, clock, radio/stereo, slow cooker, rice cooker, iron, vacuum cleaner, humidifier/dehumidifier, toaster, electric kettle, coffee maker, broiler toaster oven, laptop, desktop, personal heater, and personal fan. For example, if an occupant responded that they own five of the 22 electronics, their electronic ratio would be 0.227 (5 out of 22).

Energy behaviour ratio is the relationship between occupants exhibiting the behaviour, Question #21 of the survey, in not performing the behaviour. The ratio takes the overall average score of occupant's responses in Question #21. The energy behaviour ratio ranges from "1", which means they always perform the energy behaviour to "5", which means they never perform the energy behaviour. For example, if an occupant responds that they always perform the energy behaviour such as turning off the lights when not at home or always buying green appliances, then their energy behaviour ratio would be 1.

The responses related to heating and equipment (Question 18 and 19 of the survey) varied amongst occupants. For instance, some occupants responded by temperature (degrees Celsius), while others responded the questions categorically (e.g., high, medium and low). So, responses were categorized as shown in Table 5.16. A "N/A" response means that the response was inappropriate to Question 18 and 19 of the survey.

**Table 5.16: Coding system for winter and summer temperature (Question 18 and 19)**

| Coding system | Temperature (degrees Celsius) | Inputs |
|---|---|---|
| 0 | Do not use heating and cooling equipment | 0 |
| 1 | <16 | Low |
| 2 | 16 to 20 | Medium |
| 3 | Over 20 | High |
| 4 | N/A | N/A |

By creating two ratios, the number of inputs reduced from 62 to 34 inputs. Appendix D shows the coded dataset of 34 inputs for the 48 households surveyed.

### 5.2.6 Output for ANN Model

The output for the networks is the monthly sub-meter energy consumption of the apartment unit in the high-rise MURB. The sub-meters measure the total electrical draw from the apartment unit (kWh/month/household).

## 5.3 Analysis and Preprocessing of the Network Datasets

There was no evidence of missing or incorrectly entered data in the dataset. However, there were significant fluctuations in energy consumption between apartment units. All data was then scaled numerically and the final dataset included the following inputs and outputs:

**Inputs:**

*24 categorical columns:* Month, Year, Orientation, Gender, Age, Grow Up, Residency, Hours per day, Income, TV – Use, TV – Type, Cable Box Use, Stove Use, Oven Use, Microwave Use, Computer Use, Computer – Age, Internet Use, On an average day, how many light bulbs are turned on longer than 3 hours or more?, Winter – Hours per day light bulbs turned on, Summer - Hours per day light bulbs turned on, Winter temps, Summer temps, How satisfied are you with the appliances in your apartment (i.e. stove, refrigerator, etc.).

*10 numeric columns:* Number of people per household, Mean Temp (°C), Sum Total Precip (mm), Mean Dir of Max Gust (10's deg), Mean Speed of Max Gust (km/h), Electronic ratio, CFLs, Incandescent, Number of light fixtures, Energy consumption behaviour ratio.

**Output**: energy consumption (kWh/month)

## 5.4 Determination of Architecture Search and Activation Functions

An exhaustive search was used to determine the architecture and suitable activation function for the network. An exhaustive search explores the best performing network architecture amongst all inputs. In this case, the determination of network's architecture and activation functions were used amongst 62 and 34 inputs. Thus, an exhaustive search was used up to three hidden layers. Tables 5.17 and 5.18 summarize the performance of 62 and 34 inputs with different architecture and activation functions.

**Table 5.17: Summary performance of 62 inputs with different architecture searches and activation functions**

| Hidden layer activation function | Output activation function | Architecture | Number of weights | $R^2$ | Correlation |
|---|---|---|---|---|---|
| ***Logistic*** | ***Logistic*** | ***[62-61-54-1]*** | ***7246*** | ***0.995*** | ***0.995*** |
| Logistic | Logistic | [62-61-1] | 3905 | 0.975 | *0.988* |
| Tangent | Logistic | [62-44-1] | 2817 | 0.963 | 0.982 |
| Logistic | Logistic | [62-61-54-48-1] | 9880 | 0.986 | 0.993 |
| Logistic | Tangent | [62-56-1] | 3585 | 0.946 | 0.975 |
| Logistic | Linear | [62-22-1] | 1409 | 0.880 | 0.880 |
| Linear | Logistic | [62-58-1] | 3713 | 0.682 | 0.826 |

**Table 5.18: Summary performance of 34 inputs with different architecture searches and activation functions**

| Hidden layer activation function | Output activation function | Architecture | Number of weights | $R^2$ | Correlation |
|---|---|---|---|---|---|
| ***Logistic*** | ***Logistic*** | ***[34-85-54-1]*** | ***7674*** | ***0.993*** | ***0.997*** |
| Tangent | Logistic | [34-70-39-1] | 5259 | 0.992 | 0.996 |
| Tangent | Logistic | [34-68-1] | 2449 | 0.974 | 0.987 |
| Logistic | Logistic | [34-73-1] | 2629 | 0.975 | 0.987 |
| Logistic | Tangent | [34-77-1] | 2773 | 0.961 | 0.981 |
| Logistic | Linear | [34-72-1] | 2593 | 0.935 | 0.967 |
| Linear | Logistic | [34-8-1] | 289 | 0.593 | 0.771 |

As a result, the best performing architecture search and activation functions was found to be logistic and logistic with a architecture of [62-61-54-1] for 62 inputs and [34-85-54-1] for 34 inputs. They were the best architecture searches and activation functions due to the high $R^2$ values. The best architectures and activation functions from 62 and 34 inputs were then trained.

## 5.5 Training of the Network

The termination criterion (when to stop training) occurred when the network error had increased or the number of 1,000 iterations had been reached. Table 5.19 shows the different training algorithms and iterations applied to the dataset. Correlation coefficient ($R^2$) is also shown in Table 5.19, which is the performance predictor for all datasets. The best network was not determined solely on the results of one dataset; but by analyzing all three datasets - training, validation, and testing. When comparing all three datasets, the best overall network found is using the Quick Propagation training algorithm with 151 iterations and architecture of [34-85-54-1]. The best overall network had a training $R^2$ of 0.857, validation $R^2$ of 0.942, and testing $R^2$ of 0.937.

It is important to note that the highest $R^2$ for training is found using the Quick Propagation training algorithm with 151 iterations and architecture of [62-61-54-1]. However, the validation and testing $R^2$ is significantly low compared to the best overall network, mentioned above.

**Table 5.19: Summary table of training algorithms for the ANN model**

| Architecture | Training Algorithm | Number of iterations | $R^2$ | | |
|---|---|---|---|---|---|
| | | | Training | Validation | Testing |
| 62-61-54-1 | QP | 151 | 0.940 | 0.403 | 0.506 |
| 62-61-54-1 | OBP | 254 | 0.567 | 0.293 | 0.212 |
| 62-61-54-1 | BBP | 3256 | 0.202 | 0.006 | -0.098 |
| 62-61-54-1 | CGD | 196 | 0.861 | 0.518 | 0.593 |
| ***34-85-54-1*** | ***QP*** | ***151*** | ***0.857*** | ***0.942*** | ***0.937*** |
| 34-85-54-1 | QP | 201 | 0.956 | 0.276 | 0.642 |
| 34-85-54-1 | CGD | 176 | 0.895 | 0.743 | 0.764 |
| 34-85-54-1 | QP | 351 | 0.979 | 0.509 | 0.389 |
| 34-85-54-1 | LMQ-N | 415 | 0.873 | 0.762 | 0.784 |
| 34-85-54-1 | CGD | 173 | 0.817 | 0.608 | 0.690 |
| 34-85-54-1 | OBP | 1000 | 0.778 | 0.568 | 0.679 |

## 5.6 Validation and Testing of the Network

As stated earlier, 218 cases (19%) were randomly used to validate the network and 184 cases to test the network (16%). The $R^2$ found by the ANN software is 0.942 for validation and 0.937 for testing.

The ANN software allows querying every case in the dataset. This query (predicted energy consumption) dataset was compared to the actual energy consumption. Every month was summed and the percentage of error found is 0.37%. Figure 5.1 shows the comparison between the predicted and the actual energy consumption. The predicted energy consumption values show a strong relationship to the actual energy consumption values.

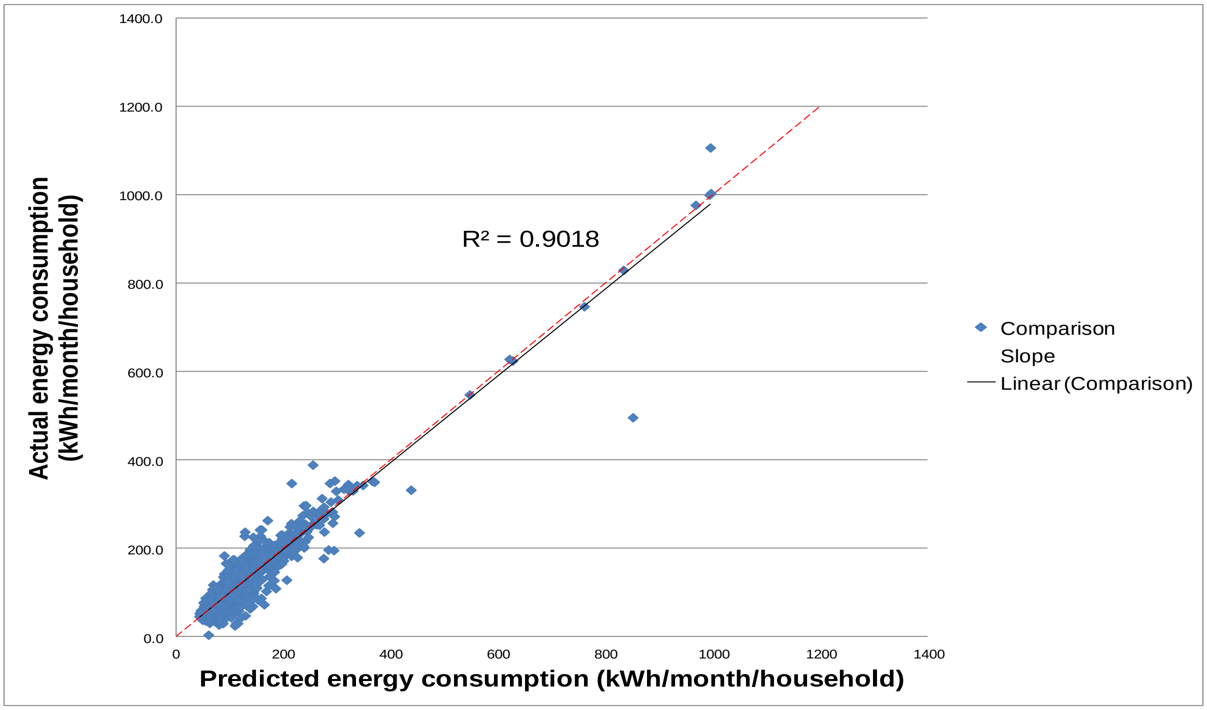



**Figure 5.1 : Comparison between the predicted and the actual energy consumption (kWh/month/household)**

## 5.7 Query of the Network

A manual query was conducted in order to measure the effects of demographics on monthly energy consumption in the Toronto MURB. The demographics that were measured were the following: gender, age, income, orientation, residency (number of years living in the Toronto MURB), country occupant's grew up, and number of hours spent in apartment unit.

In order to measure the effects of demographics, a selected set of household energy behaviour inputs were fixed, while the demographics were changed. This means that the energy behaviour inputs did not matter as long as it was selected consistently throughout the query. This enabled a comparison between age groups, for example, and monthly consumption trends from October 2010 to September 2012. All data was manually entered to develop monthly demographical trends for the selected set of household behaviours.

The selected set of household energy behaviour was randomly selected from the survey results. The selected set of household behaviours are defined by the following characteristics: apartment unit located on the East side of the building, male, between the ages of 46 to 60 years old, grew up in Africa, living in the Toronto MURB between 5 to 7 years, single-family household, spends 9 to 13 hours per day in their apartment unit (includes sleeping), household income between $15,000 and $29,999 per year, and appliance ownership, type. The other selected characteristics (e.g., energy behaviour) from the survey are as follows:

- Electronic ratio of 0.227
- Television use: one to three hours per day
- Television type: Plasma
- Cable box is always turned off after use
- Stove use: one hour or less per day
- Oven use: one hour or less per day
- Computer use: 1 hour or less
- Computer age: 5 years or less
- Internet Use: 1 hour or less per day
- Two compact fluorescent light bulbs
- Two incandescent light bulbs
- One light bulb is turned on longer than three hours per day
- During the winter, light bulbs are turned on for three to five hours per day
- During the summer, light bulbs are turned on for three to five hours per day
- One light fixture (e.g., lamp)

- During the winter, heating and cooling equipment is set at a low temperature (See Table 5.16)
- During the summer, heating and cooling equipment is set at a low temperature (See Table 5.16)
- Energy behaviour ratio of 1.589
- Occupants are satisfied with the appliances in the unit (e.g., stove, over, refrigerator) - rating of two out of seven

# Chapter 6 Survey Results

## 6.1 Sample

A total of 49 households completed the survey, with a response rate of 36%. Thirty-seven surveys were mailed in, and 12 face-to-face interviews were conducted, no surveys were completed on-line. This response rate is very similar to Abrahamse *et al.* (2007) study, which also had a response rate of 36%. Appendix E presents the survey results for each question in the survey.

At a 95% confidence level, the sample size yields a confidence interval of +/- 11.45%. This means that if the same survey is conducted 100 times, 95 out of the 100 survey responses yield results within +/- 11.45% of the response.

## 6.2 Demographical Distribution

The following demographical distribution was found by the survey responses[5]:

- Gender: 80% of the surveys were completed by males.
- Age: A majority of the respondents (60%) are above the age of 46 years.
- Years of residency: 45% of the respondents have lived in the Toronto MURB for more than seven years.
- Ethnic origin: 45% of the respondents grew up in Africa.
- Hours per day in household: 49% of the respondents spend 9 to 13 hours each day in their apartment unit (includes sleeping).

[5] Any response of "0" in the survey means that the respondent did not complete the question. These responses were not taken into account for averaging.

- Income: 37% of the respondents have a total income of $15,000 to $29,999 and 29% who have a income of $0 to $14,999. There are no respondents that have an income over $50,000.

## 6.3 General Findings

### 6.3.1 Household Appliances and Electrical Devices

Figure 6.1 shows the ownership percentage of appliances and electrical devices within the surveyed households. A majority of the survey respondents own a television, phone charger/phone, lamp/light fixture, radio/stereo, DVD player and computer.

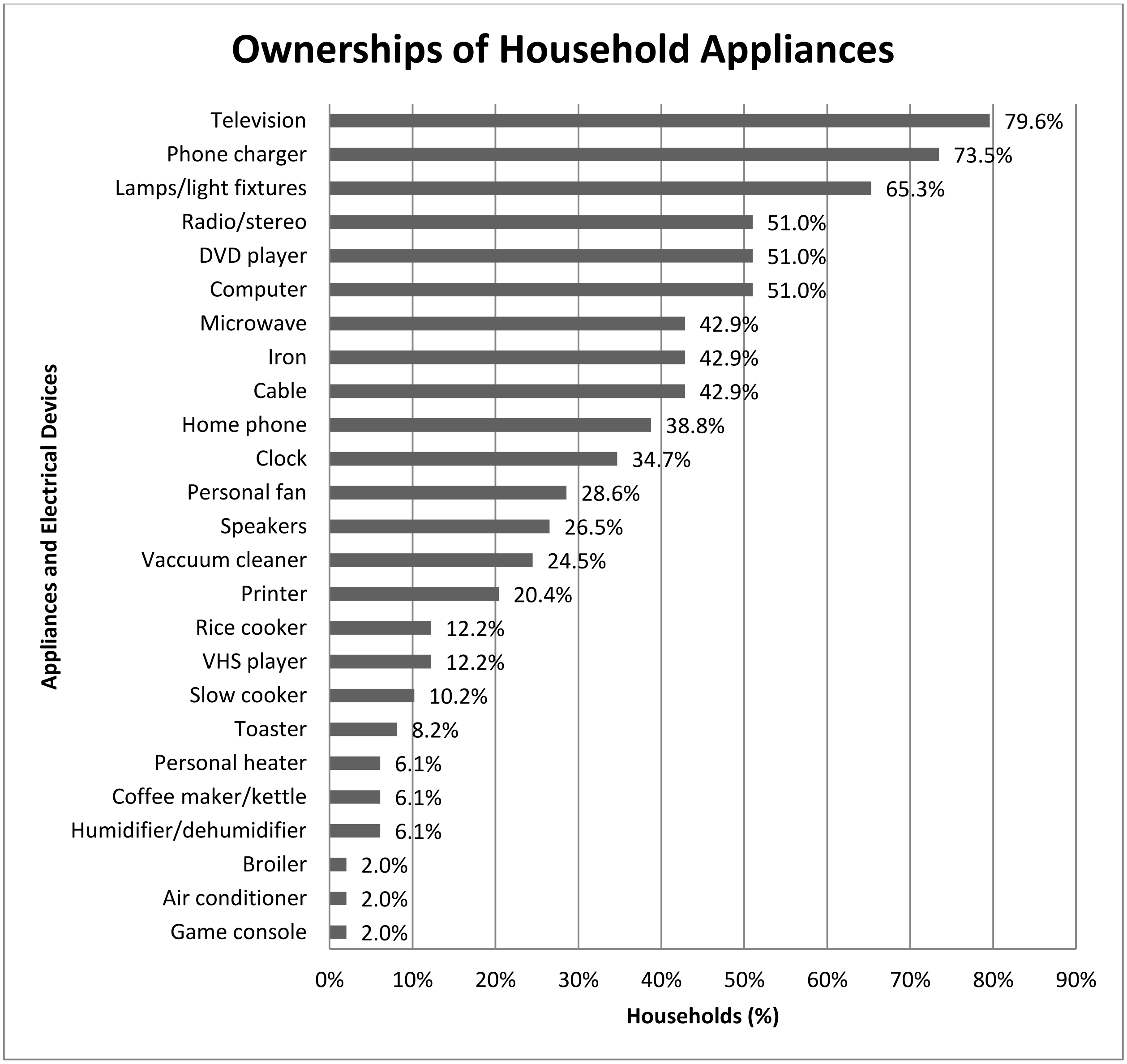



**Figure 6.1: Ownerships of appliances and electrical devices in the surveyed households**

## 6.3.2 Television

- 57% of the respondents own a television that is five years old or less
- 33% of the respondents watch one to three hours of television everyday

For those respondents who own a television:

- 36% of the respondents own a regular (tube) television, 23% own a plasma television, and 41% of the respondents own a LCD/LED television

### 6.3.3 Computer

A personal computer is either a desktop or laptop computer.

- 53% of the respondents do not own a computer or the respondent does not use it.

  For those respondents who own a computer:

- 32.6% of the respondents have a laptop.
- 43% of the respondents spend about one to three hours a day on the computer.
- 42.9% of the respondents own a new computer (five years or less).

  For those respondents who have the Internet:

- 39% of the respondents spend approximately four to eight hours on the Internet every day.

### 6.3.4 Heating and Cooling

- A majority of the respondents open and close their windows in order to adjust to their thermal comfort (80%). Figure 6.2 shows the other ways the respondents adjust to their thermal comfort such as putting on or removing clothing, closing drapes or blinds, and so forth.

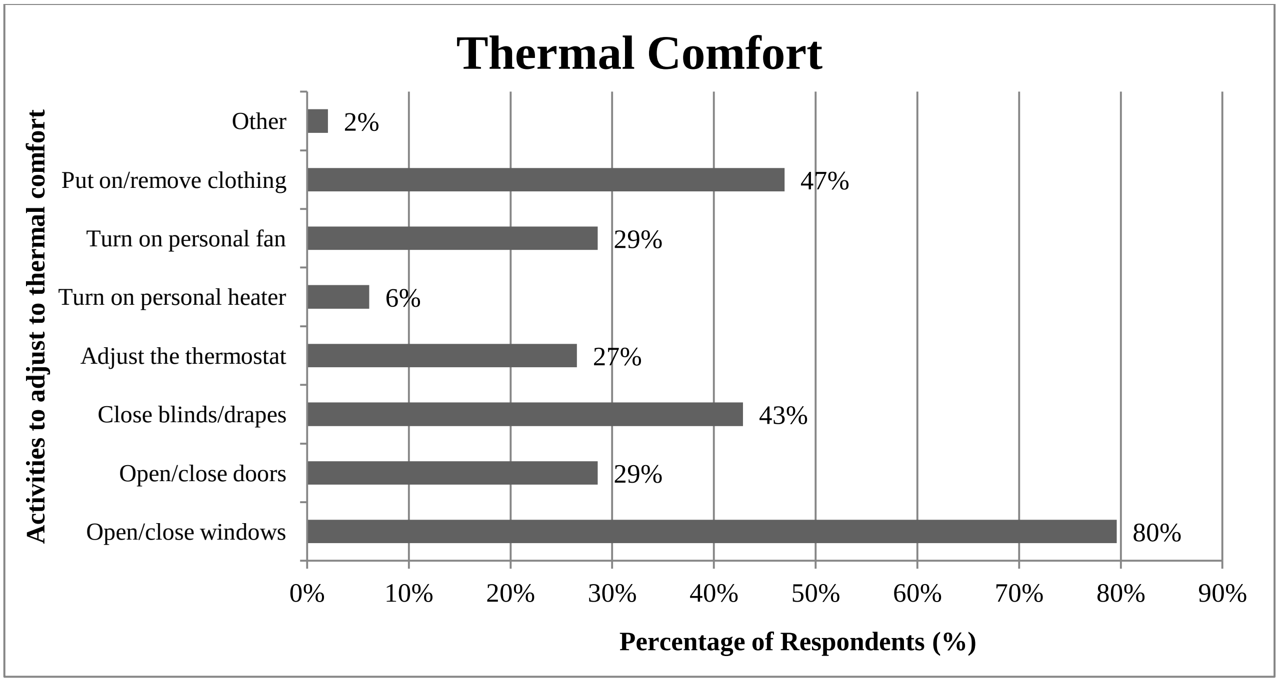



**Figure 6.2: Respondent's adjustments to thermal comfort**

### 6.3.5 Energy Behaviour

The average rating scores show that respondents "always" perform energy saving behaviours by turning off their electronics, lights, and computers when not in use or not at home (Table 6.1). Respondents, however, rarely use timer controls or purchase green appliances.

**Table 6.1: Energy Behaviour – Average and standard deviation**

| Do you... | Average Rating | Standard Deviation |
|---|---|---|
| Turn off lights when not at home | 1.21 | 0.68 |
| Turn off lights when not in use | 1.41 | 0.70 |
| Turn off electronics when you are not at home | 1.27 | 0.74 |
| Turn off electronics when not in use | 1.40 | 0.95 |
| Use timer controls to control your electrical devices/electronics | 3.83 | 1.61 |
| Turn off computer when not in use | 1.81 | 1.19 |
| Turn off (shut down) computer when you are not at home | 1.60 | 1.35 |
| Buy green appliances/ devices | 2.44 | 1.71 |

### 6.3.6 Lighting

- The average number of CFLs in the respondent's apartment unit is 2.4.
- The average number of incandescent light bulbs in the respondent's apartment unit is 1.6.
- A majority of the respondents (81.6%) have one to two bulbs on longer than three hours per day.
- During the winter, 38% of the respondents leave their light bulbs on for three to five hours (Figure 6.3).
- During the summer, 63% of the respondents leave their light bulbs on for less than three hours (Figure 6.3).

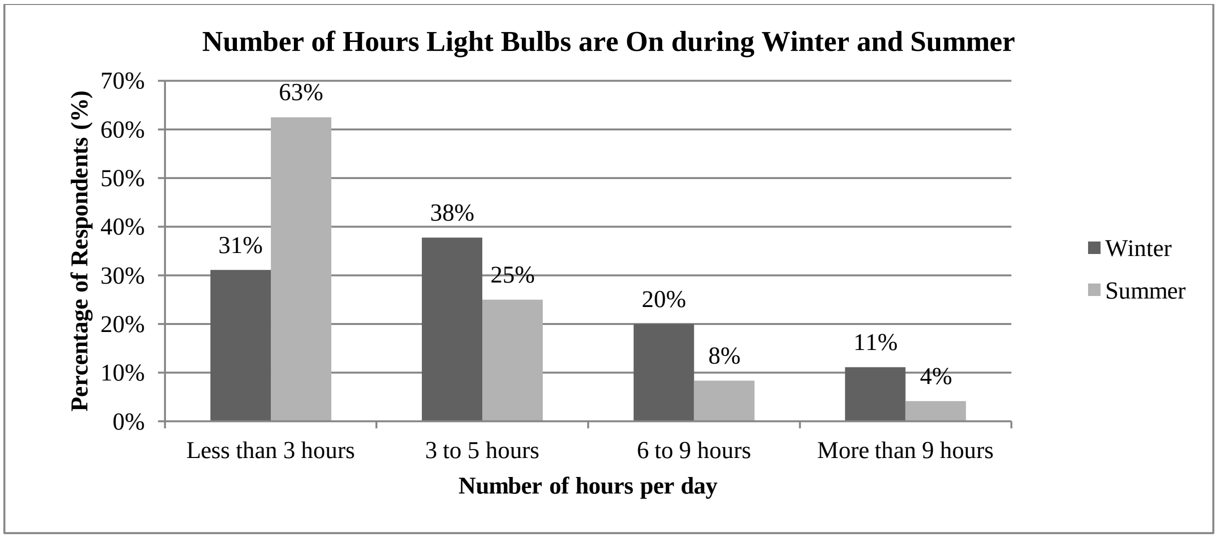



**Figure 6.3: Number of hours light bulbs are on during the winter/summer seasons**

### 6.3.7 Water Usage

- The average number of flushes per day is 4.2.
- 89.8% of the respondents prefer showering over bathing (10.2%).
- 49% of the respondents said that they run the tap while brushing their teeth, shaving, etc.
- 69.4% of the respondents leave the sink/tap running while washing the dishes.
- 55% of the respondents shower/bathe once a day.

### 6.3.8 Household Activities

- 67% of the respondents use their stove one hour or less per day.
- 47% of the respondents do not use their oven.
- 45% of the respondents use their oven one hour or less per day.
- 57% of the respondents do not use a microwave.

### 6.3.9 Indoor Environment Satisfaction and Thermal Comfort

The following chart below summarizes the survey of respondent's indoor environment satisfaction and thermal comfort (Table 6.2):

**Table 6.2: Average indoor environment satisfaction and thermal comfort survey respondent scores**

| | **Average respondent score (1 being very satisfied or enhances; 7 being very dissatisfied or interferes)** |
|---|---|
| Amount of space available for individual daily activities? | 3.52 |
| Apartment unit layout? | 2.90 |
| Quality of water in your apartment? | 2.23 |
| 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 |
| Overall, does your thermal comfort in the apartment during the summer enhance or interfere with your comfort? | 3.65 |
| The temperature of your apartment unit during the winter? | 2.82 |
| Overall, does your thermal comfort in the apartment during the winter enhance or interfere with your comfort? | 2.82 |
| The temperature of your apartment unit during the spring/fall? | 2.67 |
| Overall, does your thermal comfort in the apartment during the spring/fall enhance or interfere with your comfort? | 2.67 |
| The air quality in your apartment (e.g., stuffy/stale air, odours, cleanliness, etc.)? | 3.33 |
| Overall, does your air quality in the apartment enhance or interfere with your comfort? | 3.04 |
| The sound privacy between apartments? | 2.84 |
| Overall, does your acoustic quality in the apartment enhance or interfere with your comfort? | 2.63 |
| How satisfied are you with the building upgrade? | 2.53 |

- Some concerns about indoor environment satisfaction and thermal comfort are the following:
    - The windows are too small.
    - No air circulation within their apartment units.
- 24% of the respondents were not living in the Toronto MURB during the building upgrade.
- Strong correlation between temperature satisfaction and enhancement of their thermal comfort, see Appendix F. The correlation analyses found relationships between indoor environment satisfaction and thermal comfort. Six relationships were found statistically significant at the $p < 0.01$ (two-tailed):
    - Satisfaction for apartment unit layout and amount of space for daily activities ($r=0.772$, $p<0.01$).
    - Satisfaction for maintenance and cleanliness of building ($r=0.747$, $p < 0.01$)
    - Dissatisfaction for apartment unit temperature during the summer and how it enhances their thermal comfort ($r=0.86$, $p<0.01$)
    - Satisfaction for apartment unit temperature during the winter and how it enhances their thermal comfort ($r=0.759$, $p<0.01$)
    - Satisfaction for apartment unit temperature during the spring and fall and how it enhanced their thermal comfort ($r=0.933$, $p<0.01$)
    - Satisfaction for the air quality within their apartment and how it enhances their thermal comfort ($r=0.81$, $p<0.01$)

### 6.3.10 Your Neighbourhood

- 14% of the respondents had said that they had an outstanding sense of belonging within their local neighbourhood.
- 16% of the respondents had said they had a very strong sense of belonging.
- 22% of the respondents had said they had a somewhat strong sense of belonging.
- Respondents had positive comments about living in the Toronto MURB. Some positive comments referred to their safety, location, and comfortable living conditions.
- Some areas of concerns about living in the Toronto MURB related to summer conditions, air circulation, windows, and the retrofits that been done over the past years.

Overall, the respondents felt that the Toronto MURB had changed their life by giving them a sense of security and privacy. In addition, the Toronto MURB also changed their life by having affordable housing (finances).

Appendix G presents the survey results with respect to four occupant predictors: gender, age, income and hours per day. Some highlights in Appendix G include:

- All female respondents are of a low-income household (less than $29,999).
- Almost 71% of the respondents who do not own a computer are over 30 years old.
- Overall, high income households spend less hours per day in their apartment unit compared to low income households.
- Overall, a majority of the respondents are satisfied with their appliances, cleanliness, and maintenance of their apartment unit and building.

For more survey highlights, see Appendix G.

# Chapter 7 ANN Results

## 7.1 Overview

Chapter 7 presents the impacts of demographics on household energy consumption in the Toronto MURB. The model, developed in Chapter 5, was used to compare monthly energy consumption profiles for each of the following: gender, age, income, orientation, residency, geographical area grew up in, and number of hours spent in apartment unit. In order to evaluate the effects of household demographics, selected household characteristics were obtained. These characteristics were presented in Chapter 5.7.

It is crucial to note that the results of this chapter was discovered using the ANN model developed in Chapter 5. It is important to emphasize that the ANN model represents the 48 respondents living in the Toronto MURB during a twenty-four month period. The best network found is using the Quick Propagation training algorithm with 151 iterations and an overall $R^2$ of 0.895. On average, the energy consumption for the selected household characteristics was 171 kWh/month. In addition, when comparing the ANN model predictions and actual energy consumption, it was found to have a percent error of 0.37%. Table 7.1 displays the average household monthly energy consumption in the Toronto MURB.

**Table 7.1: Selected household's energy consumption (kWh) from October 2010 to September 2012 from querying the ANN model**

| Year | Month | Household's energy consumption (kWh) |
|---|---|---|
| 2010 | October | 159 |
| | November | 159 |
| | December | 206 |
| 2011 | January | 227 |
| | February | 215 |
| | March | 194 |
| | April | 165 |
| | May | 163 |
| | June | 175 |
| | July | 173 |
| | August | 161 |
| | September | 155 |
| | October | 162 |
| | November | 158 |
| | December | 205 |
| 2012 | January | 183 |
| | February | 187 |
| | March | 172 |
| | April | 173 |
| | May | 140 |
| | June | 140 |
| | July | 142 |
| | August | 141 |
| | September | 148 |
| **Average:** | | 171 |

## 7.2 Lower and Upper Bounds of Energy Behaviour Inputs

To test the reliability of the ANN model, the lower, selected household characteristics, and upper bounds of energy behaviour was compared. The lower bound means querying the model, where the occupants do not own or use any appliances or electrical devices. Inversely, the upper bound is when the occupant owns and uses a high amount of appliances and electrical devices. For example, the upper bound would mean that the occupant would have the highest electronic ratio, high energy behaviour score, own all appliances, use frequently, and so forth. Table 7.2

shows the data of querying between the lower and upper bound, and compared to the selected household characteristics presented in Chapter 5.7. Overall, the occupants with a higher upper bound consumed more energy; occupants with a lower bound consumed less.

**Table 7.2: Lower bound, selected, and upper bound household energy consumption**

| Year | Lower bound (kWh) | Selected Household Characteristics (kWh) | Upper bound (kWh) |
|---|---|---|---|
| 2011 | 105 | 179 | 214 |
| 2012 | 118 | 158 | 173 |
| **Average household energy consumption (kWh):** | **111** | **171** | **191** |

## 7.3 The Impact of Demographics on Household Energy Consumption

### 7.3.1 Gender

Figure 7.1 shows the energy consumption comparison between males and females obtained from ANN model. On average, males used more energy than females did during winter (December, January, and February). The mean difference is approximately 5 kWh/month above the female's consumption of 199 kWh/month during the winter season. During the summer season, however, males and females tend to have equivalent energy consumption patterns. Another energy consumption relationship found was that the monthly energy consumption runs parallel to the heating degree days[6] (HDD) and cooling degree days[7] (CDD). Table 7.3 shows the

[6] Heating degree day: Heating degree-days for a given day are the number of degrees Celsius that the mean temperature is below 18°C. If the temperature is equal to or greater than 18°C, then the number will be zero. (http://www.climate.weatheroffice.gc.ca)

[7] Cooling degree day: Cooling degree-days for a given day are the number of degrees Celsius that the mean temperature is above 18°C. If the temperature is equal to or less than 18°C, then the number will be zero. (http://www.climate.weatheroffice.gc.ca)

calculated mean difference and percentage difference between genders. A similar trend is found in Guerin *et al.* (2000), where males were found to consume more energy than females.

**Table 7.3: Calculated mean difference and percentage difference between genders**

| Year | Month | Female Energy Consumption | Male Energy Consumption | Difference (kWh/month) |
|---|---|---|---|---|
| 2010 | December | 201 | 206 | -5 |
| 2011 | January | 222 | 226 | -4 |
| 2011 | February | 209 | 215 | -6 |
| 2011 | December | 201 | 205 | -4 |
| 2012 | January | 177 | 182 | -5 |
| 2012 | February | 182 | 187 | -5 |
| | | Average: 199.1 | Average: 203.9 | |
| **Average difference between females and males (kWh):** | | | | -4.8 |
| **Percentage difference females from males (%):** | | | | -2.4 |

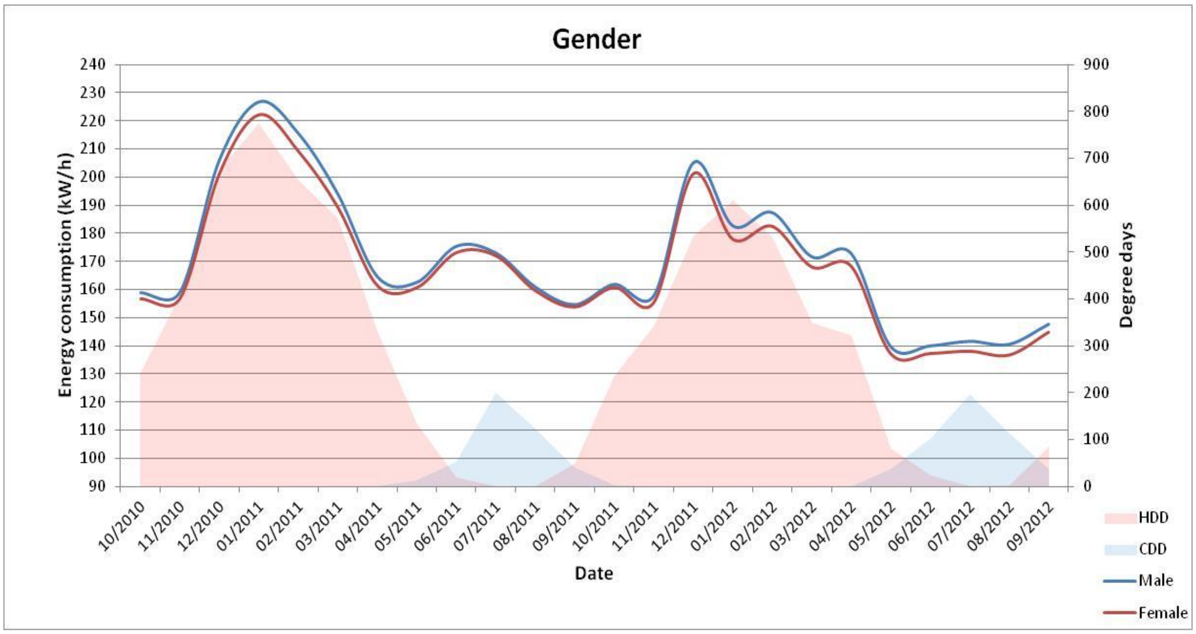



**Figure 7.1: Comparison of energy consumption between male and female surveyed respondents in the Toronto high-rise MURB**

### 7.3.2 Age

Since females consumed less energy than males did during the winter season, two different results were extracted by using the ANN model. First, a comparison between different male age group shows that middle-aged males (31 to 45 years old) use less energy than other male age groups - approximately 26 kWh/month (see Figure 7.2). Second, different female age groups were compared and it was found that middle-aged females (31 to 45 years) use less energy than the other age groups (Figure 7.3). Approximately 26.71 kWh/month compared to the average female. Figure 7.3 also illustrates that during the winter seasons, females over the age of 60 years use more energy than the average females did- approximately 10.96 kWh/month.

This result is valid because 33% of the respondents that are between the ages 31 and 45 years old spend 8 hours or less in their apartment unit per day. In addition, a majority of the middle-aged occupants spend 9 to 13 hours per day in their apartment; less time spent in their unit means less energy that is consumed.

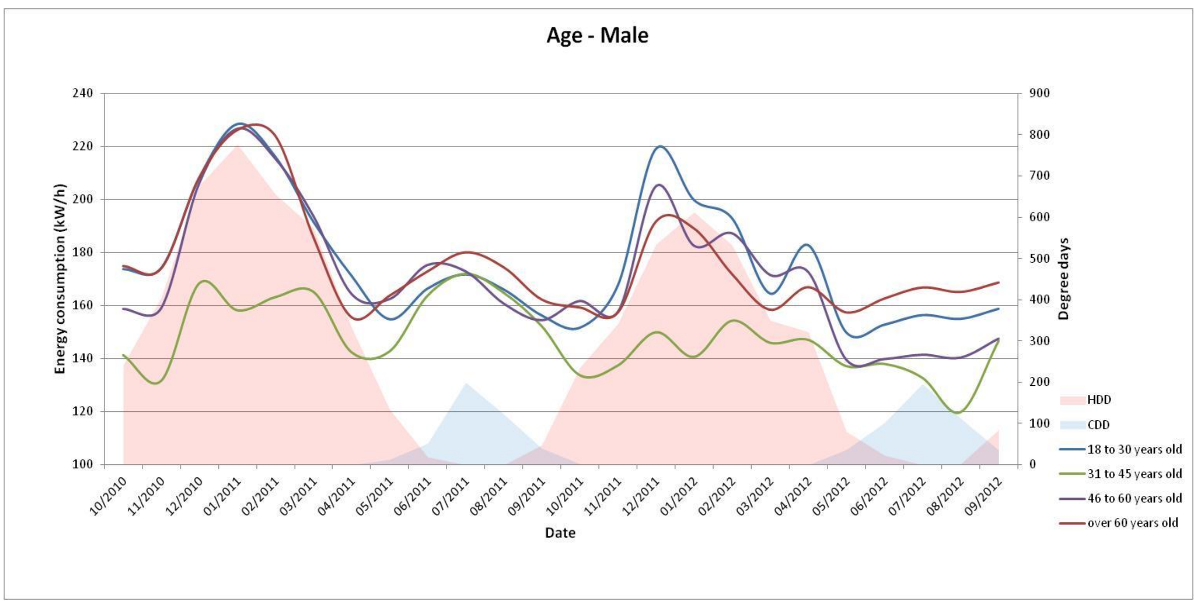



**Figure 7.2: Comparison of energy consumption between different male age groups**

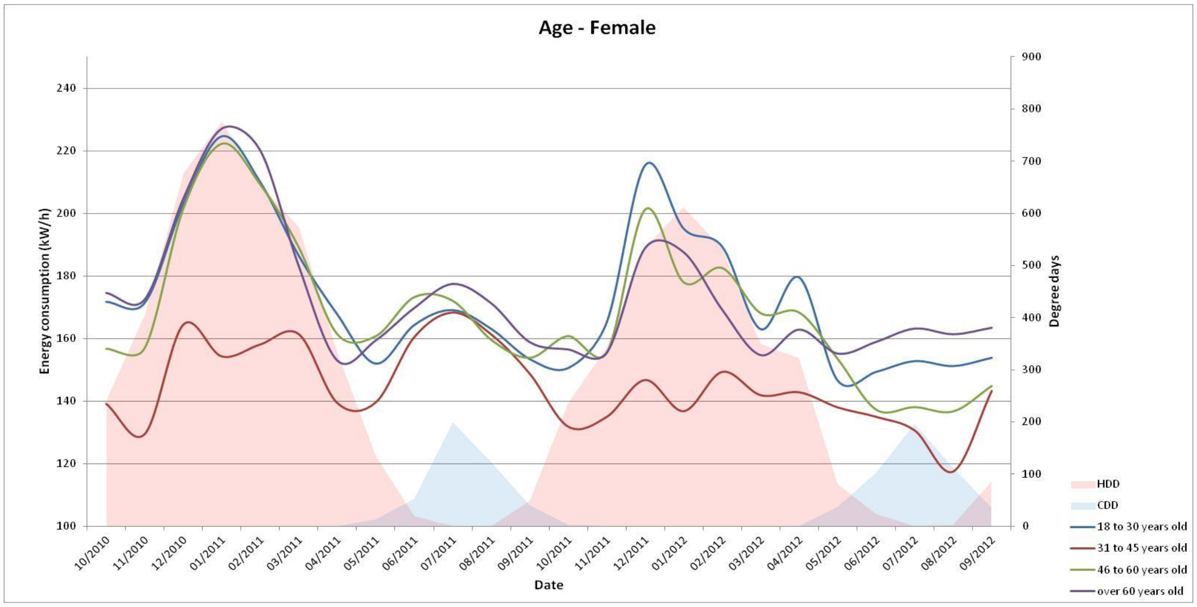



**Figure 7.3: Comparison of energy consumption between different female age groups**

It is worth noting that overall females between the ages 31 to 45 years old consumed, on average, 145 kWh/month; whereas, males between the ages of 31 to 45 years old consumed more than females between that age bracket (on average, 148 kWh/month).

### 7.3.3 Income

Figure 7.4 shows that households with the highest income ($30,000 to $49,999) consume about 18% less energy than the other income groups. The mean difference is approximately 25 kWh/month below the average of 165 kWh/month (average of the other income groups). This result is valid because a majority of the respondents (57% of the respondents) spend 9 to 13 hours per day in their apartment unit compared to other respondents spending over 13 hours.

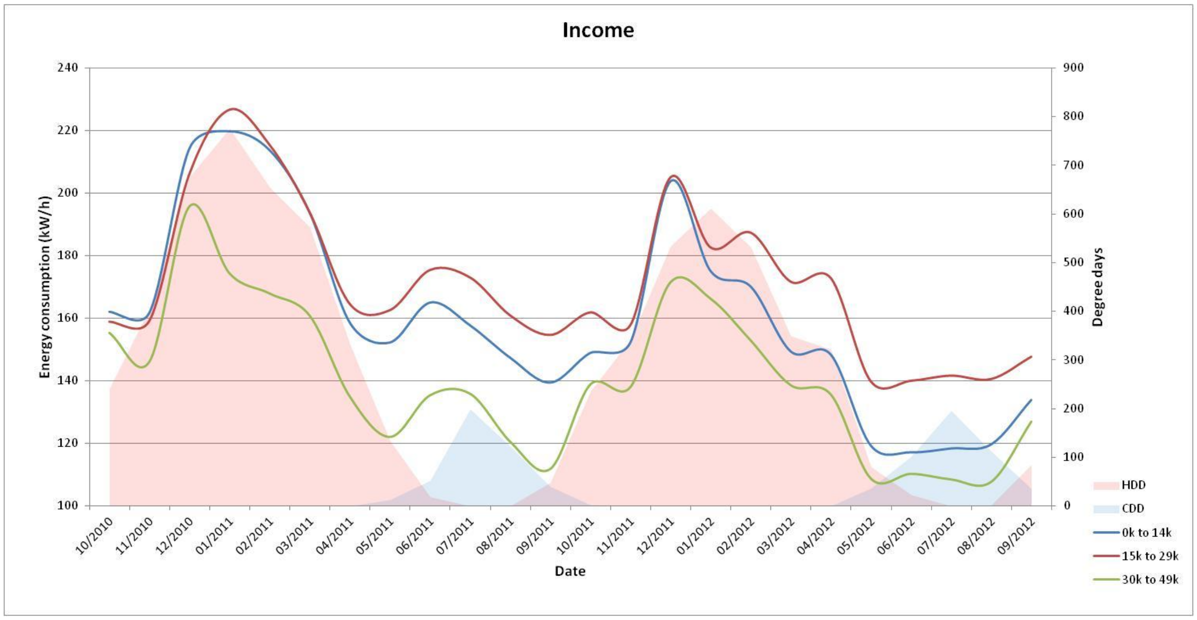



**Figure 7.4: Comparison of energy consumption between different incomes**

### 7.3.4 Orientation

Figure 7.5 shows that West side orientated units consumed less energy than the East orientated apartment units. On average, the West side consumed about 17% less energy than the East side. The mean difference is approximately 29 kWh/month below the East average of 171 kWh/month. Appendix C analyzes monthly mean energy consumption with respect to orientation. It is found that West oriented apartment units use less energy than the East. A similar trend is found using the ANN model (Figure 7.5).

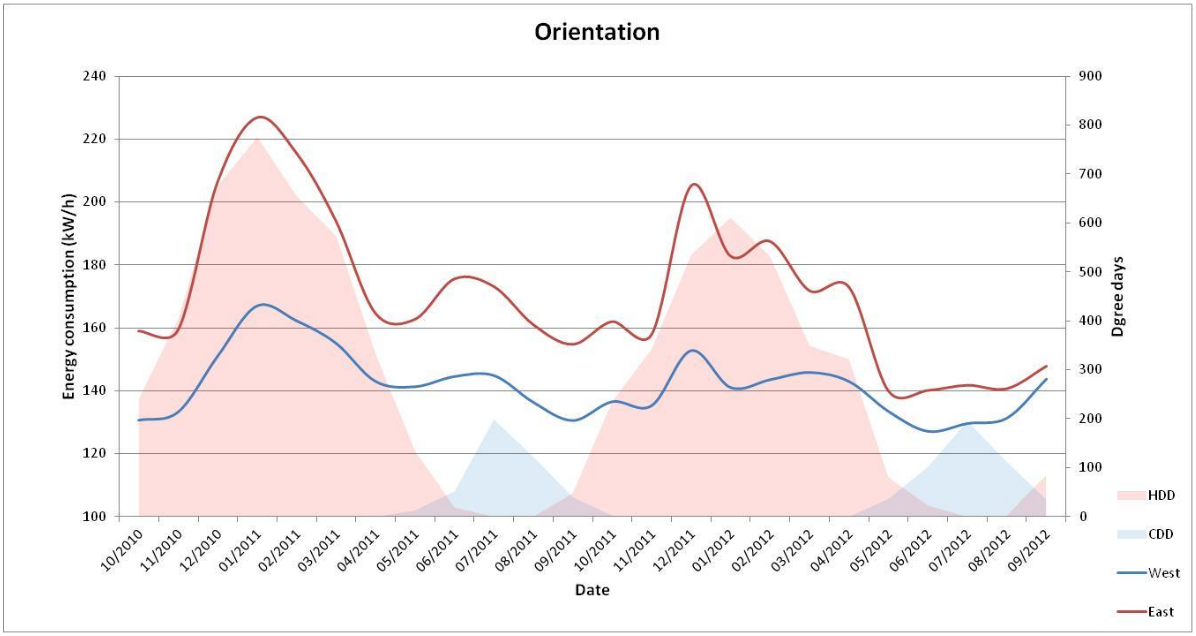



**Figure 7.5: Comparison of energy consumption between orientations (East or West)**

### 7.3.5 Residency (Number of years living in their apartment unit)

Figure 7.6 shows occupant's monthly household energy consumption did not vary as much as occupant's residency did. However, during recent months (June 2012 and onwards), newer occupants (0 to 1 year) consumed almost 4% less energy than the average of the other residency categories did. The mean difference of 6 kWh/month below the average of 145 kWh/month.

In recent months (June 2012 and onwards), older residency (more than 7 years) consumed about 3.7% more energy than the average of the other residency categories did. The mean difference of 5 kWh/month above the average of 142 kWh/month. These results are valid because newer occupants spend less time in their apartment unit than older residency occupants. Twenty-seven percent of older residency occupants are also found to spend more than 18 hours in their apartment unit. Fifty-five percent of older residency occupants were also found to be over 60 years old.

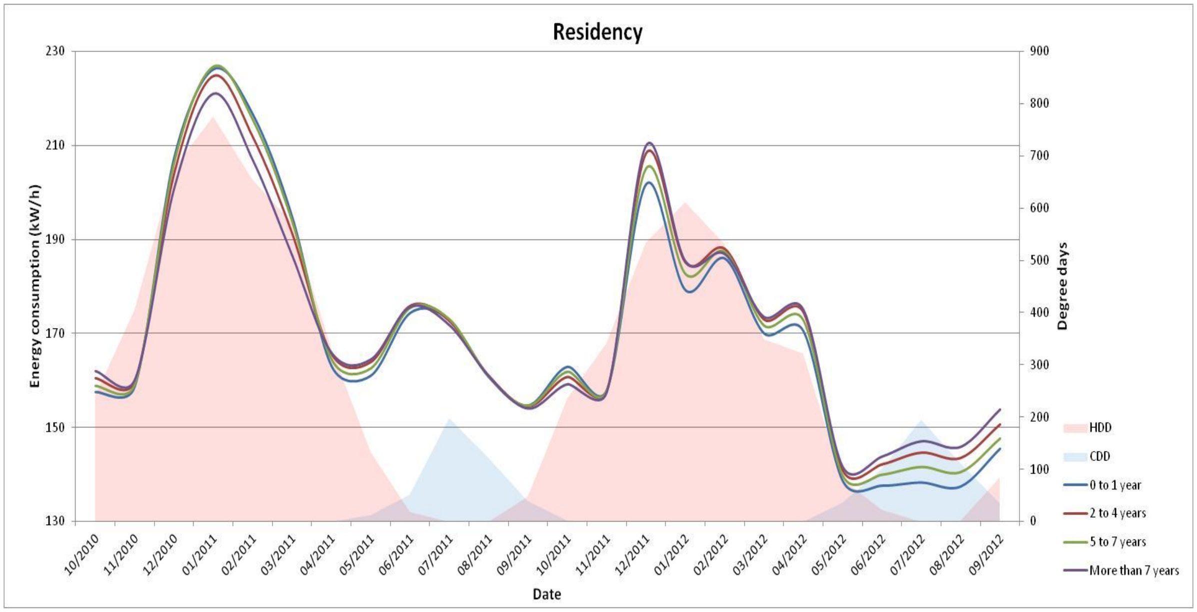



**Figure 7.6: Comparison of energy consumption between different residencies (years living in their unit)**

### 7.3.6 Geographical Area Occupant's Grew Up In

Figure 7.7 shows occupant's monthly household energy consumption based on the occupant's geographical area in which they grew up. Occupants who grew up in South and Central America consumed 21.6% less during winter months (e.g., December to February) than the average of the other geographically categories did. The mean difference is 38 kWh/month below the average of 216.5 kWh/month during the winter months. Occupants who grew up in Canada consumed 12.5% more energy during winter months than average of the other geographical categories did. The mean difference of 29 kWh/month above 203 kWh/month.

These results are valid because 33% of occupants that grew up in Canada spend more than 18 hours in their apartment unit. Whereas, South/central American occupants 50% spend 14 to 18 hours per day.

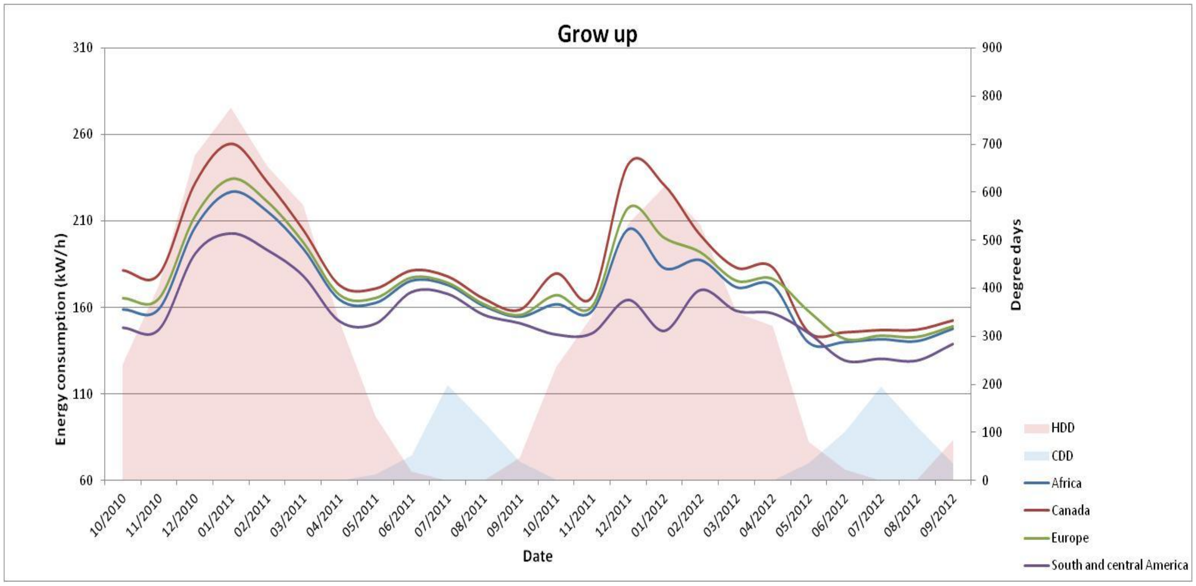



**Figure 7.7: Comparison of energy consumption between different countries grown up**

### 7.3.7 Number of hours spent in their apartment unit

Figure 7.8 shows occupant's monthly household energy consumption between the number of hours occupants spend per day in their apartment unit. Occupants who spend 9 to 13 hours per day in their apartment unit consume 2.7% less energy than the average of the other categories. The mean difference of 4 kWh/month less than the average of 175 kWh/month. The other categories are found to have similar consumption relationships throughout the 24 months. These results are valid because 86% of older occupants (over the age of 60 years) spend more than 18 hours or more in their apartment unit. In addition, 71% of the occupants that spend more than 18 hours or more have an income between $0 and $14,999.

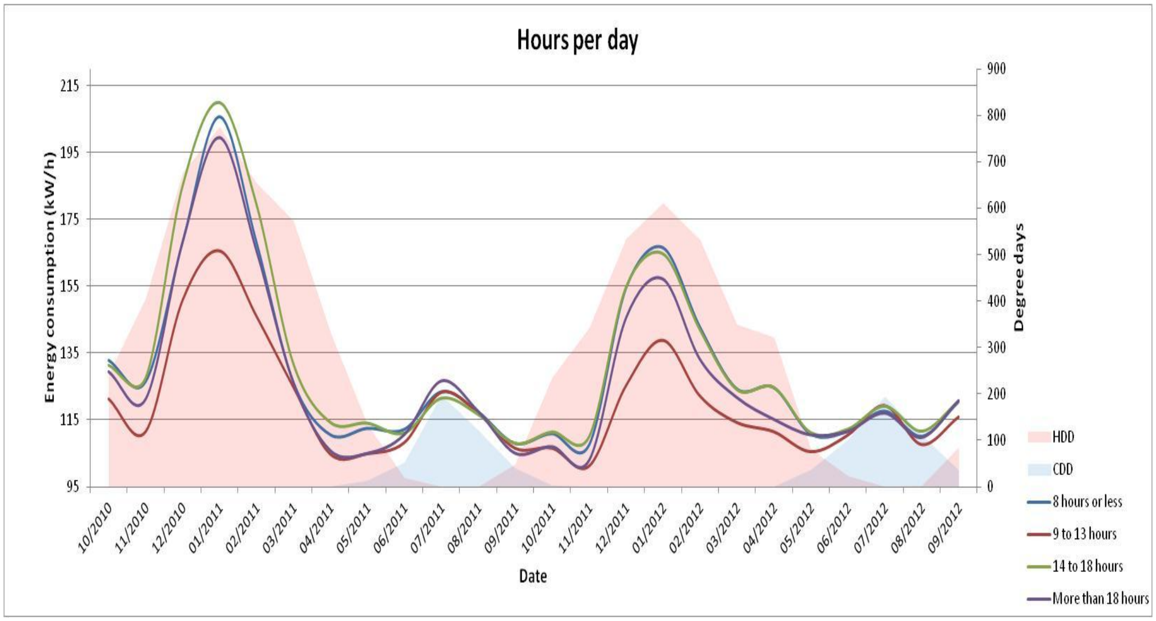



**Figure 7.8: Comparison of energy consumption between different hours spent in apartment**

## 7.4 Closing Remarks

This chapter evaluates the impact of demographics on occupant's household energy consumption in the Toronto multi-unit residential building by using the artificial neural network model. The model investigates occupant's energy consumption in relation to their gender, age, income, orientation, number of years living in the Toronto MURB, geographical area in which they grew up, and the number of hours spent in their apartment unit per day. The model examined these factors within a 24 month period from the first day of October 2010 to the last day of September 2012. It is interesting to note that occupant's household energy consumption follows the HDD and CDD weather conditions (see Figures 7.1-7.8).

Overall, males consumed slightly more energy per month than females. During winter months (December to February), males consumed a mean difference of 5 kWh per month over 199 kWh per month. However, middle-aged males (31 to 45 years old) consumed the least out of all the other age groups. Middle-aged males consumed approximately 26 kWh/month compared to the average of the other age groups. Similarly, the same relation was found from middle-aged females.

This ANN model also finds the following relationships:

- The highest income households ($30,000 to $49,999) consumed 18% less than the other incomes did.
- Eastern-oriented apartment units consumed more energy than Western-oriented units.
- There was no distinct relationship between the number of years living in the Toronto MURB and household energy consumption throughout the 24-month period. However, from June 2012 and onwards, occupants who reside more than 7 years in the Toronto MURB consumed almost 4% more energy than the other residency categories. Occupants, who recently lived in the Toronto MURB (0 to 1 year), consumed almost 4% less than the other residency categories.
- During the winter months (December to February), occupants who have grown up in Canada consumed 12.5% more energy than other geographical categories. Whereas, occupants who have grown up in South and Central American consumed 21.6% less during the winter months.
- Occupants who spent 9 to 13 hours in their apartment unit consumed 2.7% less energy compared to the other categories (Figure 7.8).

This chapter shows that the ANN model is able to predict the impact of demographics on household energy consumption in a Toronto multi-unit residential building. By using the ANN model, this chapter presents significant energy consumption relationships based on demographics. Neural networking is also able to estimate energy consumption based on other variables, which will be partially discussed in the following chapter.

# Chapter 8 Achieving Energy Conservation for Low-Income Renters in Toronto MURBs

## 8.1 Overview

In the previous chapters, the survey results and the impact of demographics on household energy use were presented. Evaluating occupant's household energy use has shown to have interrelated effects amongst various factors (e.g., demographics, orientation, number of hours spent in their apartment). On a larger-scale, occupant's energy use behaviour contributes significantly towards the total energy consumption within the residential sector. Thus, occupants conserving energy is an effective way to reduce energy consumption and its associated effects on the environment (e.g. GHG emissions and climate change; Aydinalp *et al.*, 2003). The purpose of this chapter is to present the barriers of achieving energy conservation for low-income households. In this thesis, all of the occupants in the Toronto MURB are low-income households and renters. One way of overcoming these barriers is by introducing tenant engagement strategies. Additionally, tenant engagement strategies will also be presented in explaining effects on occupant's energy behaviour and conserving energy.

## 8.2 Barriers of Low-Income Households in Achieving Energy Conservation

There are three main barriers that categorize the hindrances of achieving energy conservation in low-income renter households: a lack of information and knowledge of renters concerning energy consumption, relationship between renter and landlord, financial, and other potential barriers.

### 8.2.1 Knowledge and Information

Tenants who lack knowledge or are uninformed about residential energy conservation have shown to consume more energy than those tenants who can be considered more informed about energy consumption (Guerin *et al.*, 2000). However, people who do take energy-saving measures are generally aware of household energy use problems. Access to information and knowledge about tenant's household appliances and how much energy these appliances consume must be available in order to improve energy conservation.

Typically in rental housing units, major appliances are provided and landlords would likely invest in energy efficient technologies depending on whether tenants pay for utilities or not. If tenants do pay for utilities, then landlords are less inclined to invest; however, if tenants do not pay for utilities, then landlords are more inclined to invest in energy efficient technologies. As briefly mentioned before, despite the investment in these technologies in reducing energy consumption, it is the renter's behaviour or the intensity in which they use the technology. For example, landlords may provide all ENERGY STAR™ appliances but renters may leave the appliances on all day, such as leaving the lights, television or heating and cooling equipment turned on; thereby cancelling out the energy efficiency of the appliances. In Natural Resource Canada's Survey of Household Energy Use (SHEU) summary report 2007, the number of appliances per household and household energy use have increased from 1990 to 2008 (Natural Resources Canada, 2010). In today's world, energy efficient technologies are available everywhere, it is the matter of how often and for how long residents use them.

There are informational barriers when a landlord provides energy efficient technologies. First, tenants may not know whether technologies are efficient or not. They may think that the larger the appliance, the more energy it uses. Second, renters may not know what energy efficient means or how they not know whether they are conserving energy or wasting it, with little knowledge of how to track or measure their use. Lastly, if renters do try to carry out energy efficient behaviour, they may not know whether they are conserving a significant amount. Therefore, providing information and awareness of energy efficiency will help foster a better energy conserving behaviour.

## 8.3 Renter-Landlord Relationship

While low income renters are a diverse group, when it comes to energy consumption and conservation they share two inherent characteristics. First, low-income households are financially restricted investing in energy efficient appliances or improvements. Second, monthly rental costs, sometimes, includes utilities such as electricity and natural gas. The following four scenarios explain the renter-landlord relationship barriers in achieving energy conservation. This is also referred to as the 'agency problem' (Table 8.1) that is based on a report by American Council for an Energy-Efficient Economy (ACEEE, 2007).

Table 8.1 shows four scenarios to the renter-landlord relationship in achieving energy conservation are (Maruejols & Young, 2011; Levinson & Niemann, 2006).

**Table 8.1: "Agency Problem" - four scenarios illustrating the renter-landlord relationship**

| | **Renter selects technology** | **Landlord selects technology** |
|---|---|---|
| **Renter pays for utilities** | Scenario #1: No Principle-Agent Problem<br>Renters are responsible for their own energy use | Scenario #2: An Efficiency Problem |
| **Landlord pays for utilities** | Scenario #3: A Usage and Efficiency Problem | Scenario #4: A Usage Problem |

***Scenario #1: Renter pays for utilities, and renter selects the technology (Maruejols & Young, 2011).*** This case is referred to as the "no principal-agent problem" and also "responsible for their own behaviour" because renters are accountable for how much energy they consume.

Utilities refer to any energy commodity such as electricity and gas. Technology refers to major appliances, electrical devices, heating and cooling equipment; any service within their housing unit that needs energy.

***Scenario #2: Renter pays for utilities, and landlords select technology.*** This case is referred to as "an efficiency problem" because if renters pay for their utilities, landlords do not see any benefit investing in energy efficient technologies. In some cases, where they do decide to invest in energy efficient technologies to lower their utility costs, it may not be as beneficial to them as the payback period of purchasing the technology could be for a number of years, for example, and they only reside in the rental unit for one year. The payback period is the elapsed time in which the accumulated energy savings from the technology or services throughout time offset the initial investment cost.

***Scenario #3: Landlord pays for utilities, and renters select technology (Maruejols & Young, 2011).*** This situation occurs when renters select their technologies (appliances) and they do not pay for utility costs, it is included within the monthly rent. Low-income renters would shy away from large "upfront" costs in order to be energy efficient, such as purchasing ENERGY STAR™ major appliances, because they don't have to pay for utilities. Although this is not a common case, it does occur in owned condominiums. Renters would not see any benefit investing in energy efficient technologies nor would they care for the intensity level in which they use these technologies.

***Scenario #4: Landlord pays for utilities, and landlord selects technology (Maruejols & Young, 2011).*** Landlords may provide major appliances such as refrigerator and stove-tops in their units. In this case, the landlord has the ability to invest in energy efficient technologies. There is a possible "usage" problem. Despite using energy efficient technologies, renters decide on the intensity of the energy-using technology. Since the utilities are included in the monthly rent, in case 3 and 4, renters tend to be unreserved in their behaviour and therefore tend to consume more energy. This also includes events where appliances or technologies require maintenance; renters are not as willing to report them to the landlord. Similarly, renters would not be as willing to make energy efficiency improvements within their units or even invest money into these technologies.

The selection of energy efficient technology and responsibility of utility costs are not the only factors that influence the renter-landlord relationship. Williams (2008) explains that vacancy rates is also another factor. For instance, if there is a low vacancy rate, landlords may increase monthly rental costs due to the market demand. Landlords would invest less in energy efficient improvements due to the high demand in units and easy replacement (Williams, 2008). Inversely, if the vacancy rate is high, then landlords may decrease monthly rental costs or become highly competitive with other residences by investing in energy efficient technologies.

Ultimately, the renter-landlord relationship is quite complex, especially with the addition of another dimension of low-income renters and energy conservation. Landlords are faced with difficult situations when deciding whether to invest in energy efficient technologies or implement strategies which change occupant's energy behaviour. Low-income renters, on the other hand, especially renters who do not pay for utilities, may vaguely have an idea of the costs associated with their energy consuming behaviour.

## 8.4 Financial Barriers

With the financial constraints of low-income households, it is difficult for these households to invest in energy efficient technologies or services. An investment in these technologies and services requires a large up-front cost, which low-income households would compromise their finances on other essentials such as food, clothes, and education (Baxter, 1998). Similarly, landlords arrive at the same dilemma. In some cases, where large up-front costs are non-existent and landlords invest in energy efficiency, landlords then question themselves whether their investment actually achieves the expected energy savings and makes up for their investment during the expected future payback period. First, investing in energy efficiency technologies or services does not imply that the household will be energy efficient. Laquarta (1992) states that institutional barriers affect renter's household energy use, despite the energy efficient building improvements. In the scenario where energy costs are covered by landlords, the expected efficiency of the technology or service will not be as effective. Secondly, the payback period is always a consideration when investing for landlords. Laquarta (1992) identifies a shorter payback period is more desirable; however, it may not necessarily be the best. This is because there are no considerations given to any savings after the payback period and capitalization effects.

The barriers that exist that impede low-income renters from conserving energy. Policies, programs, services and other strategies have been set in place to address and overcome these issues. For instance, split-incentives are a way of dividing the cost of energy efficiency improvements between the renter and landlords. Weatherization programs such as energy audits and education programs have been set out to assess renter's household energy use. Ontario Energy Board's Low-Income Energy Assistance Program (LEAP) is a program that manages low-income Ontarians electricity and natural gas bills (Stewart, Fry, & Alliance, 2006). These are only a few examples and will be further addressed in a later section of this thesis.

## 8.5 Tenant Engagement Strategies

This section discusses how to overcome these barriers and achieve energy conservation through various tenant engagement strategies. There have been many studies conducted to examine tenant engagement strategies. In addition, there have been many publications that reviewed these strategies. This section updates previous publications that have already reviewed energy conservation strategies aimed at household energy use (Abrahamse *et al.*, 2005; Cook and Berrenberg, 1981; Ehrhardt-Martinez *et al.*, 2010; and Fischer, 2008). This review includes organization reports (e.g., utility companies and NGOs), media (e.g., Internet articles), as well as strategies that were implemented from 1983 to 2012. Various journals were consulted such as Environmental Psychology and Energy. A majority of the studies referenced are field experiments; others were NGOs and government initiatives.

Studies selected for this review needed to have measured effects of the tenant engagement strategy - quantified reduction in energy consumption. Only one study, the WiRE project, measured the behavioural effects of the tenant engagement strategy (LIEN, 2011). Classifications of these interventions for this review are similarly presented in Jacobson *et al.* (2006) book - *Conservation Education and Outreach Techniques*. Classifications presented include networking, marketing, informational, and technological interventions. At the end of this section, a summary table of studies and reports of interventions are presented (Table 8.4).

### 8.5.1 Networking Interventions

Building relationships and alliances to promote conservation such as environmental groups, workshops, seminars, and presentations[8] are effective ways of reducing energy consumption. Networking can create a synergy between groups and allows individuals to become creative and productive. Staats *et al.* (2004) have created an Eco-team program, where households promote

[8] Jacobson *et al.* (2006) - pp. 250-255

energy conservation by ways of distributing information, and providing participants with individual and comparative feedback. The concept behind this is to empower and allow residents to advocate for energy conservation. The authors found that implementing an Eco-team can potentially achieve 20.5% gas savings, 4.6% in electricity savings, 2.8% in water savings and 32.1% in waste savings (Staats *et al.*, 2004). Similarly, two Canadian initiatives, Globe's Community Champions and the Brahms Energy Saving Team (BEST) animators, both involve having tenants lead and instruct other tenants on conservation (Toronto Environmental Alliance, 2008).

The Community Champion Program educates and trains residents to become actively involved within their own communities. The program's 'community champions' receive training, information, and the resources to promote conservation, resident comfort, and create positive outcomes on the environment. The program is most effective in a team approach, when there is a group of simultaneously striving community champions. This approach is very similar to Brahms Energy Saving Team (BEST) program in Toronto. Energy conservation measures for 850 residential units in 11 social housing properties were implemented using the Community Champion Program, which resulted in a 1,331 kW reduction in energy consumption in these buildings.

The result of this BEST project was a tenant participation rate of 80% and tenant-led programs. An annual energy savings of 226,928 kWh was achieved, which is a 6.6% reduction in energy consumption. Workshops, on the other hand, are organized gatherings where tenants increase their knowledge and become informed about an issue. Workshops are also very similar to seminars or public presentations, in that they present information to influence behaviour and attitudes (Jacobson *et al.*, 2006)[9]. The gathering of the tenants can range from small to large groups allowing tenants to exchange ideas and discuss about the featured topic (energy conservation). In a study by Geller (1981), workshops increased knowledge, attitude, and intention of pro-environmental behaviour regarding energy conservation. In addition, the workshops increased the perception of the energy crisis and awareness of a household lifestyle on energy consumption.

### 8.5.2 Marketing Interventions

Marketing interventions providing programs/techniques in order to communicate and understand tenant's motivations and perceptions on energy saving issues. It also incorporates social marketing that acknowledges perceptions and barriers to effectively change energy consumption behaviour. Examples of these strategies are commitment, social norms, and feedback.

Commitment entails tenants agreeing to conserve energy; this often alters the way tenants perceive themselves. Commitments can be in the form of written, verbal, private, and public commitments. According to the Self-Perception Theory, "...if we can provide opportunities for people to engage in sustainable behaviours, the very act of engaging will shape their attitudes" (McKenzie-Mohr, 2011)[10]. Pallack and Cummings (1976) have identified that private commitment is more effective than public commitments. In addition, verbal commitments are more effective that written commitments (Katzev & Johnson, 1983). However, Katzev & Johnson (1983) and Pallack and Cummings (1976) suggest that in order for commitment to be effective it must be coupled with other strategies. McCalley and Midden (2002) tested the effectiveness of combining feedback and goal setting to 100 residents. They found that self-set

[9] Jacobson *et al.* (2006) - pp.256-263
[10] McKenzie-Mohr (2011) - pp. 45-60

goals and feedback save more energy (21.9%) than those who are assigned a goal (19.5% energy savings).

Social norms are behavioural expectations that are sought to be acceptable in society; in this case, environmental behaviour. There are two types of norms (Jacobson *et al*., 2006)[11], injunctive and descriptive norms. Injunctive provides information on what behaviours are acceptable and unacceptable. Whereas, descriptive norms indicate which behaviours individuals should engage in. Allcott (2011) tests social norms and their effects on electricity use on 600,000 households for 12 months. The study found that the change in social norms reduced electricity consumption by 2%.

Feedback monitoring is informing oneself of their energy consumption. This involves tenants using an energy monitoring mechanism that calculates their energy consumption for a period of time. These feedback devices are so familiar in today's world that many studies have investigated the effect of feedback monitoring on household energy consumption. Furthermore, there are many types of feedback monitoring. Ehrhardt-Martinez *et al.* (2010) created a comprehensive review of feedback studies in nine countries, including Canada. Based on 36 feedback-related studies between 1995 and 2010, Ehrhardt-Martinez *et al.* (2010) found that the average annual household electricity savings could range from 3.8% to 12.0%. Table 8.2 gives a summary of Ehrhardt-Martinez *et al.* (2010) comprehensive review of different feedback types and average household electricity savings.

[11] Jacobson *et al.* (2006) - pp. 63-65

**Table 8.2: Ehrhardt-Martinez *et al.* (2010) summary of feedbacks effect on household electricity consumption based on 36 studies**

| Feedback Type | Indirect/Direct Feedback? | Description | Annual Percent Savings |
|---|---|---|---|
| Enhanced Billing | Indirect Feedback - provided after consumption | Household information and advice | 3.8% |
| Estimated | Indirect Feedback | Web-based tools | 6.8% |
| Daily/weekly | Indirect Feedback | Household information and advice | 8.4% |
| Real-Time | Direct Feedback - provided real time | Real-time information to household consumption | 9.2% |
| Real-Time Plus | Direct feedback | Real-time information and consumption down to appliances and devices | 12.0% |

In a recent study by Gronhoj and Thorgersen (2011), a LCD feedback monitor was tested with 20 households for a period of five months (see Table 8.4). On average, they found that the potential energy savings with the direct feedback is 8.1%. It is also important to note that the LCD monitoring system empowered the tenants to lower their energy consumption, especially households with teenage children.

Faruqui *et al.* (2010) conducted a review of continuous feedback through In-Home Displays (IHDs) and found that on average IHDs could reduce electricity consumption of about 7%. IHDs provide direct feedback to the household, informing them of their cost and energy consumption. Farqui *et al.* (2010), Mountain (2006), and Mountain (2010) have identified four Canadian IHDs monitoring feedback programs, listed below, that are all utility company-led programs.

**Table 8.3: In-Home Display (IHD) feedback monitoring pilot programs in Canada (Farqui *et al.*, 2010)**

| Pilot programs | Feedback Type | Number of customers | Energy conservation impact |
|---|---|---|---|
| Hydro One real-time feedback pilot | IHD | 382 - test<br>42- control group | 6.5% |
| BC Hydro and Newfoundland power pilot | IHD | 200 | 2.7% |
| Woodstocks Hydro's Pay as you go | IHD plus prepay for electricity use | 2500 | 15% |
| Hydro One time-of-use pilot | IHD plus varying time of use rates | 234 - Test<br>150 - control group | 6.7 to 7.6% |

Siero *et al.* (1996) found that comparative feedback could change behaviours and energy consumption but hardly changed the participant's attitudes and intention to reduce energy consumption. Another finding was that receiving feedback of others' consumption is more effective than receiving one's own consumption information. Similarly, Alahmad *et al.* (2012) found that feedback monitoring is an effective way to inform, exhibit change in behaviour, and foster awareness within a short timeframe, 30 days.

Incentives and disincentives are another intervention that have been shown to be effective. An incentive is implemented by rewarding individuals who adhere to the behaviour. Disincentives, on the other hand, is the opposite approach - individuals are fined or punished. Midden *et al.* (1983) incorporated a monetary reward and other interventions to encourage reduce consumption.

### 8.5.3 Informational Interventions

Informational interventions involve sending out a specific message to occupants on environmental issues such as posters, brochures, signs, and giveaways (e.g., magnets and stickers). Informational tools include either providing information to increase knowledge on energy-related issues (e.g., energy crises, oil prices, or global warming) or providing information to show behavioural options to deal with the energy-related issues (e.g., turning off their lights, purchasing energy efficient appliances, etc.) (Jacobson *et al.*, 2006)[12]. Studies have shown that informational tools reduce energy consumption (Kurz *et al.*, 2005; Abrahamse *et al.*, 2007; Midden, 1983). For example, Kurz *et al.* (2005) found that informational leaflets and brochures significantly reduced tenant's water consumption by 23% as well.

An informational campaign held in Toronto called Walpole is Reducing Energy (WiRE) provided 85 households with educational brochures and flyers, which resulted in 90% of the tenants reportedly learning about and reducing energy consumption (LIEN, 2011). Similarly, McMakin *et al.* (2002) carried out a similar approach and found that tailored information could reduce energy consumption by 10% using campaign messages, themes, visuals, and focus groups. Informational interventions, however, are only found effective if combined with other strategies such as goal setting or feedback (Abrahamse *et al.*, 2007). In addition, these informational tools must be tailored to target specific behaviours to the households.

### 8.5.4 Technological Interventions

Technological interventions such as radio, television, and the Internet are also effective and efficient ways to reduce energy consumption. Staats *et al.* (1996) tested the effectiveness of a mass media campaign using national television, national newspapers, and billboards to increase households to perform environmental behaviours. After two months, the study found that

[12] pp. 63-70

households were more willing to perform environmental behaviours. Staats *et al.* (1996), however, were not able to quantify the energy savings from the campaign; they only accounted for knowledge, attitude and behavioural (qualitative) variables.

Web-based tools were tested in a study conducted by Benders *et al.* (2006). The study targeted 190 households for four months, where the web-based tool allowed the households to calculate their energy consumption through their daily activities (e.g., driving their car, shortening shower time, etc.). The study had found direct energy reduction of 8.5% compared to the control group.

## 8.6 Tenant Engagement Strategies: Discussion and Conclusion

Creating environmental groups and tenant-led programs have been effective. The BEST project in Toronto and Staats *et al.* (2004) are good examples of networking interventions that encourage reductions in energy consumption. It is also important to note the long-term effects of these interventions. The BEST program showed reductions of 6.6% at the end of the year. Long-term effects are crucial, as the intervention may slowly lose its effect after it has been implemented; Staats *et al.* (2004) shows a reduction in energy consumption after two years.

Feedback is also an effective intervention to encourage energy reductions. Real-time feedback has been shown to have the most effective type, especially when physically displayed to the individual (Ehrhardt-Martinez *et al.*, 2010). In addition, comparative feedback has shown to be not as effective as individual feedback (Brandon and Lewis, 1999).

Overall, informational interventions are not effective. However, combinations of interventions plus information interventions are more effective (Abrahamse *et al.*, 2005). Technological interventions have evolved from informational techniques and have truly revolutionized energy conservation education and awareness (Jacobson *et al.*, 2006). Technological interventions communicate more effectively to younger generations. As computers are more prevalent within households, web-based tools and Internet resources have shown to be an effective measure in educating and informing people about their energy consumption (Benders *et al.,* 2006).

Ultimately, the purpose of implementing tenant engagement strategies is to change the behaviours in order to reduce consumption. Behaviour, in the context of this thesis, means adopting energy efficient actions and manners within a household setting; such as turning off the light, unplugging appliances after use, purchasing energy efficient appliances, and more. Behaviour is the basis of an energy efficient house; residents ultimately choose how intensive and what type of equipment used. The Theory of Planned Behaviour (TPB) was developed in 1986 and introduced by Icek Ajzen (1991). The theory is an extension of the Theory of Reasoned Action (Jacobson *et al.*, 2006; Ajzen, 1991). Figure 8.1 illustrates the Theory of Planned Behaviour:

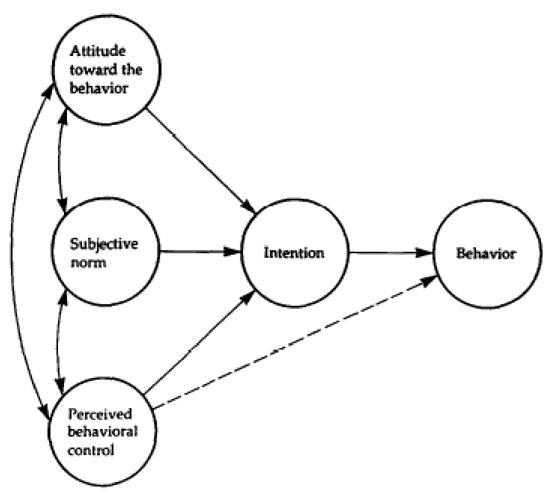



**Figure 8.1: Theory of Planned Behaviour (Ajzen, 1991)**

It is important to acknowledge this theory as it identifies key issues in conservation intervention studies aimed at household energy use. First, behaviours are influenced by various components such as attitudes, norms, and personality traits of a human. In addition, everyone is different in the type of behaviours they perform. Abrahamse *et al.* (2005) suggests that the evaluation of an intervention should be based on changes in the behavioural determinants and changes in the behaviour. Only a few studies have investigated the effects of interventions on behavioural determinants (Abrahanse *et al.*, 2007; Midden *et al.*, 1983). TPB suggests that studying attitude and personality traits is more effective in predicting behavioural aggregates rather than exhibiting specific behaviours (Ajzen, 1991).

Second, the theory explains that behaviour is linked to knowledge. If there is more knowledge on an issue, then behaviours in saving energy are more inclined to occur. Many interventions, as previously outlined, have shown to increase knowledge and positive attitude to reduce energy consumption. However, individuals learn or obtain knowledge in different ways. Therefore, many studies have combined interventions in order to accommodate individual receptivity to information and learning.

Although combined interventions have shown to reduce consumption significantly, one of the recurring problems in the literature is discerning the individual impact of an intervention (Abrahamse *et al.*, 2005). For example, incentives are effective tools to reduce a tenant's energy consumption. McClelland and Cook (1980) simultaneously combine three interventions (feedback, information, and reward) and found reductions in gas consumption (6.6%); however, they did not find impacts for individual interventions.

Thirdly, the TPB also distinguishes between 'actual behaviour' to individuals who are psychologically interested in doing the action. This means that individuals will/may perform a behaviour if they have the feeling they are being "experimented" on or pressured to do so. During the implementation of the intervention, individuals may perform the behaviour but once the intervention is removed, they would return back to their ‘old behaviour’. Another recurring problem in the literature is the intervention's long term effects on behaviour. Many studies have focused on short-term effects and have not attempted to conduct a follow up investigation of participants' behaviour and consumption use. In a review of interventions by Abrahamse *et al.* (2005), only a few studies have attempted to investigate the long-term effects. It is evident that the interventions did not have any significant impact on participant's long-term behaviour or consumption use.

Lastly, the TPB teaches us that human behaviour is a complex topic. The theory gives evidence and explains how behaviour is linked to one's beliefs, attitudes and norms. It does not, however, sculpt the exact form of behaviour. A stepping-stone to forming an understanding of behaviour is to identify the individual's needs and barriers to a certain action. In doing so, it will allow programmers and educators to formulate interventions tailored to one's needs. As a result, it will effectively overcome an individual's barriers compared to generic information or irrelevant tools. Kurz *et al.* (2005) and Abrahamse *et al.* (2007) are examples of tailoring information in order to successfully reduce energy consumption and change behaviours.

In conclusion, the intent of this review is to update previously published reviews and identify effective intervention measures for reducing energy consumption. Despite the very small sample size of this review, twenty studies were identified and correlated with similar trends to the other intervention reviews - Abrahamse *et al.*, 2005; Cook and Berrenberg (1981) ; Ehrhardt-Martinez *et al.* (2010); and Fischer (2008). Studies have shown the effectiveness of these interventions but have not addressed identifying the households'/individuals' needs or barriers to achieve energy consumption. In addition, only a few studies such as McClelland and Cook (1980) have investigated a multi-unit residential building environment.

Tenant engagement strategies can be implement in this Toronto MURB. However, the first step is to understand how occupants currently use their energy and motivating for them. This thesis provides an understanding of how 48 occupants use their energy. The next steps are to create a tenant engagement program that is tailored, led by occupants, and informative for occupants to achieve energy conservation.

**Table 8.4**: **Studies on Household energy conservation strategies; author/organization, intervention(s), targeted behaviours, number of people in the study, design, duration, and the effect (behaviourally and energy consumption)**

| Author(s)/ Organization | Intervention (s) | Target Behaviour | Number of households/participants | Design | Duration | Behavioural Changes and Other | Effect |
|---|---|---|---|---|---|---|---|
| Abrahamse *et al.* (2007) | 1.Tailored information,<br>2.Goal setting,<br>3.Tailored feedback | Energy-related behaviours (e.g. thermostat, water use, lighting use, heating/cooling use, appliance use) - website calculation tool | 1. 71<br>2. 66<br>Control: 53 | 1. Information, individual goal setting, and tailored individual feedback<br>2. Tailored information, individual goal setting, individual feedback, group goal and group feedback<br>Control: No interventions | 5 months | Individuals exposed to interventions have shown to have greater knowledge and change behaviours. | Experimental groups (Exp): reduced energy by 5.1%<br>1. Reduced by 5%<br>2. Reduced by 5.3%<br>Control groups used 0.7% more energy |
| Alamhad *et al.* (2012) | 1.Feedback (real-time monitoring)<br>In-home display (IHD)<br>Power Cost Monitors (PCM) | Electricity use | 151 | 1. 50 AZI<br>2. 50 AZII<br>3. 51 PCMs | 16 months | Surveys provided insight that residences have the desire to conserve energy because of the monitors. | Insignificant reduction of 12% in mean electrical consumption with PCM<br><br>No reduction in the mean consumption in homes using IHD |
| Allcott (2011) | Social norm comparison (Home Energy Report letters) | Electricity use | 600,000 households | Home Energy Reports (Social norm comparison)<br>It has two components:<br>1. Descriptive norm - comparing households to the mean of electricity use<br>2. Efficiency standard - injunctive norm by categorizing the household has "Great, Good, or below average". | 12 months | The social norm approach has shown to be cost-effective. The effect is equivalent to that of short-run electricity price increase of 11 to 20%.<br>Cost-effective compared to other programs. | On average, the program reduced electricity consumption by 2.0%. Households in the highest decile of consumption decrease their consumption by 6.3%; whereas, households in the lowest decile decrease their usage by 0.3%. |
| Benders *et al.* (2006) | Web-based tools | Energy consumption - natural gas, electricity and motor fuel | Total: 190 households | 1. Web-based tools<br>2. Control group | 4 months | In direct behavioural changes were not significant. However, top successful saving options were using different mode of transportation than the car, | 1. Direct energy reduction about 8.5% compared to the control group. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | shortening showering time, etc. | |
| Brahms Energy Saving Team (BEST) (Gorrie, 2008; TEA, 2008) | Energy saving team<br>1. Information<br>2. Tenant led (focus groups) - animators<br>3. Workshops (education program)<br>4. Energy saving kits | Electricity use | 2 rental apartment buildings (342 units) - over 800 tenants | 1. Energy saving team (tenant-led, animators) Items 1 to 4 (in intervention section) | 6 months | 75% participation rate. Tenants led the energy program and the money was reinvested back into the community. | Annual energy savings of 226,928 kWh ($25,000)<br>A 6.6% reduction in energy consumption. |
| Community Champion Program by Globe (Toronto, Ontario) (2011) | Community champion program<br>- Educates and trains residents to become actively involved in their community | Energy consumption (in general) - electricity, water, gas | 850 residential units in 11 social housing properties | 1. Community champion program empowering individuals to take the lead and empower other residents to save energy. | Varies | Not measured.<br>Weblink:<br>http://www.globeservices.ca/index.php/our-services/community-champion-program/;<br>http://www.globeservices.ca/index.php/globe-and-shsc-finalist-in-energy-conservation-at-2011-green-toronto-awards/ | Energy reduction of 1,331.51 kW |
| Gronhoj and Thorgersen (2011) | Feedback monitoring (with LCD monitor) | Electricity consumption | Total:<br>20 households | 1. Feedback monitoring<br>2. Control group | 5 months | Empowered the households to take action in lowering their energy consumption. Households with teenage children are more receptive to this type of feedback. | 1. On average, energy savings of 8.1%.<br>2. On average, energy savings of 0.8%. |
| Kurz *et al.* (2005) | 1. Information<br>2. Labels<br>3. Social comparative feedback | Water and Energy use (electricity and natural gas) | Total: 1667<br>1. 23<br>2. 21<br>3. 19<br>4. 18<br>5. 22<br>6. 19<br>7. 21<br>8. 23 | 1. Information<br>2. Information and labels<br>3. Information, labels, and social comparative feedback<br>4. Social comparative feedback<br>5. Labels<br>6. Labels and Social comparative feedback<br>7. Information and social comparative feedback<br>8. Control group | 14 weeks | Percentage of respondents indicating that the program cause behavioural change:<br>85.7% using less water in the garden; 68.8% not leaving the lights on; 62.3% reducing shower time; 55.8% not leaving the fridge door open; and more. | There were no significant effect of three-way interactions between the variables for either water or energy consumption. |
| McCalley and | 1. Feedback | Water | Total: 100 | 1. Feedback with no | 30 | Self-set participants saved more | 2. Energy savings of 21.9% |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Midden (2002) | 2. Goal setting (commitment) | consumption (laundry washing trials) | residents<br>1.25<br>2. 25<br>3. 25<br>4. 25 | goal manipulation<br>2. Feedback with self-set goal<br>3. Feedback with an experimenter assigned goal<br>4. Control group (no interventions) | minutes/ 20 washings | energy and more inclined to save energy than all the others. | 3. Energy savings of 19.5% (compared to the control) |
| McMakin et al (2002) | 1. Tailored information (Study 1)<br>2. Tailored information (Study 2) | 1. Gas and electricity (heating-related)<br>2. Electricity use (for cooling) | Total: 1406<br>1. 1231<br>2. 175 | 1. Information<br>2. Information<br>Tailored information - campaign messages, themes, visuals, interviews, and focus groups | 1. 1 year<br>2. 4 months | Not measured but discussed in literature review the link between knowledge, attitude and behaviour. | 1. Energy savings of 10% (compared to baseline)<br>2. No energy savings - used 2% more electricity compared to baseline. |
| Midden *et al.* (1983) | 1. Feedback<br>2. Information<br>3. Incentive (Reward) | Gas and electricity consumption | Total: 91 | 1. Individual feedback and information<br>2. Comparative feedback and information<br>3. Comparative feedback and information, and incentive (reward)<br>4. Information<br>5. Control: no interventions | 12 weeks | Attitude factors that are most important are those that cause people to feel guilty about their consumptions levels and where people blame the industry and government. | 1. Electricity 18.8%<br>Gas 18.4%<br>2. Electricity 18.4%<br>Gas 5.8%<br>3. Electricity 19.4%<br>Gas 17.5%<br>4. Electricity 7.6%<br>Gas 0%<br>5. Electricity 5.6%<br>Gas 11.6% |
| Mountain (2006) | 1. Real time feedback monitors | Electricity consumption | Total: 552<br>1. 500<br>2. 52 | 1. Real-time monitors<br>2. Control group | 2.5 years | 60.5% of the customers felt that the monitor made a difference in their home. 65.1% also planned to continue to use the monitor once the pilot was complete. | Overall, the average reduction in energy consumption across the whole sample was 6.5%. Non-electric heating household reduction in energy consumption of 8.2%. |
| Mountain (2010) | 1. Real-time feedback monitors | Electricity consumption | Total:<br>1. 180<br>2. 40 | 1. Real-time feedback (power) monitors<br>2. Control group | 15 months | Participants were very positive with the performance and usefulness of the real-time monitors.<br>86% said that the monitors were easy to use.<br>66% felt that that monitors made a difference in their electricity | During the summer months (July to August), there was a reduction of 3% for non-electric water heating participants and 16% for electric water heating participants.<br>For all electric participants |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | use.<br>63% said they would use the monitors even after the pilot was over. | (heating and water heating), the reduction was 2%. For the participants with non-electric heating and water heating resulted in a 2% reduction as well.<br>15% reduction is observed for electric water heating participants without electric heating. |
| Staats et al (1996) | Mass media campaign<br>1. Information | Knowledge, problem awareness, willingness to show ecologically sound behaviours | 704 | 1. Information National television, national newspaper, billboards. | >2 months (not really specified ) | Increase in willingness to perform environmental beahaviours. | Not measured - only knowledge, attitude and behavioural variables were measured. |
| Staats et al (2004) | Eco-Team<br>1. Information<br>2. Individual feedback<br>3. Comparative feedback | Garbage, gas, electricity, water, transportation and consumer behaviour (documentation) | 150<br>Note: No attempt to collect data from the control group after the Eco-team | 1. Eco-team (includes 1 to 3)<br>2. Control group | 8 months | Using another mode of transportation other than the car when travelling less than 5km away.<br>Increased pro-environmental behaviour. | Gas: savings of 20.5%<br>Electricity: savings of 4.6%<br>Water use: 2.8% savings<br>Waste: 32.1% savings |
| Walpole is Reducing Energy (WiRE) Program (LIEN, 2011) | Informational campaign (educational) | Energy consumption in general | 118 units | Information and education campaign | Not specified. | 70% participation rate (85 households).<br>90% of the tenants learned and saved energy; there was no energy consumption data, however, on how much energy was saved. | Not measured. |

# Chapter 9 Impact of the Survey on Household Energy Consumption using ANN

## 9.1 Overview

As discussed in Chapter 8, tenant engagement strategies have shown to affect occupant's energy behaviour and potentially reduce their consumption significantly. By the implementation of the survey, all occupants became aware and informed of the Ryerson University project on energy efficiency in Toronto MURBs. This may have increased occupant's knowledge or empowered occupants to conserve energy. This chapter investigates the possible impact on occupant's energy consumption due to the implementation of the survey in the Toronto MURB.

As mentioned in Chapter 3.5, the survey was conducted from April 16 to May 4. There was a month notification period prior to the survey. The month of April was used as a "buffer" period and was not used to compare energy consumption data. To measure the impact of the survey, two methods were used:

1. Comparison of the actual energy consumption before (May to September 2011) and after the survey (May to September 2012).
2. Creation of an ANN model before the survey. This model was referred to as the Before Survey (BS) model. This model includes energy consumption from October 2010 to March 2012, weather conditions, and survey data. This model then predicted the energy consumption from May to September 2012. Afterwards, the predicted values were compared with the actual energy consumption data. A similar approach in Chapter 5.

The second method, creation of the ANN model, was used to take into consideration of external parameters such as weather conditions, orientation of the apartment units, and so on.

ANN modeling has the ability to normalize all parameters. Table 9.1 illustrates the timeline of implementation of the survey and energy consumption data that was used for the model.

**Table 9.1: Timeline of the implementation of the survey and the start/end of energy consumption data for the model**

| Date | Activity |
|---|---|
| October 2010 | Start of Energy Consumption Data |
| April - May 2012 | Implementation of Survey<br><br>Buffer Period for Models - April 2012 |
| September 2012 | End of Energy Consumption Data |

## 9.2 Method #1: Comparison of Actual Energy Consumption

The first method used to compare the impact of the survey is the actual household energy consumption before and after the survey. This is done by examining months before the survey was conducted (May to September 2011) to the same months after the survey was conducted (May to September 2012). The comparison only used the 48 households that were surveyed. Table 9.2 shows the sub-metered energy consumption before and after the survey. The results indicated that the actual energy consumption dropped 8.3% after the survey was introduced.

**Table 9.2: Comparison of energy consumption data between May to September 2011 (before the survey) and May to September 2012 (after the survey)**

| | Total energy consumption before the Survey (2011) | Total energy consumption after the Survey (2012) |
|---|---|---|
| May | 6951 | 5540 |
| June | 6134 | 5691 |
| July | 6797 | 6691 |
| August | 6838 | 6272 |
| September | 6333 | 6103 |
| Sum of energy consumption: | 33054 | 30299 |
| Difference between before and after survey (kWh): | | - 2754 |
| Percentage difference: | | -8.3% |

## 9.3 Method #2: Before Survey (BS) Model

The intention of the second method was to create an ANN model before the survey and predict the energy consumption after the survey. The predicted energy consumption values were then compared to the actual energy consumptions after the survey. If the predicted energy consumption is less than the actual energy consumption, then this suggests that energy consumption has increased after the survey. However, if the predicted energy consumption forecasts more than the actual energy consumption, then this suggests that the energy consumption has decreased after the survey.

To measure the impact of the survey on household energy consumption, the following procedure was conducted:

1. Creating the Before Survey (BS) model (using date data from October 2010 to March 2012).
2. Using the BS model to predict energy consumption from May to September 2012.
3. Compare the predicted consumptions to the actual energy consumption from May to September 2012.
4. Calculate the percent difference between the predicted and actual energy consumption.

To develop the BS model, a similar approach was adopted from Chapter 5. The next section will describe the process in developing the BS model.

### 9.3.1 Development of the BS Model

***Development of the Network Datasets.*** The same inputs were used to create the network datasets - 48 surveys and 24 months of monthly energy consumption data. In addition, the same procedure and inputs in Chapter 5 were similarly applied to the development of the BS model. The only difference between the developed model in Chapter 5 and the BS model is the data collection period is October 2010 to March 2012 rather than October 2010 to September 2012. In this way, the BS model excludes the data during the implementation of the survey.

***Analysis and Preprocessing of the Network Datasets.*** Since the same inputs were used, the network data set consisted of a total of 24 categorical columns, 10 numeric columns, and one output column. During the preprocessing of the network dataset, all columns were scaled to numeric values between -1 and +1.

***Determination of Architecture Search and Activation Functions.*** Since the same inputs were used from Chapter 5.4, similar parameters were taken during the architecture search and activation function procedure. Only logistic hidden activation function and logistic output activation functions were considered because it was the most suitable activation functions in Chapter 5.4. Table 9.3 shows a summary of the architecture search and activation functions for the BS model.

**Table 9.3: Summary of the architecture search and activation functions of the Before Survey (BS) model**

| Hidden layer activation function | Output activation function | Architecture | Number of weight | $R^2$ | Correlation |
|---|---|---|---|---|---|
| *Logistic* | *Logistic* | *[34-87-50-1]* | *7496* | *0.9999* | *0.9999* |
| Logistic | Logistic | [34-82-50-1] | 7071 | 0.9962 | *0.9984* |
| Logistic | Logistic | [34-86-49-1] | 7323 | 0.9998 | 0.9999 |
| Logistic | Logistic | [34-84-49-1] | 7239 | 0.9999 | 0.9998 |
| Logistic | Logistic | [34-84-1] | 3025 | 0.9985 | 0.9999 |
| Logistic | Logistic | [34-81-1] | 2917 | 0.9908 | 0.9962 |

***Training of the Network.*** Similar to the model developed in Chapter 5, the training of the BS model used the same training algorithm, termination criterion (when to stop the training), and overtraining controls. The best network found for the "before survey" model was using the Quick

Propagation training algorithm with 301 iterations. Table 9.4 shows a summary of the network used for the BS model.

**Table 9.4: Summary of Training of the Network - BS Model**

| Architecture | Training Algorithm | Number of iterations | $R^2$ | | | |
|---|---|---|---|---|---|---|
| | | | All | Training | Validation | Testing |
| [34-87-50-1] | Quick Propagation | 301 | 0.821 | 0.932 | 0.489 | 0.709 |

***Query of the network.*** Prior to predicting the energy consumptions between May 2012 and September 2012, a total query of the network was conducted from October 2010 to March 2012. Table 9.5 shows that the prediction and the actual energy consumption. It is important to note the resulting value is close to zero, which suggests that the BS model is very accurate in predicting occupant's energy consumption.

**Table 9.5: Comparison of the prediction and actual energy consumption from October 2010 to March 2012**

| | Prediction from "Before Survey" Model From October 2010 to March 2012 | Actual Energy Consumption From October 2010 to March 2012 | Difference (Predicted - Actual) | Percent Difference |
|---|---|---|---|---|
| **Total Energy Consumption (kWh)** | 116867 | 116243 | +623 | +0.54% |

Figure 9.1 shows the comparison between the predicted energy consumption and the actual energy consumption from the query of the BS model. The comparison is found to have a high $R^2$ of 0.92.

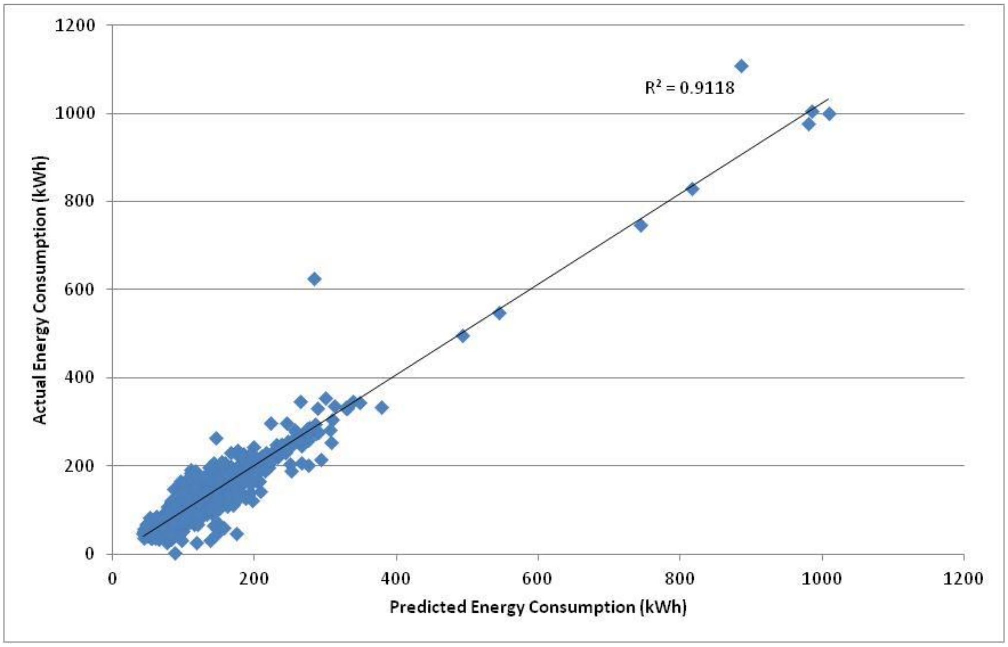



**Figure 9.1: Comparison between predicted energy consumption and actual energy consumption from the query of the Before Survey (BS) network**

### 9.3.2 Comparison between Predicted Values and Actual Energy Consumption

This section presents the comparison between the predicted values for May to September 2012 using the "Before Survey" model to the actual energy consumption from May to September 2012. A query of the model was conducted by inputting the respective weather conditions and occupant's information into the model. The query of the model included the period between May to September 2012. The predicted values were compared to occupant's actual energy consumption. Table 9.6 shows the difference between the actual energy consumption and energy consumption prediction using the BS model.

Table 9.6 indicates that the prediction from the BS model overestimated compared to the actual energy consumption. This suggests that the respondents consume less after the implementation of the survey (May to September 2012). Appendix H presents a detailed comparison between energy consumption averages of the BS model and actual energy consumption. It can be inferred that by using the BS model, the survey may have some influence to decrease occupant's energy consumption by 7%.

**Table 9.6: Difference between Prediction from BS Model to Actual Energy Consumption - May to September 2012**

| | Prediction from BS Model | Actual Energy Consumption | Difference (Predicted - Actual) | Percent Difference |
|---|---|---|---|---|
| **Total Energy Consumption (kWh)** | 32329 | 30170 | +2159 | + 6.7% |

## 9.4 Closing Remarks

This chapter presents the potential impact of the survey on household energy consumption using two methods. The purpose of using two methods is reinforce the reduction that there was a reduction in energy consumption after the survey. However, there are many factors that may have influenced this reduction that the ANN model did not consider. The first method compared the actual energy consumption from May to September 2011 and May to September 2012. This method found a reduction in energy consumption of 8.3%. The second method, BS model method, used artificial neural networking to model months prior to the implementation of the survey, forecast energy consumption after the survey, and compare with actual energy consumption after the survey (May to September 2012). This method found that the BS model overestimated compared to the actual energy consumption by 6.7%. Furthermore, the literature review presented in Chapter 8 has shown that information and conservation awareness can reduce occupant's energy consumption. Thus, the survey implemented at the Toronto MURB may have influence occupant's reduction in energy consumption.

# Chapter 10 Conclusions and Recommendations

## 10.1 Conclusions

This thesis investigates occupant's household energy use behaviour and consumption of 48 households in a high-rise multi-unit residential building in Toronto. A survey was conducted by ways of mail-in, interviews, and on-line. The survey of household energy use incorporated many elements of demographics, appliance ownership, type, usage, indoor environment satisfaction, and social aspects. Occupant's energy consumption was collected by ways of sub-meters, which captured the electrical draw of each apartment unit from October 2010 to September 2012. A total of 49 surveys were collected out of 136 households in the Toronto MURB. This results in a thirty-six percent response rate. In order to analyze the data, the ANN modeling approach was applied using survey data, energy consumption and weather conditions. The purpose of the model was to examine the effects of demographics on household energy consumption. The survey and ANN methodologies used in this thesis can be applied to other Toronto MURBs in order to investigate occupant's household energy use.

In general, males were found to consume more energy per month than females. During winter months (December to February), males consume a mean difference of 5 kWh per month over 199 kWh per month. Middle-aged males (31 to 45 years old) consumed the least out of all the other age groups. Middle-aged males consumed approximately 26 kWh/month less compared to the other age groups. The highest income households ($30,000 to $49,999) consumed 18% less than all the other incomes. Eastern-oriented apartment units consumed more energy than Western-oriented units. There was not much of a distinction between the number of years living in the Toronto MURB and household energy consumption throughout the 24-month period.

However, from June 2012 and onwards, occupants who live more than 7 years in the Toronto MURB were found to consume almost 4% more energy than those who recently lived in the Toronto MURB (0 to 1 year). During the winter months (December to February), occupant's who have grown up in Canada consumed 12.5% more energy than other geographical categories. Occupants who have grown up in South and Central America consumed 21.6% less energy during the winter months. Occupants who spend 9 to 13 hours in their apartment unit are found to spend 3% less energy compared to the other categories.

After the implementation of the survey, respondent's household energy consumption had reduced. Using ANN approach, the survey may have influenced the reduction in respondent's energy consumption by 6.7%. By comparing the actual energy consumption, an overall 8.3% reduction is found.

## 10.2 Limitations

Some limitations in this research are as follows:

- This thesis focuses on a single MURB located in downtown Toronto. Thus, the results found in this thesis are not generalizable or yield the same results for other Toronto MURBs.
- Because of limited access to personal information, mail-in, interviews, and on-line survey collection methods were used. Other methods such as telephone could increase the survey response rate to have a greater representation of the pilot site.
- The ANN model developed in this thesis is representative of the 48 surveys during a 24 month period. It cannot be generalizable to the whole building. However, by applying a similar survey and ANN methodology to other buildings, a model can be developed to investigate occupant's household energy use.

## 10.3 Recommendations for Future Research

Recommendations for future research on occupant's household energy use in other Toronto MURBs are as follows:

1. The survey and artificial neural network methodology can be applied to other high-rise MURB in developing a larger database on occupant's household energy use. A larger dataset would improve the prediction performance of the ANN model. Additionally, a larger dataset will provide a greater knowledge and evaluation on occupant's household energy use in Toronto.
2. The study site, Toronto MURB, was used to acquire information about occupant's energy use. The survey included questions from asking information on demographics, appliance type, usage, indoor environment, etc. To improve and strengthen the validity of the survey questions, more stringent "usage time" options should be considered, such as questions relating to oven and stove usage.
3. The survey collected information by ways of mail-in, interviews, and on-line. Other survey methodologies such as telephone interviews can be used to potentially improve and test the response rate of the survey.
4. Chapter 2.4 presented various energy modeling techniques such as CDA and engineering modeling; other energy modeling techniques can be used to develop occupant's household energy use in a high-rise MURB.
5. Different combinations of learning algorithms and activation functions can be used to develop a different model and enhance its prediction performance. In addition, different neural network software may offer different learning algorithms and

activation functions; therefore, using different software may also enhance the performance of the model.

# Appendices

## Appendix A: The Survey

# Toronto MURB:
# Household Energy Use Survey

**Sponsors**

Tenant Survey

Code Location - Survey

**Dear Toronto MURB tenant,**

Ryerson University team supported by the sponsors listed on the cover page is launching a project to look at tenant's energy/water usage and their attitude towards energy/ water use. How can tenants save energy and water? Do tenant engagement strategies really work? The purpose of this study is to see whether tenant engagement strategies will conserve energy and water in Toronto's Toronto MURB building. Tenants will have the opportunity to participate and be exposed to various tenant engagement strategies such as informational tools (e.g. poster and brochures), workshops, and energy- water--saving commitments. For more details, please see the posters throughout the building.

Confidentiality will be maintained and only general non-identifying data will be disclosed in any report and research publication. Further details regarding the protection of your privacy are in the "***Ryerson University Consent Agreement***" included with the survey.

**<u>Ryerson University Team has Research Ethics Approval for this project.</u>**

If you have any questions about the research study, please contact Miles Roque - miles1.roque@ryerson.ca

**Please take the time to complete the survey and SUBMIT it to:**

**<u>DROP BOX is located in the MAIN LOBBY, near the Front Entrance Door</u>**

**Remember:**

- As a token of appreciation, $5.00 will be given to you for taking part in the survey. Please enter your apartment unit number in Question 1 of the survey so that we know which mailbox to put the $5.00 in.

We hope you enjoy participating in our research. We truly appreciate your time to complete the survey!

**THANK YOU FOR YOUR COOPERATION!**

## Instructions

Please complete all questions below. **CHECK OFF ☑** the appropriate option.

## Part 1: General Information

1. What is your apartment unit #? ________________________________________

You will receive **$5.00** in your mailbox when entering your apartment unit #.

2. Are you male or female?

- ❑ Male
- ❑ Female

3. What is your age?

- ❑ 18-30 years old
- ❑ 31-45 years old
- ❑ 46-60 years old
- ❑ Over 60 years old

4. What part of the world did you grow up in?

- ❑ Canada
- ❑ USA
- ❑ Europe
- ❑ South or Central America or Caribbean
- ❑ South Asia (e.g. India, Pakistan, Sri Lanka)
- ❑ East Asia (e.g. China, Japan, Korea)
- ❑ Southeast Asia (e.g. Vietnam, Philippines, Malaysia)
- ❑ West Asia & Middle East (e.g. Lebanon, Iran)
- ❑ Africa (e.g. Ethiopia)

- ❑ Austrailia, New Zealand or the South Pacific
- ❑ Other, please specify.________________
- ❑ Prefer not to answer.

5. How many years have you been living in the Toronto MURB?

- ❑ 0 to 1 year
- ❑ 2 to 4 years
- ❑ 5 to 7 years
- ❑ More than 7 years

6. How many people live in your household?

- ❑ 1 person
- ❑ 2 persons
- ❑ 3 or more persons

7. On an average day, how many hours do you spend in your apartment (includes sleeping)?

- ❑ 8 hours or less
- ❑ 9 to 13 hours
- ❑ 14 to 18 hours
- ❑ more than 18 hours

8. What is your total household income?

- ❑ $0 to 14,999
- ❑ $15,000 to 29,999
- ❑ $30,000 to 49,999
- ❑ over $50,000
- ❑ Prefer not to answer.

## Part 2: Electrical Devices
## TELEVISION

9. How OLD is your TELEVISION?

- ❑ I DO NOT HAVE A TELEVISION.
- ❑ 5 years or less
- ❑ 6 to 10 years
- ❑ 11 to 15 years
- ❑ 16 years or more

10. How many hours a day do you leave your TELEVISION turned ON?

- ❑ 1 hour or less
- ❑ 1 to 3 hours
- ❑ 4 to 8 hours
- ❑ 9 to 13 hours
- ❑ 14 hours or more

11. What TYPE of TELEVISION do you have?

- ❑ Regular (tube)
- ❑ Plasma
- ❑ Liquid Crystal Display (LCD/LED)
- ❑ Other

**CABLE BOX (DIGITAL ANALOG BOX)**

12. Do you turn off the cable box when you are done watching TV?

- ❑ I DO NOT HAVE CABLE - NO CABLE BOX.
- ❑ Always turn off my digital analog box after using the TV
- ❑ Sometimes turn it off
- ❑ Leave it ON all the time

**COMPUTERS - DESKTOP AND/OR LAPTOP**

13. Do you have a laptop, desktop, or both? (Check all that apply.)

- ❑ I DO NOT HAVE A COMPUTER.
- ❑ Laptop
- ❑ Desktop (regular computer)

14. How many hours a day do you use your computer?

- ❑ 1 hour or less
- ❑ 1 to 3 hours
- ❑ 4 to 8 hours
- ❑ 9 hours or more

15. How OLD is your COMPUTER?

- ❑ 5 years or less
- ❑ 6 to 10 years
- ❑ 10 years or more

**INTERNET CONNECTION**

16. On an average day, how long do you spend on the Internet?

- ❑ I DO NOT HAVE AN INTERNET CONNECTION.
- ❑ 1 hour or less
- ❑ 1 to 3 hours
- ❑ 4 to 8 hours
- ❑ 9 to 13 hours
- ❑ 14 hours or more

## OTHER ELECTRICAL DEVICES

17. What appliances do you have at home?

Please **CHECK OFF** ☑ all electrical devices that you have at home.

**(Check off all devices that you have at home.)**

- ❑ Cell phone charger
- ❑ Home phone
- ❑ VHS player
- ❑ DVD player
- ❑ Game console (e.g. Nintendo, Xbox, Play Station)
- ❑ Printer
- ❑ Speakers
- ❑ Clock
- ❑ Radio/stereo
- ❑ Slow cooker
- ❑ Rice Cooker
- ❑ Iron
- ❑ Vacuum cleaner
- ❑ Humidifier/dehumidifier
- ❑ Other? Please specify: ______________________

# Part 3: Heating and Cooling

18. **<u>During the winter</u>**, what temperature do you set your heating/cooling equipment at?

- ❑ Temperature setting during the winter. ________(specify)

19. **<u>During the summer</u>**, what temperature do you set your heating/cooling equipment at?

- ❑ Temperature setting during the summer. ________ (specify)

20. Which of the following do you use to adjust you thermal comfort? (Check all that apply)

- ❑ Open/close windows
- ❑ Open/close doors
- ❑ Close blinds/drapes
- ❑ Adjust the thermostat
- ❑ Turn on personal heater
- ❑ Turn on personal fan
- ❑ Put on/remove clothing

Other? Specify:______________

## Part 4: Energy Behaviour

21.

For each item listed below, circle the number on HOW LIKELY YOU ARE TO DO the following. Use the scale shown on top to select the behavioural scale from **1 (Always) to 5 (Never).**

| | Scale | | | | |
|---|---|---|---|---|---|
| **Do you...** ⇩ | Always | | I don't know | | Never |
| 1. ...turn off the lights when you are not at home | 1 | 2 | 3 | 4 | 5 |
| 2. …turn off the lights when not in use | 1 | 2 | 3 | 4 | 5 |
| **3.** ...turn off electronics when you are not at home | 1 | 2 | 3 | 4 | 5 |
| 4. …turn off electronics when not in use | 1 | 2 | 3 | 4 | 5 |
| 5. ...use timer controls to control your electrical devices/electronics | 1 | 2 | 3 | 4 | 5 |
| 6. …turn off (shut down) computer when not in use | 1 | 2 | 3 | 4 | 5 |
| 7. …turn off (shut down) computer when you are not at home | 1 | 2 | 3 | 4 | 5 |
| 8. ...buy green appliances/devices (e.g. energy saving light bulbs, ENERGY STAR) | 1 | 2 | 3 | 4 | 5 |

## Part 5: Lighting

22. How **many COMPACT FLUORESCENT** (CFL) (Energy Saving) light bulbs do you use in your apartment?

- ❑ Please write down how many CFL light bulbs you use. ________(NUMBER)

23. How **many INCANDESCENT (regular)** light bulbs do you use in your apartment?

- ❑ Please write down how many INCADESCENT light bulbs you use. ________(NUMBER)

24. On an average day, how many light bulbs are turned on longer than 3 hours or more?

- ❑ 1 to 2 bulbs
- ❑ 3 to 5 bulbs
- ❑ 6 to 10 bulbs
- ❑ More than 10 bulbs

25. How many hours are the light bulbs turned on **during the winter**?

- ❑ Less than 3 hours
- ❑ 3 to 5 hours
- ❑ 6 to 9 hours
- ❑ More than 9 hours

26. How many hours are the light bulbs turned on **during the summer**?

- ❑ Less than 3 hours
- ❑ 3 to 5 hours
- ❑ 6 to 9 hours
- ❑ More than 9 hours

27. How many lamps, floor lamps, or any other light fixtures do you have?

- ❑ Please write down how many lamps or any other light fixture you have.______(NUMBER)

## Part 6: Water Usage

28. Do you run the tap (faucet) while brushing your teeth, shaving, etc.?

- ❑ Yes
- ❑ No

29. Do you leave the sink/tap running while washing the dishes?

- ❑ Yes
- ❑ No

30. How many times do you flush your toilet in a day? _________(Number)

31. Do you prefer taking a shower/bath? (Please choose one)

- ❑ Shower
- ❑ Bath

32. In a week, how many times do you shower/bathe?

- ❑ 1+ per day (More than once a day)
- ❑ Once a day
- ❑ Every other day
- ❑ Once a week
- ❑ Other? Specify. ________

# Part 7: Household Activities

## Cooking

33. On an average day, for how long do you use your **stove**?

- ❑ I do not use the stove at home
- ❑ 1 hour or less
- ❑ 1 to 3 hours
- ❑ more than 3 hours

34. On an average day, for how long do you use your **oven**?

- ❑ I do not use the oven at home
- ❑ 1 hour or less
- ❑ 1 to 3 hours
- ❑ more than 3 hours

35. On an average day, what is the total time spent using your **microwave**?

- ❑ I do not have a microwave
- ❑ Less than 3 minutes
- ❑ 3 to 9 minutes
- ❑ 9 to 15 minutes
- ❑ 15 minutes or more

## Part 8: Indoor Environment Satisfaction and Thermal Comfort

36.

For each item listed below, circle the number on HOW SATISFIED YOU ARE ABOUT THE FOLLOWING, listed below. Use the scale shown on top to select the satisfaction level from **1 (Very satisfied) to 7 (Very dissatisfied).**

| | Scale | | | | | | |
|---|---|---|---|---|---|---|---|
| **How satisfied are you with...** ⇩ | **Very Satisfied** | | | **Neutral** | | | **Very Dissatisfied** |
| A. The amount of space available for individual daily activities | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| B. The apartment unit layout | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| C. The quality of water in your apartment | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| D. The appliances in your apartment (i.e. stove, refrigerator, etc.) | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| E. The cleanliness of the building | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| F. The maintenance of the building | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| G. The air quality in your apartment (e.g. stuffy/stale air, odours, cleanliness, etc.) | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| H. The sound privacy between apartments? | **1** | **2** | **3** | **4** | **5** | **6** | **7** |

*Part 8: Indoor Environment Satisfaction and Thermal Comfort cont'd…*

**Circle the appropriate number according to your level of satisfaction/thermal comfort.**

37. On a scale from 1 to 7, 7 being very dissatisfied and 1 being very satisfied, how satisfied are you with...

The temperature of your apartment unit during the **SUMMER** (Very satisfied) 1 2 3 4 5 6 7 (Very dissatisfied)

38. On a scale from 1 to 7, **7 being interferes and 1 being enhances**…

Overall, does your thermal comfort in the apartment **during summer** enhances or interfere with your comfort?

(Enhances) 1 2 3 4 5 6 7 (Interferes)

39. How satisfied are you with...

The temperature of your apartment unit during the **WINTER**

(Very satisfied) 1 2 3 4 5 6 7 (Very dissatisfied)

40. Overall, does your thermal comfort in the apartment **during winter** enhances or interfere with your comfort?

(Enhances) 1 2 3 4 5 6 7 (Interferes)

41. How satisfied are you with...

The temperature of your apartment unit during **SPRING/FALL**

(Very satisfied) 1 2 3 4 5 6 7 (Very dissatisfied)

42. Overall, does your thermal comfort in the apartment **during spring/fall** enhances or interfere with your comfort?

(Enhances) 1 2 3 4 5 6 7 (Interferes)

43. How satisfied are you with...

The air quality in your apartment (e.g. stuffy/stale air, odours, cleanliness, etc.)

(Very satisfied) 1 2 3 4 5 6 7 (Very dissatisfied)

44. Overall, does your **air quality** in the apartment enhances or interfere with your comfort?

(Enhances) 1 2 3 4 5 6 7 (Interferes)

45. How satisfied are you with...

The sound privacy between apartments?

(Very satisfied) 1 2 3 4 5 6 7 (Very dissatisfied)

46. Overall, does the **acoustic quality** in the apartment enhances or interfere with your comfort?

(Enhances) 1 2 3 4 5 6 7 (Interferes)

**Please answer Question 46 ONLY if you have lived in the building for longer than 3 years.**

47. How satisfied are you with the building upgrade? (i.e. individual apartment thermostat, new windows, draft proofing, etc.)

(Very satisfied) 1 2 3 4 5 6 7 (Very dissatisfied)

48. Do you have other comments, concerns, or questions about your indoor environment satisfaction, thermal comfort, or energy behaviour?

## Part 9: Your Neighbourhood

49. How would you describe your sense of belonging to your local neighbourhood? Would you say it is...

- ❑ Outstanding
- ❑ Very strong
- ❑ Somewhat strong
- ❑ Somewhat weak
- ❑ Very weak
- ❑ I don't know

50. In general, how do you feel about living in the Toronto MURB?

51. In what ways has living in the Toronto MURB changed your life (financial, sense of security, well-being, etc.)?

***Thank you for your time to complete this survey!***

***For more information, please contact: miles1.roque@ryerson.ca***

## Appendix B: Research Ethics Approval

RYERSON UNIVERSITY
RESEARCH ETHICS BOARD

To: Vera Straka
Architecture

Re: REB 2011-312: Towards energy efficient MURBs

Date: March 5, 2012

Dear Vera Straka,

The review of your protocol REB File REB 2011-312 is now complete. The project has been approved for a one year period. Please note that before proceeding with your project, compliance with other required University approvals/certifications, institutional requirements, or governmental authorizations may be required.

This approval may be extended after one year upon request. Please be advised that if the project is not renewed, approval will expire and no more research involving humans may take place. If this is a funded project, access to research funds may also be affected.

Please note that REB approval policies require that you adhere strictly to the protocol as last reviewed by the REB and that any modifications must be approved by the Board before they can be implemented. Adverse or unexpected events must be reported to the REB as soon as possible with an indication from the Principal Investigator as to how, in the view of the Principal Investigator, these events affect the continuation of the protocol.

Finally, if research subjects are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and approvals of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research.

Please quote your REB file number (REB 2011-312) on future correspondence.

Congratulations and best of luck in conducting your research.

Nancy Walton, Ph.D.
Chair, Research Ethics Board

# Appendix C: Energy Consumption Data

There are two components of Appendix C. The first component presents the energy consumption data of surveyed and non-surveyed occupants from October 2010 to September 2012. The second component analyzes the energy consumption.

# Energy Consumption of Surveyed Occupants

| Suite # | Oct-10 | Nov-10 | Dec-10 | Jan-11 | Feb-11 | Mar-11 | Apr-11 | May-11 | Jun-11 | Jul-11 | Aug-11 | Sep-11 | Oct-11 | Nov-11 | Dec-11 | Jan-12 | Feb-12 | Mar-12 | Apr-12 | May-12 | Jun-12 | Jul-12 | Aug-12 | Sep-12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 99.6 | 109.5 | 101.1 | 127.8 | 109.5 | 116.9 | 106 | 131.3 | 124.9 | 103.3 | 91.2 | 123.2 | 125 | 108.1 | 101.5 | 113.7 | 103.6 | 109.5 | 96 | 123.7 | 152 | 127.7 | 110.1 | 159.9 |
| 2 | 208.1 | 182.4 | 196.8 | 194.7 | 193.2 | 199.4 | 188.3 | 188.8 | 190.5 | 229 | 222.6 | 184.9 | 184.9 | 178.3 | 186.1 | 195.1 | 182.5 | 177.1 | 174 | 186.5 | 194.9 | 211.2 | 205.6 | 181 |
| 3 | 152.7 | 137.2 | 159.2 | 161.7 | 139 | 160.5 | 147.2 | 139.7 | 136.7 | 122.7 | 126.6 | 100.4 | 103 | 84.8 | 98 | 125.3 | 121 | 127.2 | 137 | 125.3 | 113.1 | 132.5 | 108.1 | 125.9 |
| 4 | 120.6 | 112.2 | 120.3 | 129.2 | 113.8 | 126.3 | 131.9 | 132.4 | 121.5 | 137 | 126.2 | 103.6 | 108.8 | 97.3 | 101.1 | 93.9 | 96.9 | 94 | 93.9 | 94.7 | 98.7 | 102.8 | 101.5 | 101.1 |
| 5 | 79.9 | 70.7 | 74.8 | 91.5 | 80.6 | 89.5 | 82.1 | 73.4 | 75.1 | 113.8 | 93 | 85.7 | 73.4 | 83.7 | 89.2 | 82.6 | 80.9 | 85 | 78.9 | 76.7 | 57.8 | 44.5 | 105.4 | 89.3 |
| 6 | 129.3 | 137.6 | 150.4 | 130.8 | 97.6 | 97.1 | 90.8 | 95.9 | 95.1 | 118.3 | 131.5 | 109.5 | 141.5 | 130.7 | 120.1 | 151.3 | 111.7 | 83.5 | 96.1 | 94.1 | 93.9 | 166 | 154.4 | 128.3 |
| 7 | 97.7 | 98.2 | 99.1 | 101.9 | 89.5 | 91.4 | 83.3 | 84.9 | 83.9 | 86 | 84.4 | 80.1 | 89.1 | 82.7 | 100 | 96.1 | 90.2 | 83.7 | 82.9 | 82 | 80.9 | 100.7 | 89.6 | 81.4 |
| 8 | 107.7 | 111.6 | 119.9 | 115.6 | 114.9 | 106.9 | 116.7 | 119.3 | 115.9 | 153.1 | 151.4 | 126.8 | 116.1 | 113.4 | 115 | 117.5 | 98.1 | 100.6 | 105.7 | 108 | 116.8 | 201.5 | 206 | 166.1 |
| 9 | 207.3 | 218.8 | 218.6 | 209 | 194.4 | 213.7 | 234.9 | 287.6 | 223.1 | 228.6 | 187.2 | 206 | 195.5 | 163 | 171.7 | 173.1 | 164.2 | 173.5 | 167.3 | 218.5 | 196 | 164.6 | 169.9 | 220.5 |
| 10 | 124.7 | 110.1 | 113.9 | 89.8 | 81.9 | 82.1 | 83.4 | 126.7 | 160.1 | 182.7 | 198.5 | 171.8 | 116.9 | 111.5 | 138.1 | 113.8 | 90.2 | 88.5 | 83.3 | 137.6 | 143 | 180.6 | 192.3 | 146.1 |
| 11 | 78.3 | 67.8 | 178.3 | 241.8 | 227.5 | 47.2 | 29.6 | 64.5 | 87.7 | 110.2 | 87.4 | 122 | 142.1 | 146.5 | 186 | 178.5 | 118.4 | 141.8 | 111.2 | 89.4 | 90.7 | 148.3 | 161 | 149.3 |
| 12 | 153.1 | 146.2 | 150.8 | 166.5 | 137.3 | 138.7 | 140.2 | 143.5 | 133.9 | 142.2 | 127.7 | 93 | 81.1 | 66.5 | 106.4 | 91.1 | 76.4 | 79.5 | 71.8 | 73.2 | 74.8 | 103.9 | 106 | 86.4 |
| 13 | 83.5 | 82 | 71.6 | 70.6 | 83.4 | 125.8 | 124.8 | 136.7 | 143.3 | 179.5 | 177.4 | 127.4 | 120.8 | 137.6 | 143.7 | 137.3 | 124 | 142.3 | 139.4 | 134.3 | 125.1 | 163 | 136.6 | 108.4 |
| 14 | 201 | 256 | 346.9 | 334.1 | 238.3 | 213.5 | 177.5 | 196.4 | 204.2 | 257.4 | 273.9 | 277 | 248.6 | 248.7 | 196.9 | 166.4 | 158.5 | 168.7 | 151.6 | 153.3 | 169.6 | 215.2 | 217.4 | 162.8 |
| 15 | 36.7 | 35.5 | 34.1 | 40.2 | 37.1 | 42.7 | 44.3 | 42 | 37.1 | 50.5 | 54.5 | 51.5 | 53.6 | 53.1 | 51.6 | 54 | 47.9 | 52.3 | 45.9 | 50.6 | 51.7 | 60.1 | 57.3 | 53.2 |
| 16 | 75.2 | 70 | 66 | 76.7 | 66.4 | 73.9 | 78.3 | 79.2 | 75.4 | 80.1 | 85 | 78.2 | 78.7 | 79.5 | 70.9 | 84.3 | 70.4 | 77.4 | 69.8 | 74.8 | 72.4 | 74.1 | 67.5 | 75.1 |
| 17 | 114.5 | 140.7 | 153.7 | 73.4 | 26.3 | 32.5 | 132.2 | 117.4 | 106.3 | 160.9 | 118.7 | 93.1 | 81.3 | 38.9 | 36 | 68.6 | 117 | 101.8 | 111.6 | 93.7 | 92.9 | 169.5 | 133.6 | 97.2 |
| 18 | 54 | 65.8 | 65.5 | 70 | 65.9 | 69.1 | 57.1 | 49 | 46.5 | 71.2 | 80.5 | 63.8 | 58.9 | 69.4 | 48.8 | 41.5 | 63.5 | 67.8 | 48.7 | 57.2 | 63.3 | 82.9 | 80.2 | 64.2 |
| 19 | 123.9 | 130 | 130.4 | 98.3 | 127.2 | 101.8 | 47.1 | 66.9 | 79.4 | 131.3 | 137.9 | 105 | 117 | 108.5 | 112.5 | 110.8 | 115 | 98.4 | 109.2 | 97.3 | 101.1 | 143.4 | 104.1 | 86.6 |
| 20 | 141.9 | 132.3 | 127.3 | 153 | 132.9 | 130.4 | 124.2 | 121 | 101.4 | 157.7 | 206.2 | 130.6 | 137.5 | 117.8 | 127.4 | 104.2 | 75.8 | 84.5 | 84 | 85.5 | 85.5 | 105.6 | 95.1 | 87.6 |
| 21 | 75.5 | 81 | 95.7 | 124.1 | 85.2 | 124 | 187.9 | 225.2 | 155.5 | 82.6 | 90.6 | 105.4 | 124.7 | 76.5 | 96.9 | 101.4 | 84.1 | 91.8 | 78.4 | 76.1 | 92.1 | 69.1 | 73.1 | 93 |
| 22 | 92.1 | 95.1 | 98.8 | 95 | 84.9 | 92.1 | 87.2 | 76.2 | 70.6 | 83.2 | 77.3 | 68.4 | 76.4 | 87.2 | 84.1 | 82.1 | 76.9 | 77.3 | 80.5 | 81.1 | 72.8 | 81.3 | 89.1 | 88.9 |
| 23 | 72.8 | 89.2 | 296.3 | 127.6 | 171.2 | 147.4 | 68.9 | 86 | 68.6 | 80 | 85.5 | 74.6 | 97.4 | 68.8 | 69.8 | 72.5 | 69.9 | 72.5 | 68.9 | 69.9 | 69.9 | 88 | 86.2 | 75.3 |
| 24 | 329.3 | 235.1 | 257 | 1107 | 1003.7 | 1000 | 547.5 | 747.4 | 283.8 | 255.2 | 267.1 | 624.5 | 331.8 | 342.6 | 829.8 | 977 | 495.9 | 179 | 195 | 312.8 | 388.6 | 237 | 351.9 | 628 |
| 25 | 47.6 | 44.1 | 54.5 | 61.5 | 57 | 59 | 49.8 | 57.7 | 63.3 | 81.5 | 114.1 | 108.6 | 86 | 63.4 | 75.7 | 82.8 | 63.6 | 77 | 67.8 | 83.4 | 82.2 | 123.6 | 99.8 | 89.1 |
| 26 | 125.7 | 149.8 | 186.3 | 335.9 | 235.9 | 190 | 156.8 | 194.1 | 173.4 | 156.8 | 122.1 | 168.6 | 126.9 | 112.7 | 124.5 | 168.1 | 107.9 | 135.2 | 94.6 | 88.1 | 105.9 | 145.7 | 130.9 | 130.5 |
| 27 | 206.9 | 189 | 176.9 | 208.3 | 198.4 | 215.7 | 206.3 | 216.7 | 198.9 | 206.3 | 200.7 | 102.6 | 133.5 | 189.2 | 249 | 248.1 | 237.6 | 262.9 | 213.1 | 187.8 | 181.1 | 164.7 | 148.3 | 128.9 |
| 28 | 3.4 | 42.1 | 82.7 | 75.4 | 80.4 | 83.6 | 72.6 | 63 | 79.8 | 89.8 | 87.9 | 52.1 | 60 | 106.4 | 94.6 | 120.9 | 102.6 | 108.6 | 83.5 | 105.4 | 112.4 | 100.8 | 110.2 | 103.8 |
| 29 | 330.5 | 215.4 | 210.1 | 330.3 | 185.8 | 236.1 | 246.4 | 277.4 | 304.9 | 352.5 | 347.1 | 282.3 | 281.4 | 258.2 | 253.3 | 274.1 | 260.9 | 293.3 | 252.6 | 272 | 309.6 | 344.6 | 342.2 | 349.8 |
| 30 | 114.1 | 77.2 | 127.9 | 161.7 | 142.6 | 127.9 | 138 | 172.1 | 159 | 169.9 | 180.9 | 148.7 | 151.6 | 115 | 152.2 | 132.4 | 173.8 | 197.3 | 124.9 | 165.4 | 134 | 154.4 | 72.3 | 117.4 |
| 31 | 107.5 | 87.6 | 113.8 | 102.8 | 96.6 | 108.5 | 94.7 | 107.5 | 117.4 | 138.8 | 131 | 119.3 | 93.3 | 93.5 | 91.4 | 96.9 | 92 | 95.3 | 80.2 | 108.1 | 98.9 | 144.5 | 119.6 | 65.2 |
| 32 | 72.9 | 86.6 | 105.8 | 108.9 | 118.6 | 165.6 | 79.9 | 95.8 | 79.9 | 107.7 | 93.2 | 81.1 | 174.2 | 89.6 | 98.7 | 109.2 | 100.4 | 93 | 85.4 | 81.9 | 155.6 | 236.7 | 175.1 | 113.4 |
| 33 | 180.8 | 182.3 | 204.3 | 217.7 | 202.4 | 211.3 | 194.2 | 158 | 24.4 | 92.7 | 92.1 | 121.3 | 194.1 | 183.1 | 217.2 | 209.9 | 169.8 | 147.8 | 144.6 | 119.1 | 112.8 | 86.6 | 78.4 | 97.8 |
| 34 | 158.1 | 169.3 | 183.7 | 196.8 | 154.2 | 173.9 | 183 | 165.7 | 135.1 | 56.9 | 83.2 | 73.4 | 67.1 | 60.2 | 66.2 | 73.2 | 75.3 | 70.6 | 71.4 | 68.9 | 76.6 | 104.2 | 72.4 | 73.9 |
| 35 | 81.8 | 86.7 | 71 | 87.6 | 85.7 | 76.5 | 70.4 | 69.7 | 83.2 | 95.5 | 102.4 | 78.7 | 82.6 | 79.8 | 79.5 | 93.4 | 74 | 83.3 | 68.7 | 74.2 | 72.4 | 77.1 | 68.6 | 63 |
| 36 | 132.3 | 123.4 | 169.8 | 147.3 | 131.6 | 128.1 | 141.4 | 127.8 | 133.6 | 129.3 | 152.8 | 172.8 | 159.7 | 137.6 | 165.7 | 144.9 | 108.5 | 99.6 | 113.9 | 171.4 | 148.6 | 168.2 | 152.7 | 175.4 |
| 37 | 121 | 114.2 | 125.8 | 122 | 118.8 | 170.4 | 182.4 | 183.4 | 116.9 | 112.7 | 134.7 | 110.9 | 134.3 | 151.4 | 173.3 | 177.6 | 131.2 | 100 | 86.7 | 102 | 83 | 116.5 | 131 | 91.1 |
| 38 | 159.6 | 154.3 | 146.2 | 158.6 | 139.3 | 159.8 | 172.8 | 224.9 | 234.8 | 281.1 | 296.9 | 231.3 | 272.7 | 58 | 43.1 | 43.7 | 68.8 | 81.9 | 75 | 90.5 | 86.8 | 123.2 | 42.6 | 63 |
| 39 | 46 | 59.6 | 42.3 | 50.9 | 47.6 | 50.4 | 50.8 | 54.9 | 54.8 | 81.6 | 90 | 57.2 | 75.7 | 76.5 | 69.9 | 56 | 46.7 | 66 | 54.8 | 65.8 | 58.5 | 56.5 | 30.3 | 36.7 |
| 40 | 68.4 | 90.2 | 78.7 | 114.2 | 96.3 | 96.3 | 86.1 | 107 | 161 | 127 | 131.3 | 87 | 85.5 | 145.8 | 157.2 | 115.3 | 124.1 | 120.9 | 132.7 | 144.1 | 147.6 | 182.7 | 166.5 | 152.3 |
| 41 | 124.5 | 123 | 115.9 | 117.6 | 104.4 | 120.5 | 120.5 | 121 | 138.2 | 153.5 | 152.7 | 128.4 | 122 | 119.9 | 128.9 | 118 | 109.5 | 120.5 | 119.8 | 120.4 | 129.5 | 159.8 | 160.9 | 131.6 |
| 42 | 184.1 | 186 | 175.8 | 129.3 | 191.4 | 29.8 | 122.2 | 162.3 | 175.9 | 186.8 | 186.2 | 165.3 | 118.2 | 88 | 84.8 | 102 | 92.8 | 89.2 | 105.3 | 119.8 | 121.3 | 135.1 | 140 | 129.8 |
| 43 | 161.5 | 189 | 189.4 | 193.5 | 176.9 | 196.1 | 180.8 | 162.3 | 129.4 | 160.1 | 164.2 | 131.4 | 141 | 136.3 | 138.6 | 127.5 | 126.6 | 134.5 | 117.7 | 82.9 | 81.9 | 138.8 | 146.7 | 139 |
| 44 | 97.4 | 89.9 | 113.6 | 130.4 | 131.5 | 138.1 | 128.6 | 127.3 | 114.8 | 115.5 | 137.4 | 101.7 | 106.5 | 101.3 | 121.8 | 128 | 118 | 117.3 | 119.7 | 114.8 | 107.6 | 143.6 | 153.2 | 132.9 |
| 45 | 140.5 | 174.3 | 190.2 | 202.4 | 163.3 | 136.3 | 169.4 | 182.1 | 191.8 | 206 | 198.6 | 188.7 | 165.1 | 169 | 145.5 | 162.3 | 187.8 | 181 | 183.9 | 161 | 169.1 | 193.9 | 162.1 | 146.1 |
| 46 | 70.8 | 69.8 | 59.4 | 78 | 79.2 | 80.1 | 80.7 | 81 | 83.8 | 94.6 | 84.4 | 65.6 | 67.7 | 68.9 | 73.9 | 73.1 | 51.8 | 60.5 | 70 | 79.6 | 72.1 | 97.8 | 97.3 | 81.8 |
| 47 | 78.3 | 67.8 | 178.3 | 241.8 | 227.5 | 47.2 | 29.6 | 64.5 | 87.7 | 110.2 | 87.4 | 122 | 142.1 | 146.5 | 186 | 178.5 | 118.4 | 141.8 | 111.2 | 89.4 | 90.7 | 148.3 | 161 | 149.3 |
| 48 | 123.4 | 125.5 | 205.6 | 203.4 | 152.7 | 229.7 | 189.6 | 243.5 | 172.2 | 174.1 | 184.4 | 128 | 178.7 | 159.5 | 196.6 | 230.6 | 210.7 | 189.1 | 166.3 | 148.6 | 155.4 | 171.1 | 108.7 | 85.7 |
| Average: | 122.8438 | 121.0854 | 140.3021 | 164.7208 | 146.2458 | 142.7875 | 130.3833 | 144.8146 | 127.8063 | 141.6125 | 142.4583 | 131.9479 | 129.6667 | 118.8521 | 136.8583 | 141.6375 | 120.5375 | 117.1729 | 108.8521 | 115.4354 | 118.5667 | 139.4146 | 130.6833 | 127.1479 |

## Energy Consumption of Non-surveyed Occupants

| Suite # | Oct-10 | Nov-10 | Dec-10 | Jan-11 | Feb-11 | Mar-11 | Apr-11 | May-11 | Jun-11 | Jul-11 | Aug-11 | Sep-11 | Oct-11 | Nov-11 | Dec-11 | Jan-12 | Feb-12 | Mar-12 | Apr-12 | May-12 | Jun-12 | Jul-12 | Aug-12 | Sep-12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 108.8 | 113.3 | 290.7 | 402.4 | 275 | 123.8 | 78 | 52 | 57.8 | 76.3 | 75.2 | 41.7 | 52.7 | 46.8 | 42.9 | 52 | 45 | 49.8 | 44.4 | 49 | 33.9 | 79.3 | 79.3 | 59.3 |
| 2 | 106.7 | 97.1 | 95.8 | 103.1 | 96.1 | 115.6 | 125.8 | 101.5 | 132.7 | 122.3 | 98 | 85 | 79.1 | 69.3 | 70.6 | 71.3 | 68.9 | 80 | 74.7 | 80.2 | 85.5 | 97.9 | 109.7 | 95.9 |
| 3 | 75.8 | 84.7 | 91.8 | 94 | 82.8 | 87.3 | 96.2 | 130.9 | 100.5 | 141 | 130.2 | 125.5 | 112.7 | 87 | 102.4 | 91.4 | 72.8 | 81.5 | 90.5 | 82.9 | 116.9 | 109 | 106.9 | 96.5 |
| 4 | 244.2 | 294.7 | 399.6 | 447.8 | 359.2 | 437.4 | 361.9 | 375.1 | 284.7 | 298.7 | 416.5 | 428.6 | 447.9 | 323.8 | 289.9 | 211.1 | 176.5 | 180.1 | 206.8 | 180.7 | 208.9 | 460.4 | 395.4 | 272.7 |
| 5 | 110 | 112.8 | 158.3 | 182 | 161.1 | 175.1 | 109.1 | 102.6 | 107.7 | 120.1 | 137.2 | 96 | 110.2 | 97.2 | 146.9 | 194.7 | 179.9 | 135.8 | 140.9 | 100.8 | 114.9 | 135.2 | 116.6 | 100.7 |
| 6 | 69.5 | 24.2 | 22.7 | 25.5 | 24.8 | 108.9 | 29.2 | 65.9 | 69.9 | 85.5 | 76.4 | 69.8 | 26.8 | 24.5 | 25.2 | 24.3 | 23.3 | 25.4 | 43.9 | 76.3 | 74.1 | 79.8 | 84.4 | 78.1 |
| 7 | 102.1 | 90.4 | 98.8 | 110.6 | 92.5 | 103 | 82.9 | 94.7 | 89.5 | 103.7 | 106.2 | 75.7 | 81.4 | 85.2 | 104.5 | 85.1 | 94.6 | 100.2 | 62.2 | 94.3 | 97.3 | 94.8 | 92.8 | 84.8 |
| 8 | 85.9 | 100.2 | 130 | 135.5 | 108.4 | 117.4 | 120.2 | 127.9 | 148.3 | 203.6 | 186 | 152.8 | 141.2 | 141.7 | 162.4 | 158.8 | 130.2 | 102.1 | 42.7 | 83.4 | 96.8 | 92.1 | 75.6 | 108.3 |
| 9 | 80.3 | 97.2 | 82.1 | 101.6 | 100.6 | 85 | 93.3 | 99.1 | 105.9 | 127.2 | 140.6 | 85.1 | 106.8 | 61.9 | 103.9 | 102.2 | 183.4 | 142.8 | 139 | 151.5 | 138.6 | 158.2 | 168 | 146.1 |
| 10 | 75.8 | 56.4 | 61 | 100.8 | 69.8 | 81.3 | 57 | 56.4 | 76.1 | 81.7 | 86.7 | 61.3 | 61.3 | 44.9 | 50.9 | 38.9 | 44.7 | 45.9 | 51.5 | 49.3 | 66.4 | 84.4 | 79.3 | 65.9 |
| 11 | 115.6 | 124 | 132.4 | 135.3 | 139.4 | 109.3 | 116.2 | 134.1 | 128.7 | 174 | 169.6 | 140.7 | 136.2 | 151.5 | 146 | 146.6 | 135 | 146 | 137.4 | 140.7 | 148.4 | 187.1 | 214.2 | 186.8 |
| 12 | 74.2 | 78.9 | 96.9 | 120 | 85 | 81.7 | 87.3 | 87.2 | 68.7 | 70.1 | 61.2 | 66 | 94.3 | 83.8 | 111.5 | 84.1 | 73.9 | 64 | 64.8 | 76.3 | 62.4 | 60.4 | 64 | 90.6 |
| 13 | 102.2 | 102.4 | 95.6 | 101.2 | 96.1 | 122.4 | 114.2 | 85.8 | 98.6 | 118.8 | 119.8 | 99 | 75.5 | 65.6 | 81.9 | 85.2 | 81.4 | 74.6 | 94.5 | 83.6 | 63.1 | 81.6 | 77.1 | 58 |
| 14 | 122.1 | 112.1 | 126.5 | 145.7 | 127 | 139.4 | 155.8 | 149.9 | 135.6 | 156.3 | 159.9 | 129.6 | 154.5 | 145.3 | 167.6 | 160 | 152.4 | 145.6 | 128.7 | 107.3 | 108 | 121 | 117.6 | 109.6 |
| 15 | 111.3 | 99.4 | 102 | 108.4 | 99.4 | 107.7 | 102 | 103.5 | 115.5 | 134.2 | 136.5 | 122.2 | 134.9 | 121.8 | 129.7 | 123.9 | 131.4 | 128.6 | 117 | 136 | 139.3 | 130.4 | 133.5 | 118.4 |
| 16 | 93.3 | 94.9 | 91.4 | 95.8 | 83.2 | 79.3 | 82.7 | 89.9 | 117.1 | 115.9 | 126.3 | 85.2 | 93.1 | 85.9 | 80.1 | 63.1 | 70.6 | 88.7 | 86.8 | 97.5 | 103.4 | 130.6 | 185.7 | 163.7 |
| 17 | 112.1 | 69.8 | 79.3 | 123.9 | 75 | 78.3 | 88.9 | 60.8 | 94.1 | 93.5 | 165.8 | 110.5 | 78.9 | 78.2 | 76.1 | 75.6 | 152.2 | 149 | 42.3 | 59.3 | 80.6 | 151.1 | 129.6 | 133 |
| 18 | 67.3 | 73.1 | 72.4 | 77.7 | 78 | 85.9 | 83.6 | 89.3 | 76.4 | 78.1 | 75 | 76.9 | 85.9 | 86.7 | 86.5 | 86.4 | 92.5 | 94.1 | 78.9 | 81.6 | 76.2 | 72.2 | 71.4 | 68.3 |
| 19 | 97.3 | 106.9 | 109.9 | 111.8 | 93.1 | 117.8 | 94.7 | 89.8 | 89.2 | 121.2 | 123.8 | 63 | 40.5 | 67.4 | 96.1 | 97 | 77.5 | 84.4 | 73 | 71.9 | 75 | 104.4 | 97.6 | 78.7 |
| 20 | 154.7 | 147.5 | 161.6 | 174.7 | 149.3 | 151.1 | 119.7 | 134.9 | 130.5 | 155.5 | 170.4 | 145.5 | 124.8 | 136 | 176.8 | 182.5 | 147.6 | 176.4 | 188.1 | 155.6 | 65.6 | 96.9 | 100.1 | 90 |
| 21 | 51.6 | 60.5 | 71.8 | 91.2 | 79.6 | 54.3 | 49.8 | 85.2 | 35.6 | 31.2 | 30.4 | 26.2 | 76.3 | 92.5 | 73.6 | 67 | 48.6 | 55.3 | 57.6 | 67.3 | 108.2 | 117.2 | 127.7 | 102 |
| 22 | 75.9 | 80.7 | 88.2 | 98.4 | 93 | 78.5 | 103.9 | 92.8 | 118.2 | 123.6 | 132 | 124.6 | 100.8 | 94.8 | 90.4 | 118.7 | 83 | 86.8 | 94.2 | 90.5 | 100.2 | 157.2 | 135.1 | 101.2 |
| 23 | 276.1 | 257.5 | 272.2 | 285.8 | 259.3 | 271 | 262.4 | 263.5 | 248.1 | 248.9 | 250.6 | 239.8 | 272.9 | 234.7 | 249.7 | 242.7 | 239.5 | 262.3 | 235.5 | 262.5 | 256.5 | 256.5 | 255.6 | 248 |
| 24 | 94.4 | 88.6 | 39 | 70.7 | 77 | 71.3 | 47 | 30.8 | 93.4 | 145.7 | 139.8 | 107.2 | 82.4 | 82.4 | 75.5 | 82.9 | 85.4 | 98.3 | 88 | 93.8 | 112.7 | 124.2 | 134.3 | 125.5 |
| 25 | 85.1 | 111.3 | 114.7 | 119.3 | 135.4 | 105.2 | 94 | 87.5 | 72.9 | 106.3 | 123.1 | 100.4 | 83.7 | 118 | 124.7 | 129.6 | 115.8 | 100.9 | 108.7 | 104.6 | 74.5 | 77.3 | 70.4 | 78.6 |
| 26 | 166.6 | 80.7 | 56.3 | 78.7 | 80.5 | 81.3 | 87.4 | 101.2 | 87.7 | 87.6 | 88.3 | 89.1 | 108.6 | 91.2 | 81.1 | 82.5 | 85 | 87.4 | 90.2 | 86.8 | 82.7 | 103.8 | 79.8 | 73.2 |
| 27 | 58.7 | 60 | 55.1 | 53.1 | 47.5 | 60 | 61.3 | 67 | 75.5 | 84.8 | 83 | 69.1 | 71.8 | 62.5 | 62.3 | 39.4 | 42.8 | 65 | 60.8 | 65 | 75.6 | 93.6 | 81.6 | 74.1 |
| 28 | 261.2 | 268.8 | 328.6 | 305.6 | 278.9 | 372.7 | 334 | 356.9 | 324.5 | 360.2 | 329.8 | 315.9 | 301.4 | 260.5 | 286.1 | 278.1 | 255.6 | 179.3 | 255.8 | 249.8 | 261 | 337.8 | 338.5 | 261.3 |
| 29 | 96.3 | 79.5 | 74.7 | 96.1 | 170.6 | 180.1 | 95.4 | 75 | 165.7 | 190.5 | 183.4 | 168.7 | 192 | 183.3 | 177.4 | 178.5 | 153.7 | 165.5 | 127.6 | 128.7 | 145.3 | 184.6 | 197.4 | 139.5 |
| 30 | 42.1 | 42.6 | 54.3 | 55.2 | 55.2 | 54.8 | 47.2 | 40.6 | 48.3 | 88.8 | 85.9 | 55.1 | 50.7 | 58.2 | 59 | 29.5 | 55.6 | 77.6 | 100 | 102 | 93.6 | 116.2 | 92.1 | 106.5 |
| 31 | 158.6 | 167.8 | 176.3 | 156.6 | 148.8 | 154.5 | 128.7 | 125.5 | 123.4 | 185.7 | 209.8 | 171.3 | 191.4 | 194.4 | 170.1 | 170.2 | 147.2 | 138.7 | 148.9 | 141.1 | 151 | 200.7 | 196.3 | 159.5 |
| 32 | 98.7 | 142.2 | 150 | 153.4 | 140.4 | 145.7 | 58.5 | 115.9 | 121 | 142.3 | 127.2 | 120.5 | 80.7 | 135 | 101.8 | 85.1 | 75.7 | 76.8 | 69.7 | 81.6 | 152.2 | 159.5 | 158.7 | 148.9 |
| 33 | 274.6 | 280.2 | 294.2 | 303.4 | 284.7 | 301.9 | 258.8 | 301.2 | 276 | 265.1 | 234.8 | 275.7 | 76.5 | 118.3 | 135.1 | 112.1 | 118.3 | 151.1 | 68.7 | 70.3 | 79.5 | 120.9 | 129.7 | 120.2 |
| 34 | 82 | 102.7 | 68.9 | 57.5 | 73.1 | 54.9 | 85.6 | 55.1 | 73 | 109.9 | 136.6 | 110.1 | 118.5 | 89.6 | 79.6 | 60.5 | 58.9 | 58.4 | 41.2 | 35.8 | 63.6 | 132.5 | 113 | 114.8 |
| 35 | 57 | 52.4 | 56.9 | 76.4 | 89 | 81 | 68.4 | 71.7 | 86.1 | 51.2 | 75.6 | 70.7 | 75.6 | 72.9 | 82.1 | 88 | 86.4 | 87.4 | 79.8 | 84.1 | 89.2 | 116 | 112.5 | 84.8 |
| 36 | 101.7 | 87.1 | 97.7 | 102.6 | 105 | 104 | 65.3 | 43.7 | 40.4 | 42.3 | 47.5 | 126 | 152.8 | 109.4 | 110.1 | 121.5 | 131.1 | 129.1 | 179.9 | 250.1 | 289.1 | 247.9 | 234.8 | 223.1 |
| 37 | 111.6 | 131.3 | 118.6 | 129.3 | 138.2 | 157.7 | 151.9 | 153 | 150.7 | 180.4 | 201.1 | 171 | 148.6 | 120.6 | 133.2 | 141.1 | 141.4 | 154.6 | 156.2 | 142.6 | 125.2 | 203.5 | 192 | 116.2 |
| 38 | 92.3 | 93.2 | 50.9 | 50.8 | 46.9 | 82.7 | 82.9 | 89.6 | 83.9 | 100.8 | 108.6 | 94.7 | 80.4 | 77.3 | 92.8 | 101 | 100.1 | 103.7 | 43.5 | 72 | 67.2 | 72 | 77.7 | 74.2 |
| 39 | 116.8 | 103.3 | 85.8 | 135.1 | 137.1 | 145.6 | 140.1 | 142.5 | 147.7 | 189.1 | 215.3 | 127 | 129 | 107.5 | 96.9 | 74.4 | 82.3 | 113.7 | 117.3 | 111.1 | 133.8 | 153.5 | 163.4 | 137.7 |
| 40 | 188.3 | 196.1 | 210.8 | 192.7 | 132.8 | 178.5 | 162.8 | 173.1 | 220.4 | 190.6 | 231.3 | 215.1 | 263.4 | 256 | 274.9 | 327.9 | 279.1 | 211.5 | 196.6 | 197.4 | 160.3 | 220.6 | 284.5 | 263.2 |
| 41 | 134.8 | 130.3 | 150.4 | 163.7 | 169.9 | 184.6 | 126.7 | 154.1 | 140.6 | 140.2 | 155.3 | 161.5 | 141.2 | 127.3 | 152.3 | 146.8 | 146.4 | 141 | 121.4 | 131.7 | 141.6 | 149.1 | 180.7 | 173 |
| 42 | 45.3 | 43.5 | 40.8 | 56.2 | 30.6 | 39.7 | 43.4 | 46.8 | 48.8 | 66.9 | 75 | 49.5 | 50.1 | 44.6 | 44 | 42.6 | 57.4 | 46.3 | 38.8 | 43.5 | 44.3 | 74.8 | 63.8 | 47.1 |

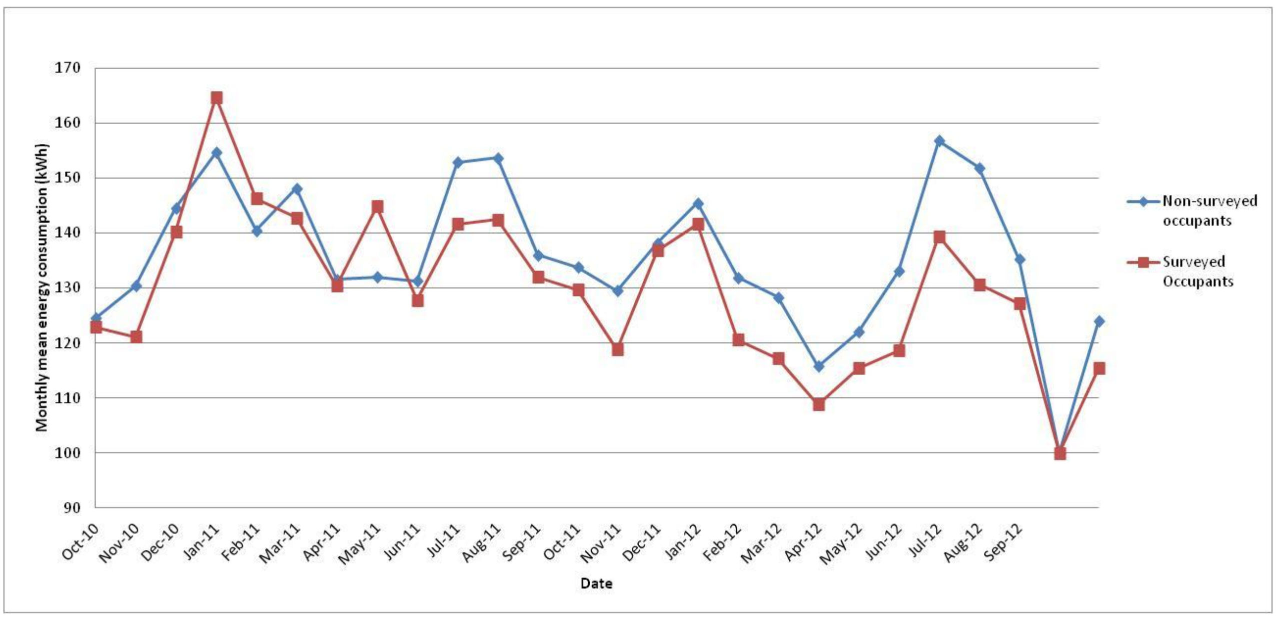
| | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 43 | 132.1 | 132.9 | 135.6 | 179.4 | 145.9 | 185.4 | 169.1 | 151.5 | 52.3 | 75.5 | 86.7 | 53 | 73.3 | 63.9 | 76.3 | 69 | 68.2 | 76.5 | 55.3 | 76.2 | 51.6 | 39.3 | 40.9 | 74 |
| 44 | 100.1 | 138.9 | 177.2 | 162.6 | 129.2 | 111.1 | 117.6 | 93.7 | 99.8 | 123.5 | 121.5 | 104.9 | 83.6 | 87.3 | 100.8 | 87.8 | 125.2 | 132.2 | 156.4 | 174 | 212.8 | 196.9 | 219.4 | 207.6 |
| 45 | 81 | 87 | 85 | 82.4 | 90.5 | 113.1 | 81.7 | 66.5 | 66.6 | 88.1 | 120.3 | 103.8 | 105.9 | 110.2 | 114.4 | 171.3 | 127.3 | 113 | 132 | 105.6 | 124.9 | 133.4 | 122 | 98.4 |
| 46 | 71.5 | 73.4 | 82.8 | 84.5 | 78.5 | 84.4 | 79.2 | 68.5 | 71.2 | 86.5 | 75.7 | 67 | 69.4 | 74.7 | 84.6 | 85.9 | 80.3 | 74.9 | 66.4 | 66.4 | 77.4 | 91.4 | 79.3 | 69.4 |
| 47 | 138.3 | 140.1 | 168.3 | 115.3 | 77.4 | 77.6 | 75.4 | 106.8 | 114.7 | 149.1 | 148.8 | 115.2 | 82.1 | 92.5 | 86.5 | 75.2 | 76.5 | 76.4 | 75.7 | 90.8 | 130.9 | 132.4 | 142.4 | 104 |
| 48 | 98.8 | 111.3 | 91.5 | 95.7 | 106.4 | 126 | 79 | 86.9 | 109.9 | 108.9 | 121.3 | 128.4 | 84.2 | 89.3 | 81.4 | 87.5 | 84 | 69 | 71.8 | 83.4 | 85.1 | 115.2 | 112 | 85.3 |
| 49 | 248.8 | 209.4 | 220.5 | 230.8 | 212.6 | 230.4 | 207.6 | 226.1 | 422.5 | 476.6 | 468.7 | 418.4 | 292.3 | 205.5 | 209.3 | 210.3 | 194.9 | 203.5 | 194.7 | 231.4 | 305.7 | 425.6 | 422.9 | 269.1 |
| 50 | 85.6 | 137.4 | 316.5 | 382.7 | 520.4 | 322.8 | 151.2 | 124 | 146.4 | 134.9 | 117.1 | 117.8 | 72.9 | 66.3 | 62.4 | 61.2 | 51.3 | 74.9 | 62.5 | 75.8 | 98 | 134.9 | 138.7 | 132.9 |
| 51 | 80.9 | 74.8 | 88.2 | 109.8 | 104.2 | 80.5 | 76.5 | 77.1 | 79.4 | 96.7 | 97.3 | 85.3 | 84.7 | 80.4 | 83.1 | 85.1 | 80.7 | 88.4 | 94 | 113.1 | 117.4 | 127.6 | 119.5 | 111.7 |
| 52 | 90.3 | 71.9 | 97.8 | 101 | 95.4 | 80.8 | 73.6 | 73.3 | 74.8 | 101.8 | 91.6 | 71.1 | 93.9 | 117.8 | 113.8 | 150.4 | 156.7 | 170.9 | 169.2 | 168 | 145.3 | 165.4 | 156.5 | 137.7 |
| 53 | 108.1 | 132.6 | 150.6 | 159.4 | 154.8 | 143.9 | 115.9 | 115.1 | 116 | 127.6 | 84 | 63.2 | 67.5 | 82.4 | 94.7 | 122.7 | 84.3 | 61.2 | 60 | 60.1 | 74.9 | 112.9 | 97.1 | 87.9 |
| 54 | 98.7 | 110.9 | 140 | 129.3 | 97.1 | 111.5 | 113 | 149.6 | 141.5 | 114.3 | 135.1 | 139.8 | 137 | 155.5 | 114.6 | 120.9 | 120.7 | 127.8 | 102.5 | 113.1 | 114.4 | 146.8 | 124.5 | 101.2 |
| 55 | 109.7 | 104.7 | 90.4 | 89.6 | 82.5 | 81.1 | 75.8 | 73.3 | 76.3 | 100 | 90.7 | 76.5 | 79.3 | 72.9 | 70.4 | 68.5 | 73.9 | 77.1 | 84 | 100.1 | 84.3 | 100.5 | 110.3 | 102 |
| 56 | 80.1 | 38.4 | 34.7 | 34.9 | 28.6 | 31.9 | 30.1 | 64.4 | 163.3 | 186.8 | 209 | 172.7 | 155.1 | 150.7 | 150.8 | 147.8 | 117.5 | 138 | 35.2 | 103.7 | 290.9 | 322.7 | 234.2 | 177.5 |
| 57 | 74.7 | 83.4 | 79.1 | 89.9 | 85.4 | 94.1 | 111.8 | 119 | 110.5 | 108.4 | 108.8 | 94.3 | 96.5 | 90.8 | 98.7 | 97.4 | 92.2 | 100.9 | 96.1 | 99.6 | 100.4 | 117.6 | 122.1 | 113.4 |
| 58 | 158.3 | 143.1 | 158.7 | 183.3 | 152.8 | 181.1 | 174.8 | 216.9 | 196.3 | 186 | 230.2 | 236.3 | 249.1 | 193.7 | 225.9 | 228.8 | 206.8 | 199.5 | 198.1 | 188.3 | 176 | 183 | 158.7 | 174.7 |
| 59 | 75.6 | 71.2 | 65.4 | 45.4 | 30.7 | 82.3 | 74.6 | 85.7 | 82.4 | 82.2 | 89 | 74 | 94.8 | 90.7 | 97.8 | 100.9 | 93.5 | 87.2 | 96.6 | 125.8 | 89.1 | 102.5 | 98.1 | 96.5 |
| 60 | 115.5 | 118.1 | 152.1 | 134.4 | 109 | 111.1 | 122.1 | 114.1 | 79.6 | 89.7 | 78.1 | 72.7 | 81.5 | 95.1 | 81.3 | 84.4 | 86.3 | 119.1 | 99.4 | 80.7 | 43.5 | 111.5 | 176.3 | 153.5 |
| 61 | 121.3 | 120.9 | 129.3 | 127.6 | 123.4 | 134.3 | 129 | 139.1 | 172.8 | 193.4 | 170.8 | 176.1 | 150.5 | 174.1 | 148.1 | 160.3 | 138.3 | 153.4 | 145.9 | 163.1 | 189.9 | 179.9 | 162.8 | 150.1 |
| 62 | 154.1 | 137.2 | 139.8 | 146.7 | 132.6 | 152.7 | 149.4 | 148.8 | 151.2 | 177.4 | 201.7 | 163.8 | 159 | 149.5 | 159.1 | 156.8 | 142.9 | 167.5 | 148.9 | 57.1 | 66.7 | 77.7 | 90.5 | 78.3 |
| 63 | 211.3 | 208.3 | 208.9 | 233.3 | 215.9 | 250.9 | 213.7 | 218 | 219.5 | 255.2 | 247.8 | 316.1 | 304.6 | 269.7 | 326.2 | 343.3 | 320 | 258.3 | 235.2 | 211.3 | 200.4 | 233.4 | 206.1 | 183.9 |
| 64 | 143.5 | 144.7 | 131 | 149.3 | 123.2 | 137.6 | 124.6 | 128.2 | 124.9 | 135.8 | 133.8 | 139.3 | 140.3 | 126.7 | 159.5 | 172.8 | 145.5 | 148.3 | 144.3 | 137 | 135.3 | 142.4 | 141.6 | 125.4 |
| 65 | 173.3 | 164 | 167 | 193.5 | 172.5 | 177.5 | 167.6 | 158.5 | 150 | 148.9 | 148.8 | 139.4 | 140.3 | 129.7 | 126.4 | 166.2 | 145.7 | 132.4 | 164.8 | 121.6 | 121.8 | 144.4 | 135.9 | 137.3 |
| 66 | 86 | 84.3 | 98.9 | 115.4 | 91.5 | 76.7 | 29.4 | 65.5 | 68.8 | 73.9 | 78.9 | 85.8 | 92.4 | 82.5 | 55.3 | 58.1 | 43.7 | 32.9 | 31.3 | 58.3 | 82.8 | 86.6 | 107.3 | 84.2 |
| 67 | 181.8 | 142.1 | 153.2 | 148.6 | 148 | 154.9 | 124.1 | 137.6 | 155.6 | 179.4 | 215.4 | 174.5 | 120.7 | 154.4 | 144.3 | 170.1 | 148.3 | 151 | 162.4 | 197.4 | 231.8 | 243.3 | 225.5 | 190.7 |
| 68 | 31 | 37.8 | 77.1 | 114.6 | 91.9 | 116.3 | 93.7 | 131.4 | 101.4 | 120.9 | 144.3 | 141 | 87.7 | 52.1 | 104.1 | 126.4 | 95.9 | 84.6 | 90.1 | 89.8 | 105.8 | 149.2 | 154.1 | 124.9 |
| 69 | 267.1 | 331.7 | 492.8 | 378.7 | 373.2 | 331.7 | 290.6 | 357.8 | 319.2 | 393.1 | 332.5 | 281.9 | 272.1 | 235.3 | 231.8 | 221.8 | 177.7 | 192.9 | 175.5 | 226.1 | 316.9 | 286.7 | 283.2 | 301.6 |
| 70 | 82.5 | 81.5 | 65.8 | 56.6 | 74 | 82.3 | 66.1 | 88.3 | 90 | 112.4 | 119.5 | 80.4 | 74.4 | 72.9 | 82.7 | 78 | 69.5 | 80.2 | 74.6 | 37.9 | 92.1 | 158.1 | 178.4 | 154.5 |
| 71 | 120.1 | 117.4 | 127 | 155.4 | 150.7 | 132.9 | 120.1 | 60.6 | 57.5 | 188.9 | 148 | 158 | 148 | 144 | 139 | 172.9 | 151.5 | 142.5 | 147.8 | 79.8 | 149.6 | 177.3 | 165.6 | 169.2 |
| 72 | 109.1 | 71.3 | 66.5 | 90.9 | 128.4 | 131.4 | 91.2 | 89 | 93.3 | 99.6 | 121.4 | 89.8 | 87.2 | 127.5 | 147.9 | 130.2 | 137.8 | 144.8 | 128.4 | 120.1 | 147.7 | 120.3 | 40 | 81.5 |
| 73 | 121.6 | 135.3 | 152.1 | 160.1 | 102.7 | 142.8 | 200.8 | 184 | 201.4 | 243.4 | 186.4 | 125.4 | 141.5 | 133.4 | 126.4 | 125.9 | 135.7 | 139.6 | 37.5 | 60.4 | 112 | 140.3 | 111.1 | 91.2 |
| 74 | 55.3 | 63.2 | 51.9 | 59.6 | 49 | 76.8 | 69.9 | 67 | 69.3 | 83.1 | 81.2 | 67.1 | 66.1 | 70.5 | 57.5 | 60.6 | 76.6 | 145.4 | 46.3 | 63.6 | 65.3 | 78.8 | 80.5 | 61.3 |
| 75 | 113.3 | 131 | 138.4 | 146.1 | 134.1 | 141.7 | 127.8 | 124.2 | 92.1 | 98.1 | 94 | 94.7 | 110.1 | 105.6 | 99.7 | 101.7 | 103.4 | 111.5 | 99 | 109.3 | 71.3 | 89.2 | 121.6 | 125.3 |
| 76 | 202.6 | 176.8 | 202 | 191 | 130.7 | 154.6 | 143.1 | 133.5 | 128.6 | 148.4 | 176.1 | 155.8 | 147.4 | 154.7 | 169.3 | 151.7 | 110.2 | 107.9 | 72.1 | 81 | 84.8 | 124.5 | 120.1 | 85.6 |
| 77 | 97.2 | 89.2 | 99.7 | 90.1 | 62 | 94.3 | 80.8 | 91.7 | 80.7 | 106.8 | 99.9 | 94.5 | 86.2 | 79.2 | 82.4 | 81.7 | 107.7 | 87 | 99.5 | 89.9 | 94.3 | 142.4 | 88.9 | 91.1 |
| 78 | 238.8 | 319.5 | 329.6 | 294.8 | 262.2 | 341.1 | 267.9 | 304.4 | 484 | 889.2 | 654.4 | 376 | 415.1 | 391.8 | 368.4 | 371.9 | 349.3 | 416.9 | 364.5 | 608.3 | 830.5 | 957.1 | 838.1 | 664.4 |
| 79 | 91.6 | 82.8 | 70.1 | 102.2 | 109 | 138.2 | 106 | 121.7 | 118.9 | 149.3 | 156 | 138 | 132 | 123.4 | 127.7 | 125 | 122.5 | 137.9 | 109.7 | 133.7 | 126.3 | 138.3 | 140.2 | 128.8 |
| 80 | 207.6 | 301.9 | 400.1 | 589 | 470.3 | 456.9 | 406.9 | 306.8 | 191.4 | 197.9 | 184.8 | 213.7 | 312.9 | 266.1 | 289.2 | 324 | 295.8 | 310.2 | 221.9 | 185.4 | 179.6 | 166.1 | 137.2 | 157.2 |
| 81 | 153.3 | 144.5 | 139.6 | 159.4 | 188.4 | 223.6 | 237 | 196.8 | 175 | 156.3 | 174.5 | 167.6 | 148.4 | 102.2 | 106.7 | 134.7 | 160.4 | 125.7 | 121.2 | 140.6 | 134.4 | 140 | 153.4 | 141.8 |
| 82 | 129.6 | 306.9 | 126.1 | 41.4 | 23.8 | 269.3 | 339.3 | 202.2 | 141.7 | 150.8 | 182.5 | 252.6 | 195.1 | 217 | 400.2 | 405.6 | 400.8 | 295.2 | 125 | 119.3 | 125.6 | 134.1 | 178.3 | 216.6 |
| 83 | 135.8 | 289 | 273.1 | 296.1 | 280.8 | 284.5 | 276.3 | 265.8 | 109.2 | 81.5 | 76.7 | 66.3 | 120.5 | 258.9 | 306.3 | 714.4 | 237.2 | 232.2 | 224.1 | 209.3 | 174.2 | 77.2 | 81.2 | 102 |
| 84 | 258.5 | 354 | 648.4 | 639.2 | 669.1 | 507.9 | 370.4 | 273.6 | 128.3 | 141.5 | 145.4 | 192.5 | 343 | 421.6 | 416.3 | 385 | 349.6 | 183.3 | 163.7 | 164.3 | 125.3 | 155.1 | 144.7 | 160.1 |
| 85 | 98.5 | 98.5 | 108.7 | 103.3 | 91.9 | 96.4 | 119.7 | 85.9 | 81.3 | 98.9 | 100.7 | 77.9 | 111.5 | 88.4 | 82.2 | 92.3 | 93 | 79.8 | 80.1 | 87 | 80.3 | 82.3 | 71.2 | 70.6 |
| 86 | 316.3 | 305.7 | 332.4 | 380.5 | 272 | 304.4 | 322.7 | 365.4 | 333.3 | 337.3 | 335.3 | 334.6 | 351.1 | 381.1 | 497.7 | 613.7 | 491.5 | 328.9 | 327.8 | 346.8 | 344.1 | 357.5 | 316.2 | 330.2 |
| 87 | 199.8 | 185.7 | 160.2 | 147.7 | 77.4 | 59.2 | 91.3 | 124.1 | 171.6 | 189.5 | 158.7 | 86.4 | 87.1 | 95 | 114.2 | 99.4 | 84.7 | 99.4 | 90 | 94.3 | 106.2 | 156.3 | 144.1 | 83.5 |
| Average: | 124.4586 | 130.4023 | 144.5874 | 154.6103 | 140.4529 | 148.1345 | 131.5241 | 132.0276 | 131.3092 | 152.8425 | 153.6678 | 136.0103 | 133.7448 | 129.454 | 138.1609 | 145.4471 | 131.9379 | 128.3437 | 115.7471 | 122.0609 | 133.1057 | 156.831 | 151.8517 | 135.2425 |

**Analysis of Energy Consumption Data**

The analysis consists the following comparison scenarios:

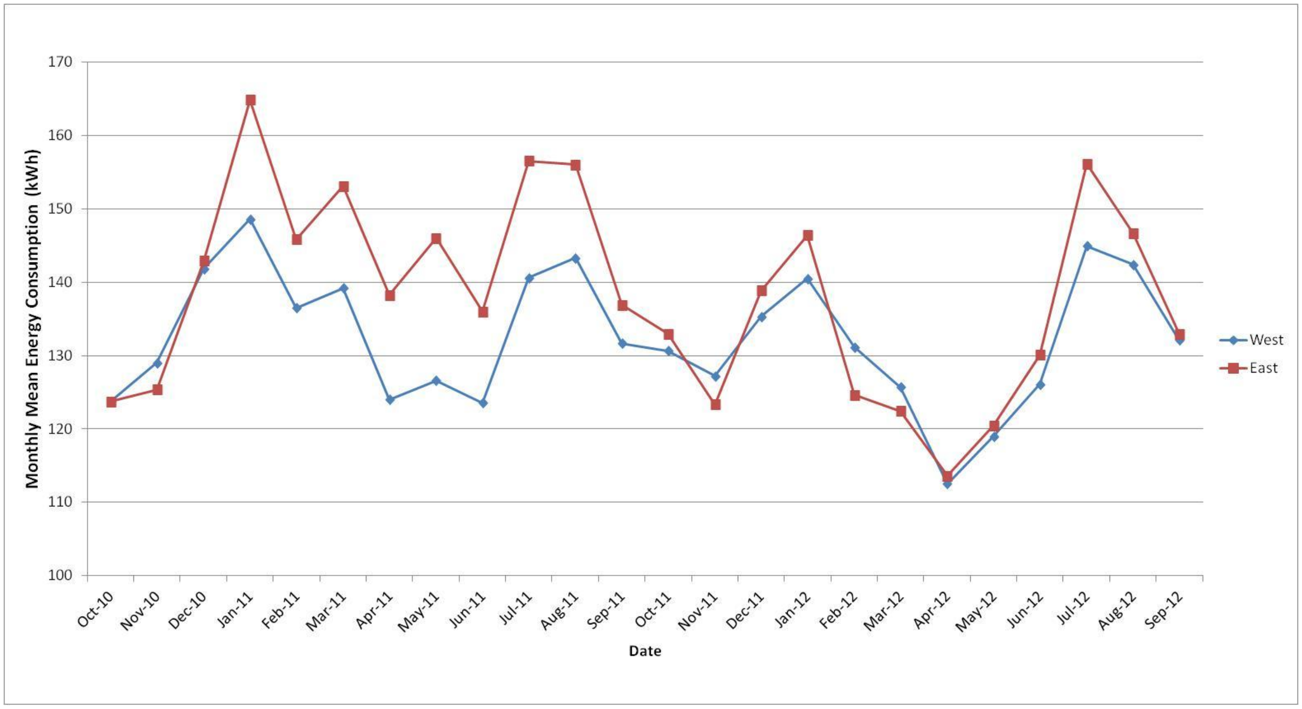
1. Surveyed and non-surveyed occupants
2. East and West (surveyed occupants)
3. East and West (non-surveyed occupants)

The purpose of the analysis to evaluate any potential bias between the samples; whether surveyed/non-surveyed occupants and orientations. If there is a significant difference between the samples, then the surveyed occupants are not representative of the Toronto MURB. The figure below shows that a majority of the time, surveyed occupants consume less energy than the non-surveyed occupants. The overall average of surveyed occupants is 131.74 kWh/month. The overall average of non-surveyed occupants is 137.58 kWh/month.

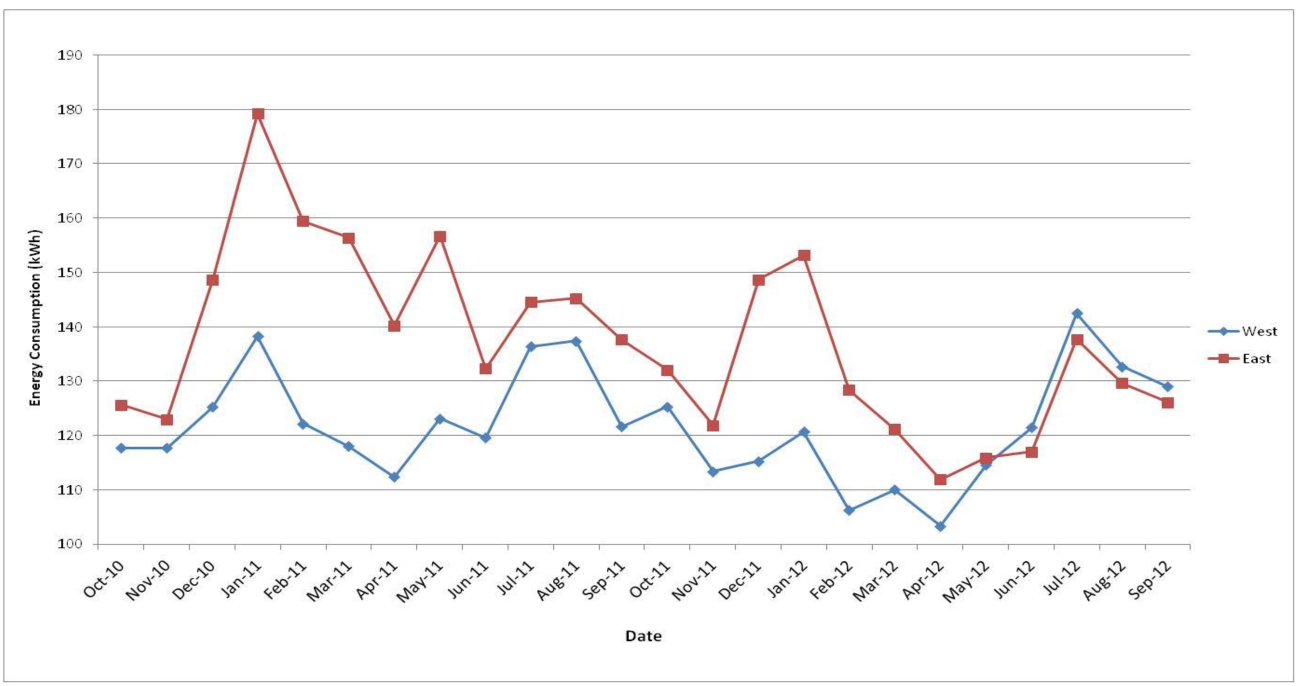



**Monthly mean energy consumption between surveyed and non-surveyed occupants**

The figures below is the comparison of monthly mean energy consumption between the orientation of surveyed occupants. It is evident that a majority of the time, West oriented apartments consume less energy than East.

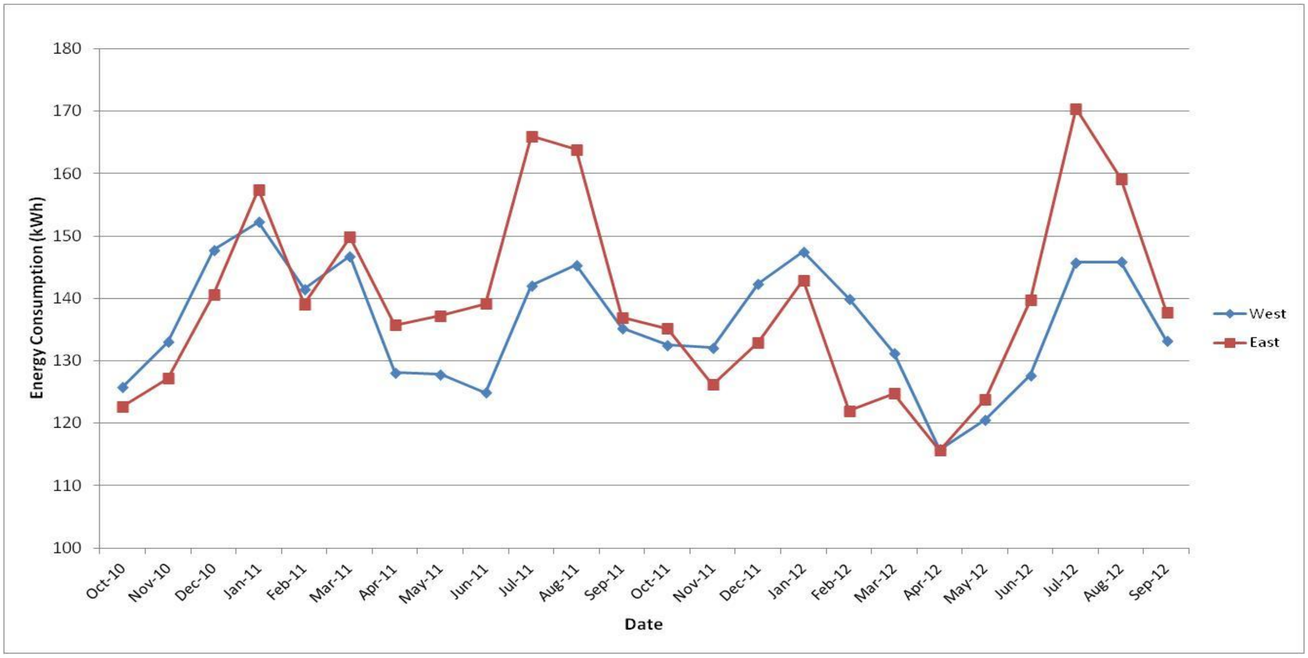



**Monthly mean energy consumption by orientation (surveyed and non-surveyed)**




**Monthly mean energy consumption of surveyed occupants by orientation**

The figure below shows a similar trend is found (like surveyed occupants) when comparing orientations between non-surveyed occupants. However, there are some months where the West consumes more than East.




**Monthly mean energy consumption of non-surveyed occupants by orientation**

Overall, surveyed occupants consumed less energy than the non-surveyed occupants. When comparing energy consumption by orientation, a majority of the time, West-orientated units consumed less than East-oriented units. There is a significant difference between energy consumption by orientation found between surveyed occupants. Non-surveyed occupants, however, had fluctuations in energy consumption and does not show a strong pattern. Thus, the surveyed population is not representative of the whole population in the Toronto MURB because the surveyed occupants pattern is not prevalent in the other groups. The surveyed population consume significantly less energy than the non-surveyed occupants and the Toronto MURB, as a whole.

# Appendix D: Coded Dataset

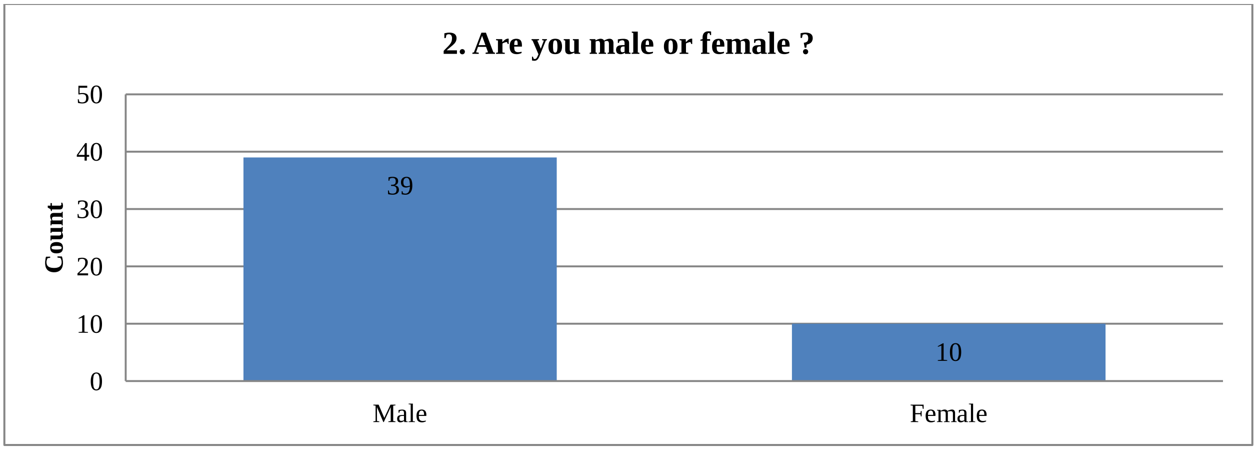
| Month | Year | Energy consumption | Orientation | Gender | Age | Grow Up | Residency | #household | Hours per day | Income | Mean Temp (°C) | Sum Total Precip (mm) | Mean Dir of Max Gust (10's deg) | Mean Spd of Max Gust (km/h) | Electronic ratio | TV - Use | TV - Type | Cable Box Use | Stove Use | Oven Use | Microwave Use | Computer Use | Computer - Age | Internet Use | CFLs | Incandescent | turned on longer than 3 hours or more? | Winter - Hours per day light bulbs turned on | Summer - Hours per day light bulbs turned on | Number of light fixtures | Energy consumption behavior ratio | How satisfied are you with...the appliances in your apartment (i.e. stove, refridgerator, etc.)? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| October | 2010 | 99.6 | 1 | 1 | 4 | 1 | 4 | 1 | 4 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.136 | 3 | 3 | 1 | 1 | 0 | 4 | 0 | 0 | 0 | 3 | 1 | 1 | 1 | 3 | 1 | 1.25 | 1 |
| October | 2010 | 208.1 | 2 | 1 | 4 | 2 | 4 | 1 | 4 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.227 | 3 | 1 | 2 | 1 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 1 | 1 | 3 | 1 | 1.875 | 4 |
| October | 2010 | 152.7 | 2 | 1 | 1 | 3 | 2 | 1 | 2 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.273 | 2 | 2 | 2 | 2 | 2 | 0 | 2 | 1 | 3 | 0 | 3 | 1 | 1 | 3 | 0 | 2.625 | 4 |
| October | 2010 | 120.6 | 2 | 1 | 3 | 4 | 4 | 1 | 2 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.273 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 2 | 4 | 0 | 1 | 3 | 3 | 0 | 1.125 | 3 |
| October | 2010 | 79.9 | 2 | 2 | 2 | 4 | 3 | 1 | 1 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.091 | 1 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 1 | 3 | 3 | 0 | 1.75 | 1 |
| October | 2010 | 129.3 | 1 | 1 | 4 | 4 | 3 | 1 | 1 | 4 | 10.2 | 57.2 | 18.16 | 31.29 | 0.182 | 1 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 3 | 3 | 0 | 1.875 | 7 |
| October | 2010 | 97.7 | 2 | 1 | 3 | 3 | 4 | 1 | 2 | 3 | 10.2 | 57.2 | 18.16 | 31.29 | 0.5 | 2 | 1 | 1 | 1 | 1 | 2 | 2 | 1 | 2 | 3 | 0 | 1 | 2 | 1 | 1 | 1.5 | 2 |
| October | 2010 | 107.7 | 2 | 1 | 2 | 4 | 4 | 1 | 3 | 4 | 10.2 | 57.2 | 18.16 | 31.29 | 0.364 | 1 | 1 | 1 | 1 | 1 | 4 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1.75 | 1 |
| October | 2010 | 207.3 | 1 | 1 | 4 | 1 | 4 | 1 | 3 | 4 | 10.2 | 57.2 | 18.16 | 31.29 | 0.227 | 3 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 1 | 2 | 3 | 5 | 1 | 1 |
| October | 2010 | 124.7 | 2 | 2 | 1 | 4 | 2 | 2 | 2 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.136 | 2 | 2 | 2 | 1 | 1 | 0 | 4 | 1 | 3 | 0 | 3 | 1 | 3 | 3 | 3 | 2 | 1 |
| October | 2010 | 78.3 | 2 | 2 | 2 | 4 | 2 | 1 | 2 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.318 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 1 | 3 | 0 | 1.75 | 1 |
| October | 2010 | 153.1 | 2 | 1 | 2 | 1 | 1 | 1 | 2 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.182 | 3 | 1 | 1 | 1 | 0 | 2 | 3 | 1 | 3 | 2 | 3 | 1 | 1 | 3 | 0 | 2 | 2 |
| October | 2010 | 83.5 | 2 | 1 | 2 | 1 | 4 | 2 | 1 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.227 | 2 | 3 | 0 | 2 | 2 | 0 | 0 | 0 | 0 | 3 | 2 | 1 | 1 | 1 | 0 | 1.75 | 2 |
| October | 2010 | 201 | 2 | 2 | 4 | 1 | 4 | 1 | 4 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.227 | 1 | 2 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 1 | 4 | 2 | 0 | 1.875 | 1 |
| October | 2010 | 36.7 | 1 | 1 | 2 | 5 | 2 | 1 | 2 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.455 | 0 | 0 | 0 | 1 | 1 | 0 | 3 | 1 | 4 | 1 | 3 | 0 | 1 | 3 | 0 | 1.875 | 2 |
| October | 2010 | 75.2 | 2 | 1 | 3 | 1 | 4 | 1 | 2 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.364 | 2 | 1 | 0 | 3 | 0 | 2 | 0 | 0 | 0 | 3 | 1 | 2 | 2 | 3 | 1 | 2.5 | 1 |
| October | 2010 | 114.5 | 2 | 2 | 3 | 4 | 2 | 1 | 2 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.227 | 1 | 3 | 0 | 2 | 0 | 0 | 2 | 1 | 2 | 3 | 1 | 1 | 1 | 3 | 0 | 2 | 1 |
| October | 2010 | 54 | 1 | 1 | 3 | 4 | 2 | 1 | 2 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.045 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 1 | 3 | 3 | 0 | 0.375 | 4 |
| October | 2010 | 123.9 | 1 | 2 | 1 | 6 | 1 | 1 | 2 | 4 | 10.2 | 57.2 | 18.16 | 31.29 | 0.182 | 0 | 0 | 0 | 1 | 0 | 4 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 3 | 1 | 1 | 1 |
| October | 2010 | 141.9 | 1 | 1 | 2 | 4 | 1 | 1 | 2 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.136 | 0 | 0 | 0 | 0 | 1 | 0 | 3 | 1 | 3 | 3 | 0 | 1 | 2 | 2 | 3 | 2 | 2 |
| October | 2010 | 75.5 | 2 | 1 | 4 | 3 | 4 | 1 | 3 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.318 | 3 | 1 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 5 | 0 | 2 | 2 | 1 | 6 | 1.125 | 1 |

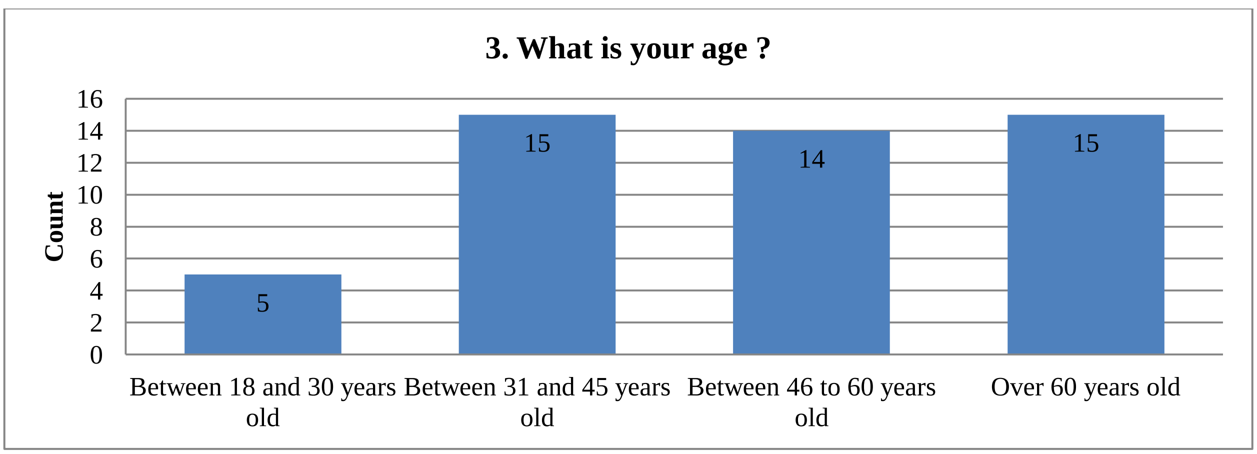
| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| October | 2010 | 92.1 | 1 | 1 | 2 | 4 | 4 | 1 | 1 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.091 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 2 | 2 | 1 | 1 | 3 | 0 | 1.375 | 1 |
| October | 2010 | 72.8 | 2 | 1 | 4 | 6 | 4 | 1 | 2 | 3 | 10.2 | 57.2 | 18.16 | 31.29 | 0.227 | 2 | 3 | 0 | 1 | 0 | 4 | 0 | 0 | 0 | 5 | 0 | 1 | 1 | 1 | 1 | 1.5 | 2 |
| October | 2010 | 329.3 | 2 | 1 | 4 | 1 | 4 | 1 | 4 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.227 | 5 | 3 | 3 | 1 | 1 | 4 | 0 | 0 | 0 | 3 | 0 | 1 | 4 | 4 | 2 | 1.25 | 1 |
| October | 2010 | 47.6 | 2 | 1 | 2 | 4 | 4 | 1 | 2 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.227 | 2 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 1 | 1 | 1 | 5 | 1 | 1 |
| October | 2010 | 125.7 | 1 | 1 | 4 | 1 | 2 | 1 | 3 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.136 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 5 | 1 | 1 | 3 | 3 | 3 | 1.25 | 1 |
| October | 2010 | 206.9 | 2 | 1 | 4 | 1 | 4 | 1 | 1 | 4 | 10.2 | 57.2 | 18.16 | 31.29 | 0.045 | 3 | 3 | 0 | 3 | 3 | 0 | 0 | 0 | 0 | 2 | 2 | 1 | 1 | 3 | 1 | 0.625 | 1 |
| October | 2010 | 3.4 | 1 | 1 | 1 | 4 | 2 | 1 | 1 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.318 | 2 | 2 | 2 | 0 | 1 | 3 | 3 | 1 | 3 | 3 | 3 | 1 | 3 | 3 | 2 | 3.375 | 1 |
| October | 2010 | 330.5 | 1 | 1 | 3 | 3 | 3 | 1 | 4 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.409 | 4 | 1 | 0 | 1 | 1 | 2 | 3 | 1 | 3 | 0 | 6 | 1 | 2 | 1 | 2 | 1.875 | 2 |
| October | 2010 | 114.1 | 2 | 1 | 2 | 4 | 2 | 1 | 2 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.318 | 2 | 1 | 0 | 1 | 1 | 4 | 2 | 2 | 2 | 1 | 3 | 1 | 1 | 1 | 5 | 1.875 | 2 |
| October | 2010 | 107.5 | 2 | 1 | 2 | 4 | 2 | 1 | 1 | 3 | 10.2 | 57.2 | 18.16 | 31.29 | 0.227 | 2 | 2 | 1 | 1 | 0 | 0 | 2 | 1 | 1 | 3 | 0 | 1 | 3 | 3 | 0 | 1 | 4 |
| October | 2010 | 72.9 | 1 | 1 | 4 | 7 | 4 | 2 | 1 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.273 | 1 | 2 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 2 | 2 | 1 | 1 | 3 | 1 | 0.75 | 4 |
| October | 2010 | 180.8 | 2 | 2 | 3 | 4 | 3 | 1 | 2 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.136 | 3 | 2 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 1 | 3 | 3 | 0 | 1.25 | 4 |
| October | 2010 | 158.1 | 2 | 1 | 2 | 4 | 1 | 1 | 2 | 4 | 10.2 | 57.2 | 18.16 | 31.29 | 0.182 | 2 | 1 | 0 | 1 | 0 | 0 | 2 | 1 | 2 | 0 | 3 | 1 | 3 | 3 | 1 | 1.75 | 4 |
| October | 2010 | 81.8 | 2 | 1 | 3 | 4 | 2 | 1 | 2 | 3 | 10.2 | 57.2 | 18.16 | 31.29 | 0.318 | 2 | 3 | 0 | 0 | 0 | 2 | 0 | 1 | 0 | 4 | 0 | 2 | 2 | 1 | 1 | 0.625 | 1 |
| October | 2010 | 132.3 | 1 | 1 | 3 | 1 | 4 | 1 | 2 | 4 | 10.2 | 57.2 | 18.16 | 31.29 | 0.182 | 4 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 2 | 2 | 2 | 0 | 1.875 | 2 |
| October | 2010 | 121 | 2 | 1 | 3 | 1 | 2 | 2 | 1 | 3 | 10.2 | 57.2 | 18.16 | 31.29 | 0.545 | 4 | 3 | 1 | 2 | 2 | 1 | 3 | 1 | 3 | 6 | 4 | 2 | 4 | 2 | 6 | 2.25 | 1 |
| October | 2010 | 159.6 | 2 | 1 | 3 | 4 | 1 | 1 | 1 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.136 | 2 | 1 | 0 | 1 | 0 | 0 | 3 | 1 | 3 | 4 | 0 | 1 | 1 | 3 | 1 | 1 | 1 |
| October | 2010 | 46 | 1 | 1 | 2 | 4 | 2 | 1 | 1 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.045 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1.75 | 1 |
| October | 2010 | 68.4 | 2 | 1 | 2 | 4 | 2 | 2 | 2 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.227 | 3 | 1 | 3 | 1 | 1 | 4 | 2 | 1 | 2 | 0 | 2 | 1 | 1 | 1 | 3 | 2 | 3 |
| October | 2010 | 124.5 | 1 | 2 | 4 | 1 | 4 | 1 | 4 | 4 | 10.2 | 57.2 | 18.16 | 31.29 | 0.364 | 3 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 2 | 2 | 3 | 2 | 1.75 | 1 |
| October | 2010 | 184.1 | 1 | 1 | 1 | 4 | 1 | 1 | 2 | 4 | 10.2 | 57.2 | 18.16 | 31.29 | 0.182 | 3 | 3 | 0 | 1 | 1 | 2 | 0 | 0 | 0 | 1 | 2 | 1 | 1 | 1 | 3 | 2 | 4 |
| October | 2010 | 161.5 | 2 | 1 | 4 | 7 | 4 | 1 | 3 | 4 | 10.2 | 57.2 | 18.16 | 31.29 | 0.136 | 3 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 4 | 1 | 1 | 4 | 1 | 4 | 1.25 | 2 |
| October | 2010 | 97.4 | 1 | 1 | 3 | 7 | 2 | 1 | 3 | 3 | 10.2 | 57.2 | 18.16 | 31.29 | 0.091 | 0 | 0 | 0 | 2 | 1 | 2 | 0 | 0 | 0 | 3 | 3 | 2 | 4 | 4 | 0 | 1.375 | 1 |
| October | 2010 | 140.5 | 2 | 1 | 3 | 7 | 4 | 1 | 1 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.182 | 3 | 1 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 4 | 0 | 1 | 1 | 3 | 1 | 1.25 | 4 |
| October | 2010 | 70.8 | 2 | 1 | 2 | 4 | 4 | 1 | 2 | 3 | 10.2 | 57.2 | 18.16 | 31.29 | 0.136 | 2 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 0 | 4 | 0 | 1 | 3 | 3 | 0 | 1.25 | 1 |
| October | 2010 | 78.3 | 2 | 2 | 4 | 1 | 2 | 2 | 2 | 2 | 10.2 | 57.2 | 18.16 | 31.29 | 0.136 | 2 | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 1 | 3 | 3 | 0 | 1.25 | 1 |
| October | 2010 | 123.4 | 2 | 2 | 4 | 1 | 4 | 1 | 4 | 1 | 10.2 | 57.2 | 18.16 | 31.29 | 0.318 | 4 | 2 | 2 | 1 | 1 | 0 | 3 | 2 | 3 | 0 | 4 | 1 | 3 | 3 | 1 | 2.75 | 4 |

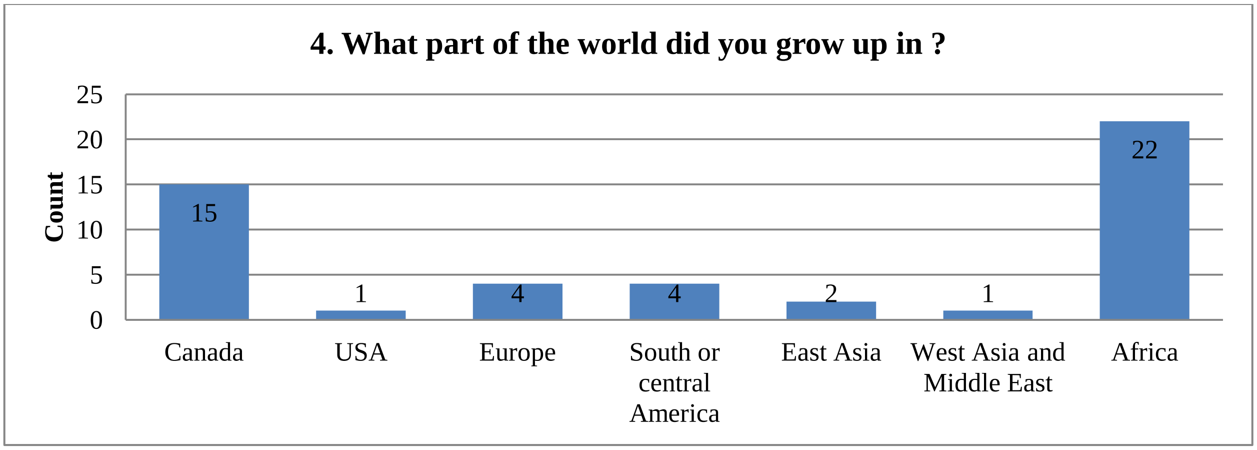
## Appendix E: Survey Results (Raw Data)

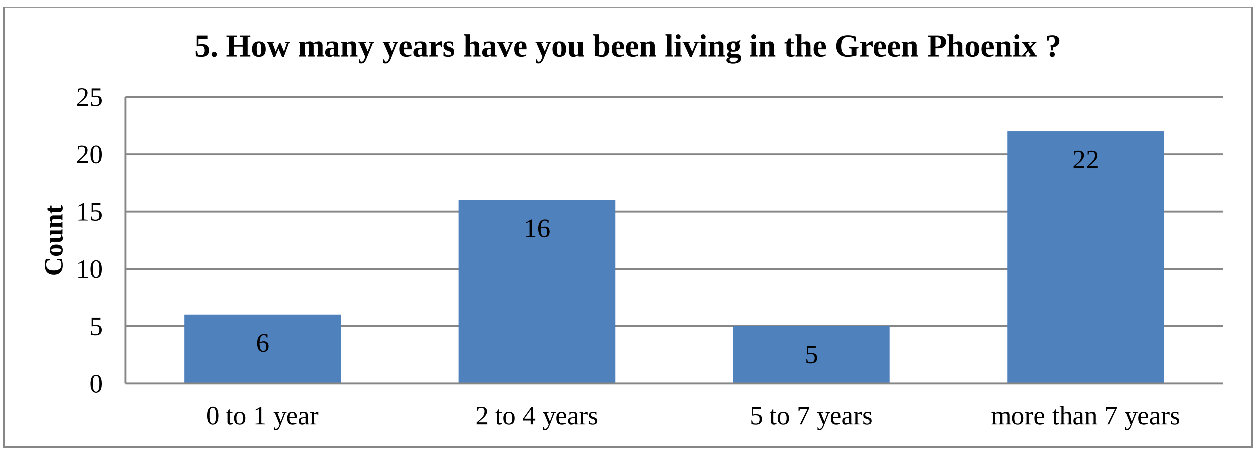
The following figures in this appendix are the raw survey results tabulated from the 49 surveys.

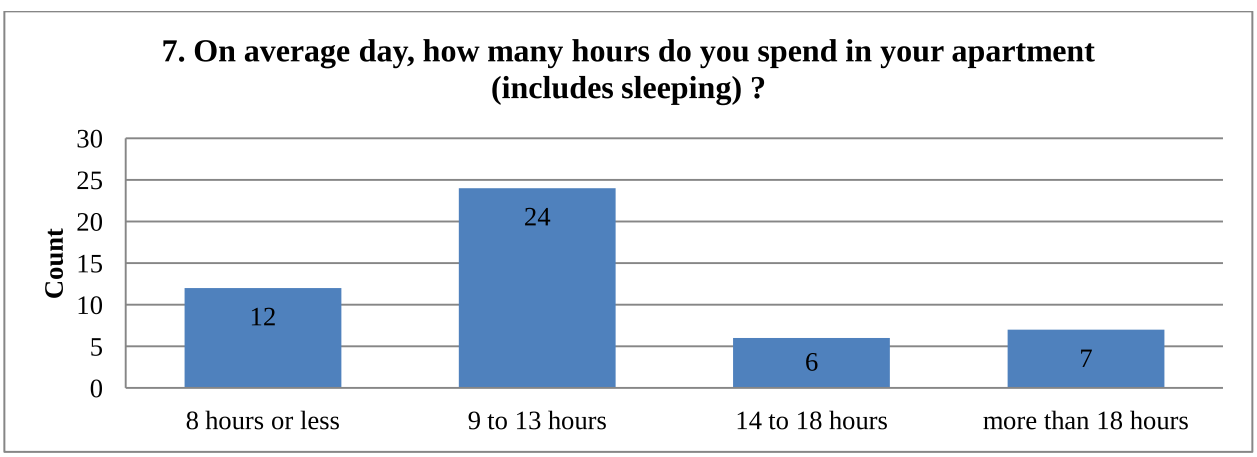
### Part 1: General Information

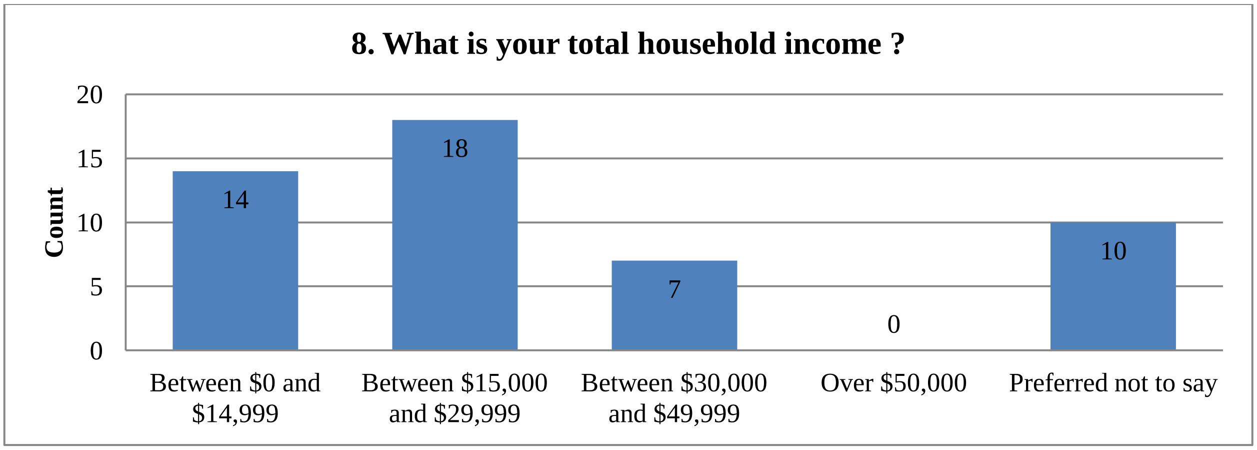


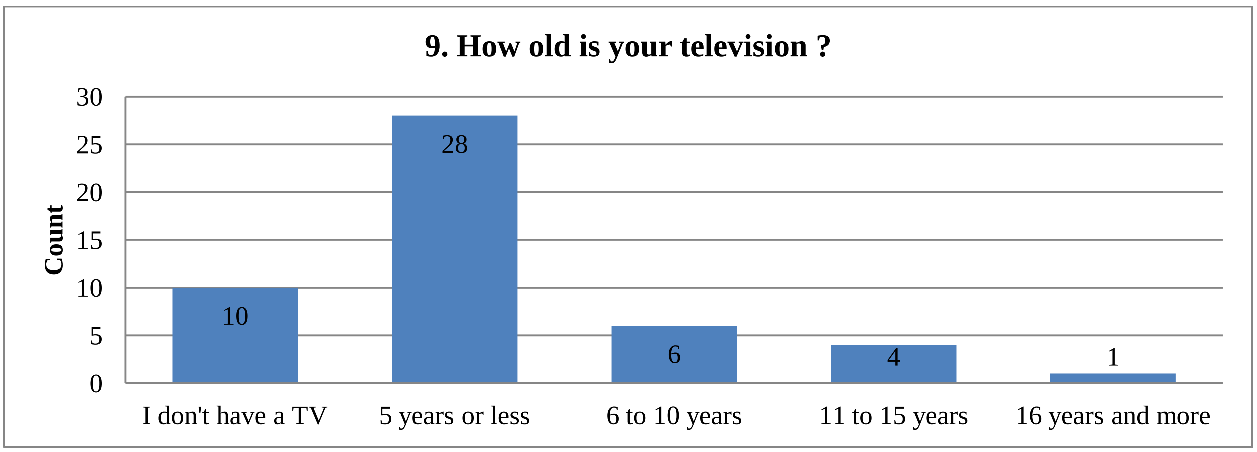

4. What part of the world did you grow up in ?
Count
25
20
15
10
5
0
15
1
4
4
2
1
22
Canada
USA
Europe
South or central America
East Asia
West Asia and Middle East
Africa

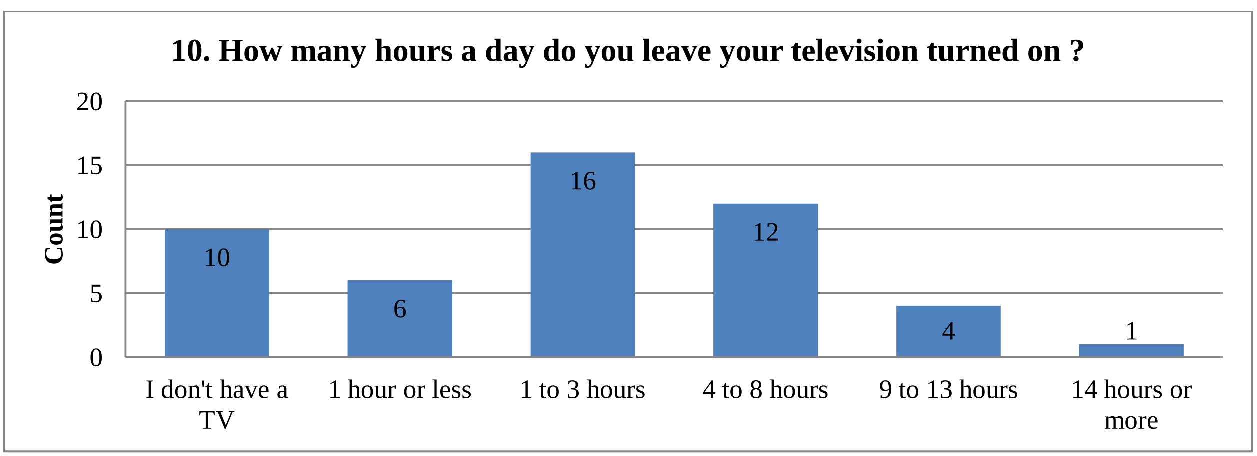

5. How many years have you been living in the Green Phoenix ?
Count
25
20
15
10
5
0
6
16
5
22
0 to 1 year
2 to 4 years
5 to 7 years
more than 7 years

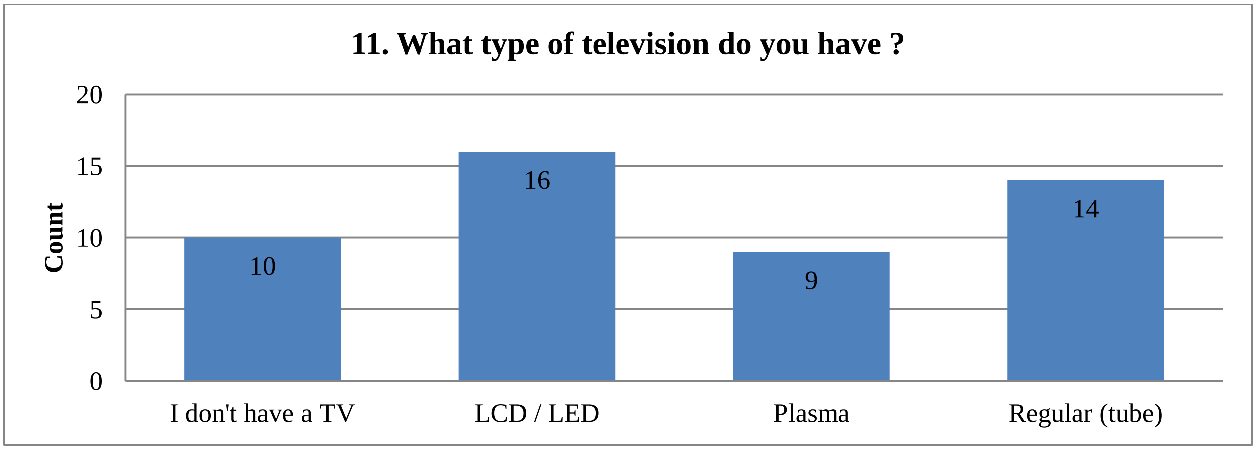

7. On average day, how many hours do you spend in your apartment (includes sleeping) ?
Count
30
25
20
15
10
5
0
12
24
6
7
8 hours or less
9 to 13 hours
14 to 18 hours
more than 18 hours

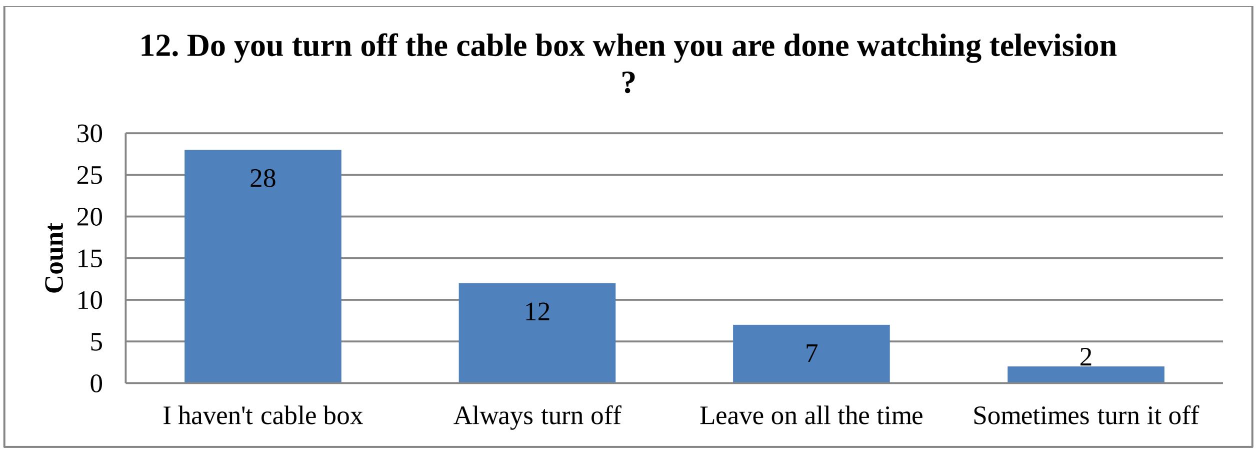


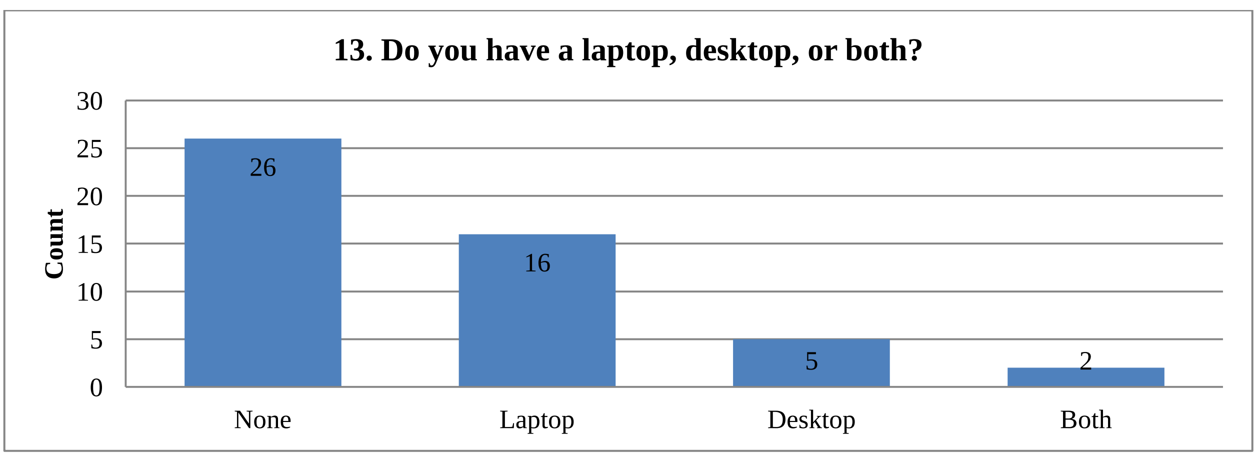

## Part 2: Electrical Devices

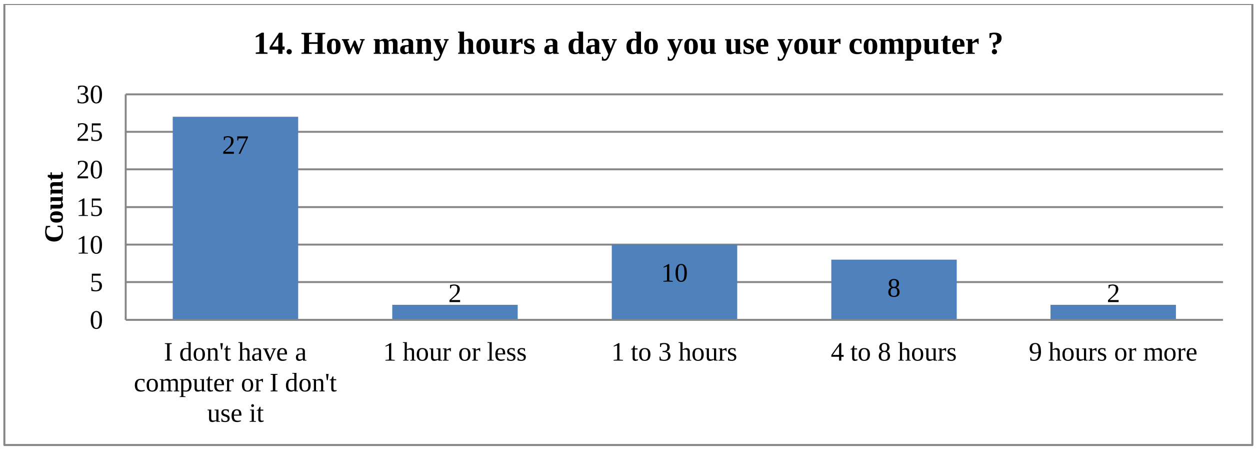


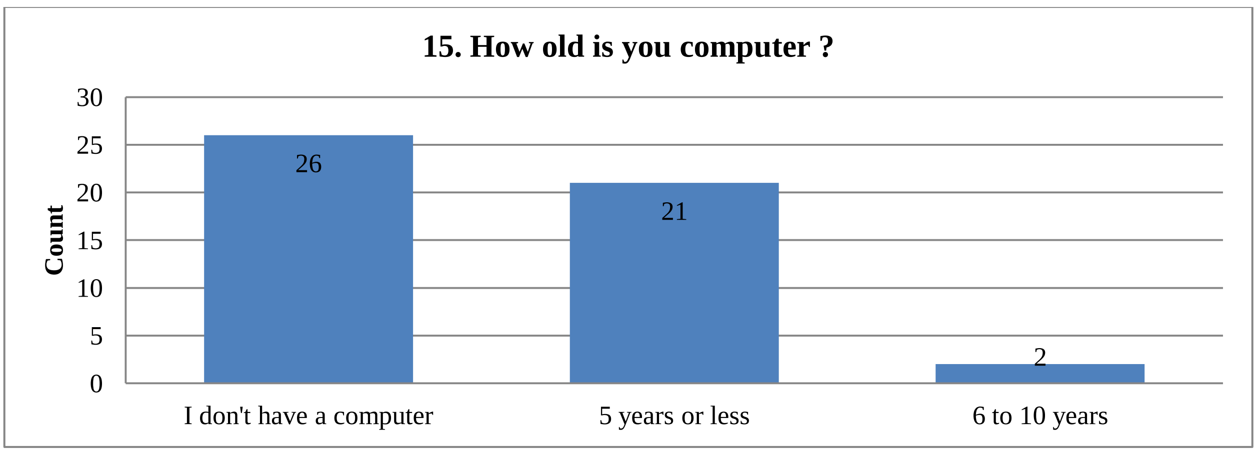



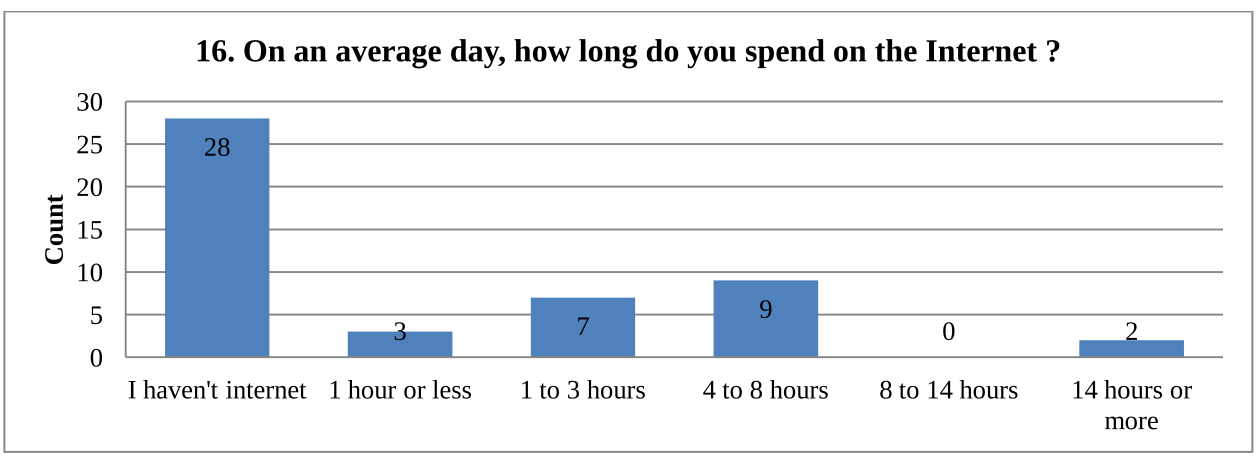

11. What type of television do you have ?
Count
20
15
10
5
0
10
16
9
14
I don't have a TV
LCD / LED
Plasma
Regular (tube)

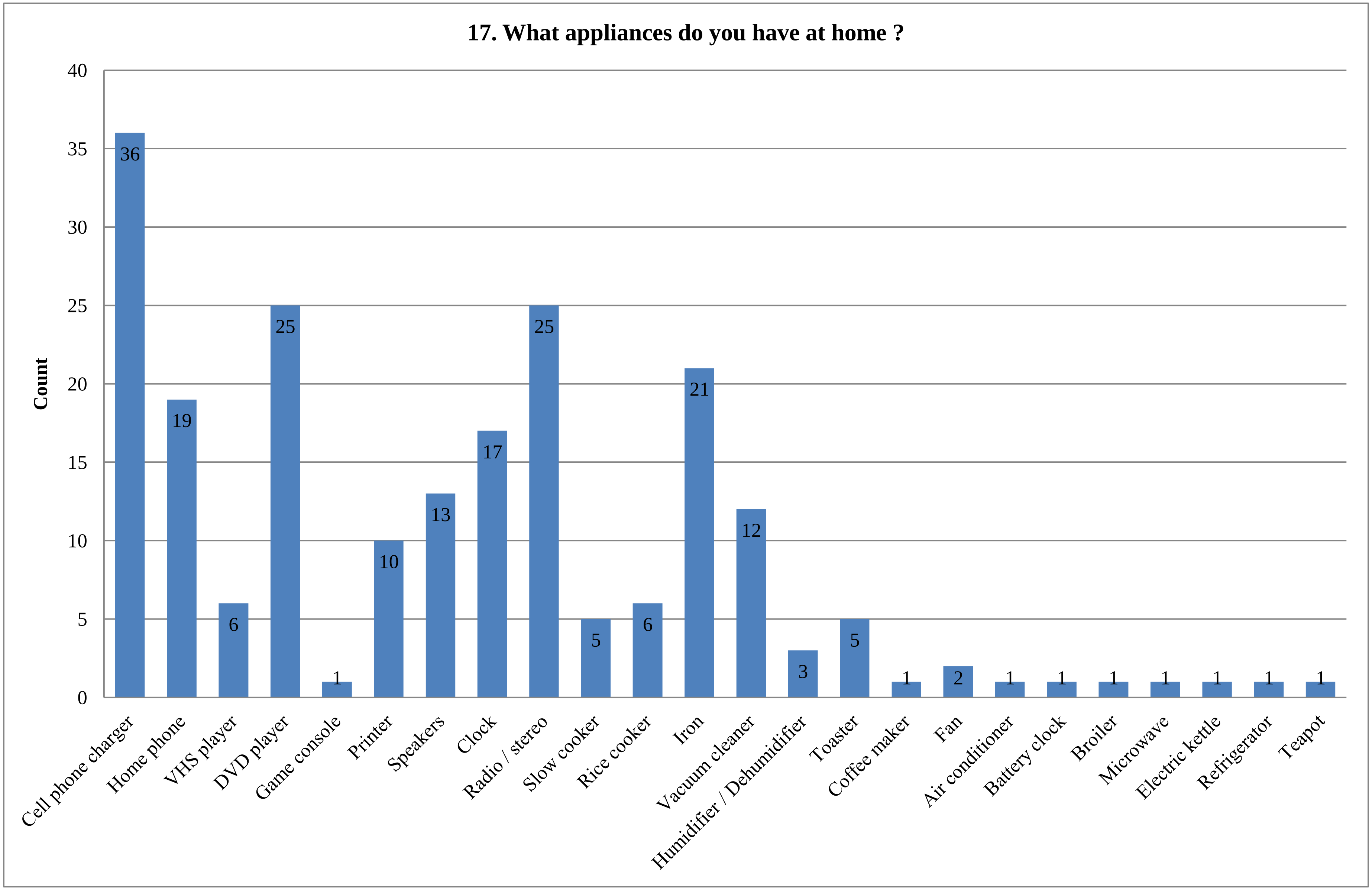

12. Do you turn off the cable box when you are done watching television ?
Count
30
25
20
15
10
5
0
28
12
7
2
I haven't cable box
Always turn off
Leave on all the time
Sometimes turn it off


13. Do you have a laptop, desktop, or both?
Count
30
25
20
15
10
5
0
26
16
5
2
None
Laptop
Desktop
Both


14. How many hours a day do you use your computer ?
Count
30
25
20
15
10
5
0
27
2
10
8
2
I don't have a computer or I don't use it
1 hour or less
1 to 3 hours
4 to 8 hours
9 hours or more

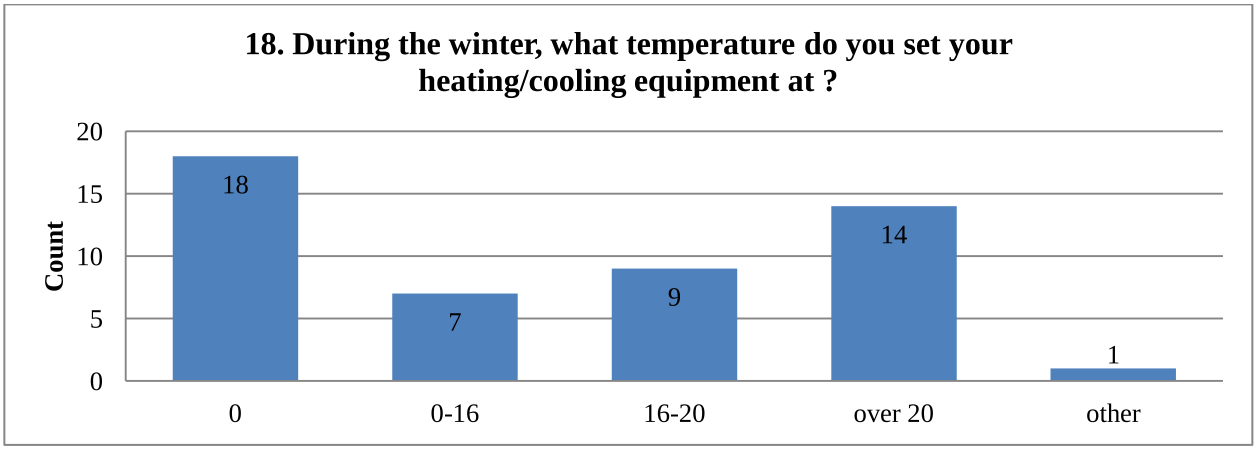

15. How old is you computer ?
Count
30
25
20
15
10
5
0
26
21
2
I don't have a computer
5 years or less
6 to 10 years

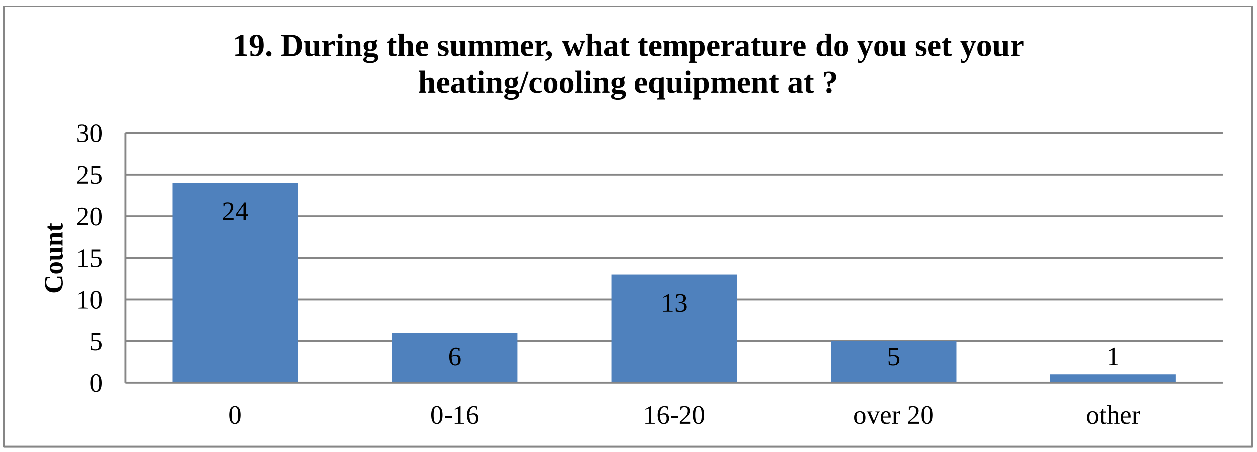

16. On an average day, how long do you spend on the Internet ?
Count
30
25
20
15
10
5
0
28
3
7
9
0
2
I haven't internet
1 hour or less
1 to 3 hours
4 to 8 hours
8 to 14 hours
14 hours or more

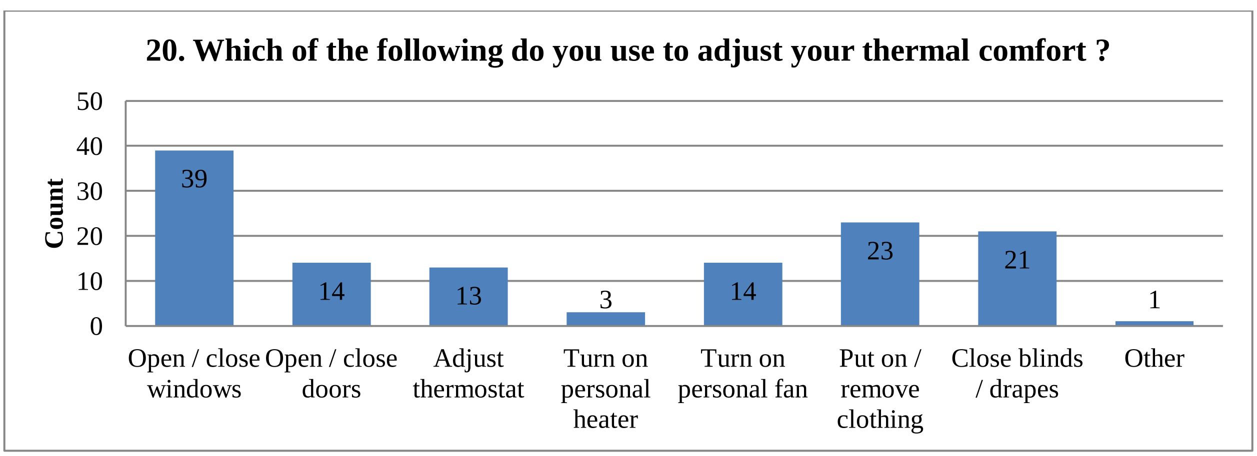


17. What appliances do you have at home ?
Count
40
35
30
25
20
15
10
5
0
36
19
6
25
1
10
13
17
25
5
6
21
12
3
5
1
2
1
1
1
1
1
1
1
Cell phone charger
Home phone
VHS player
DVD player
Game console
Printer
Speakers
Clock
Radio / stereo
Slow cooker
Rice cooker
Iron
Vacuum cleaner
Humidifier / Dehumidifier
Toaster
Coffee maker
Fan
Air conditioner
Battery clock
Broiler
Microwave
Electric kettle
Refrigerator
Teapot

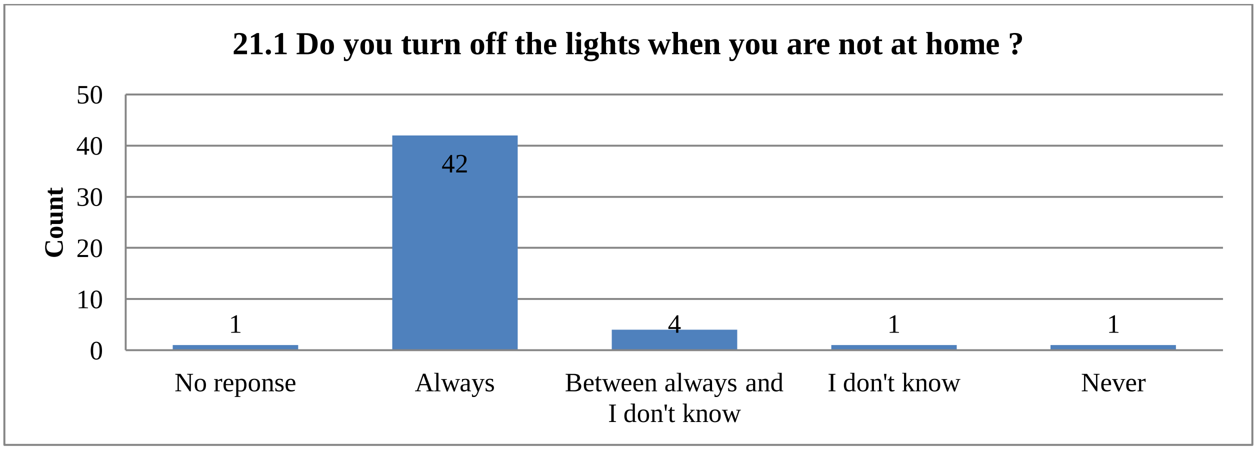
## Part 3: Heating and Cooling

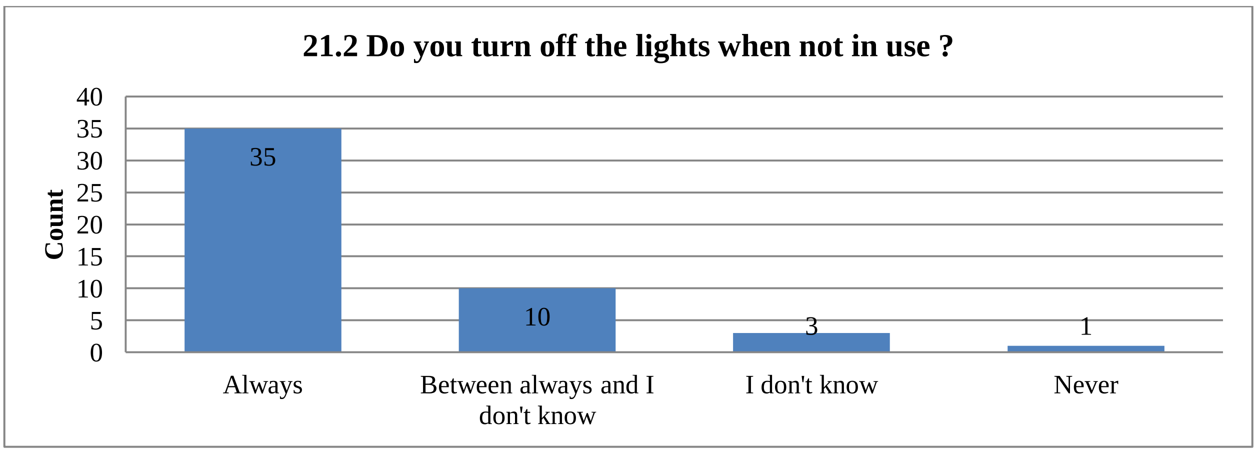


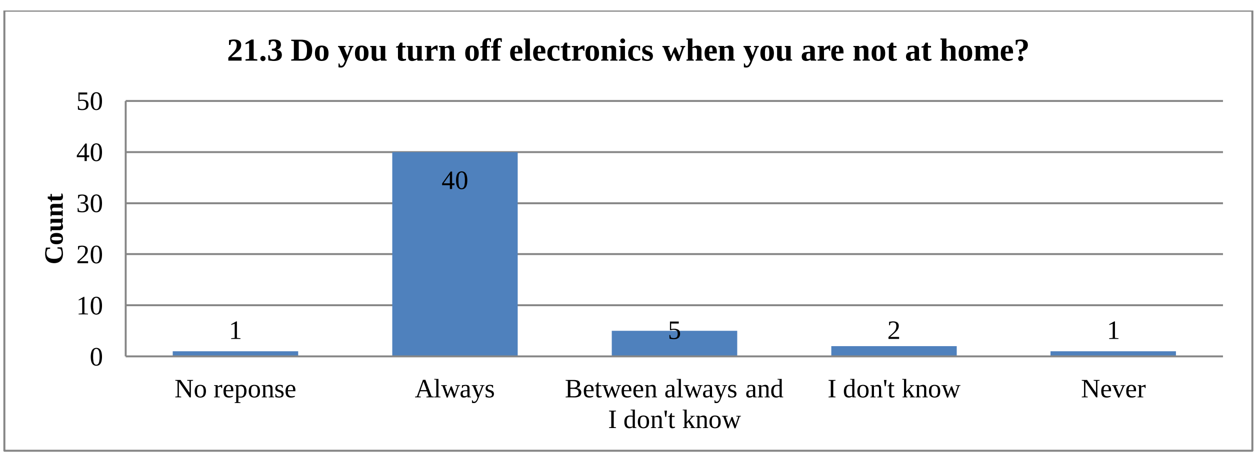



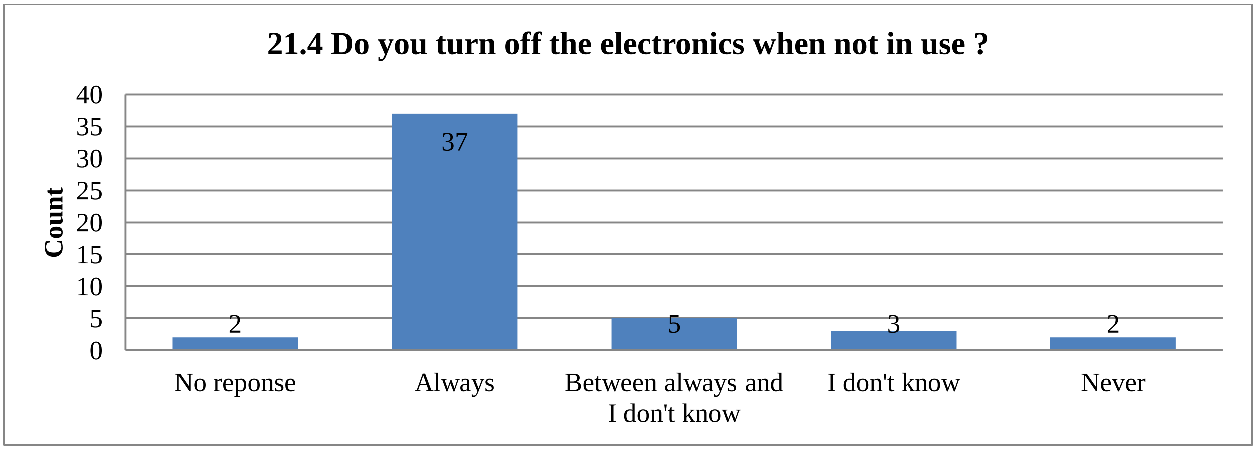



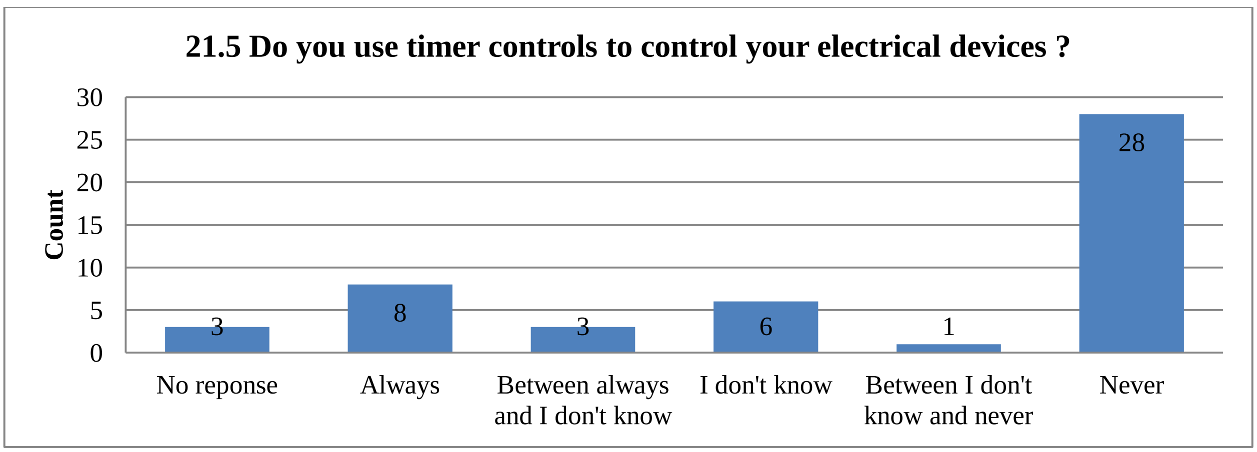
## Part 4: Energy Behaviour

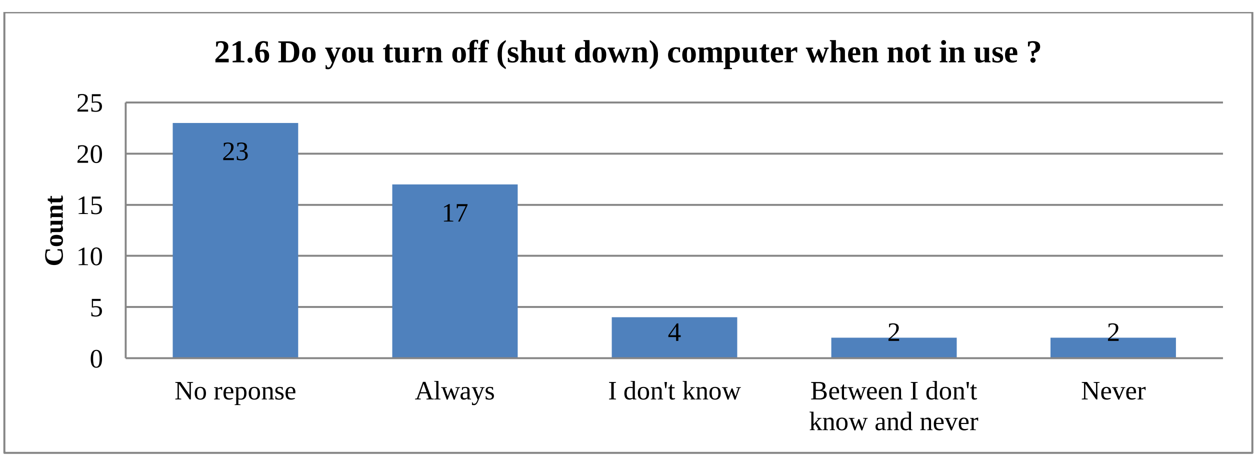


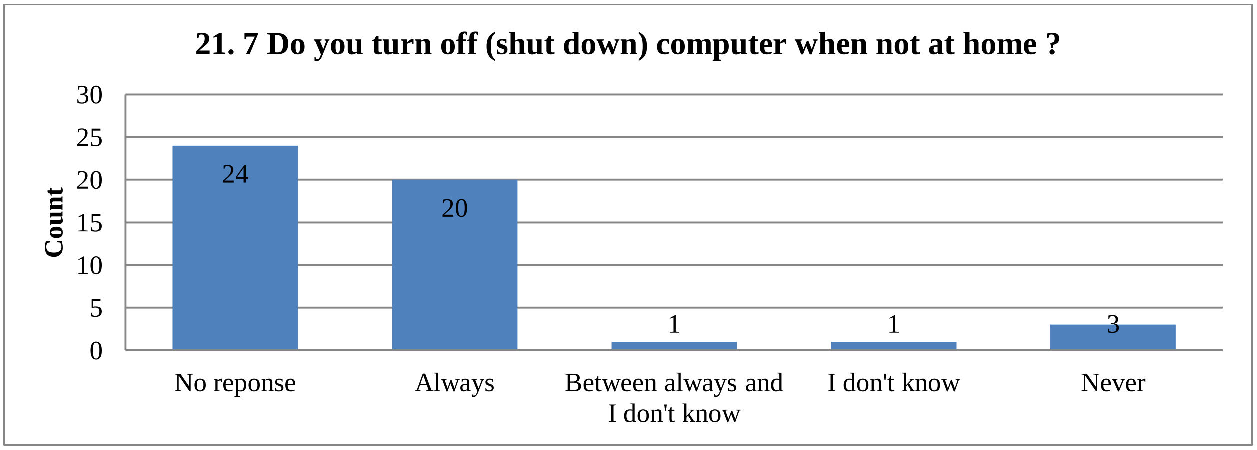



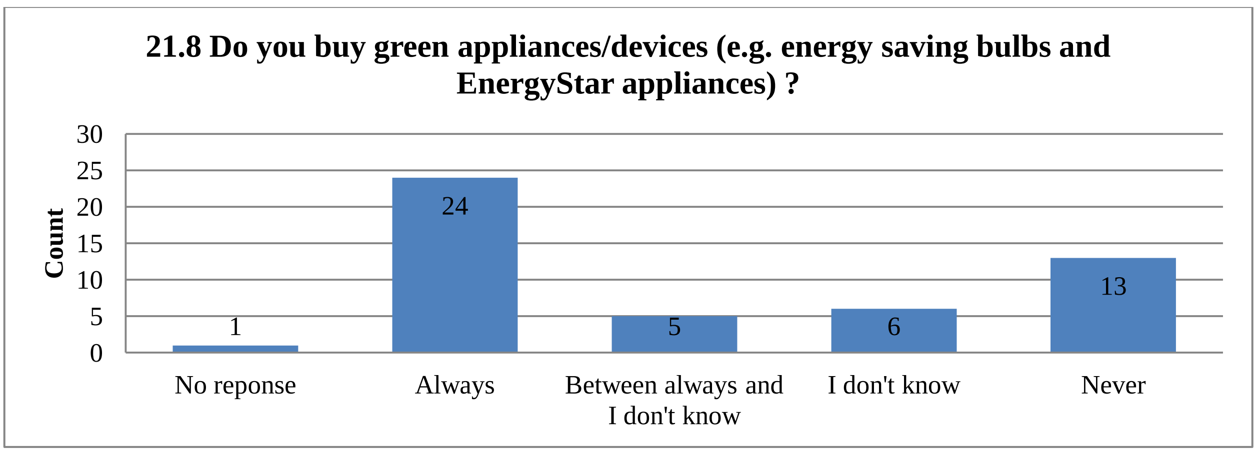




21.4 Do you turn off the electronics when not in use ?
Count
40
35
30
25
20
15
10
5
0
2
37
5
3
2
No reponse
Always
Between always and I don't know
I don't know
Never

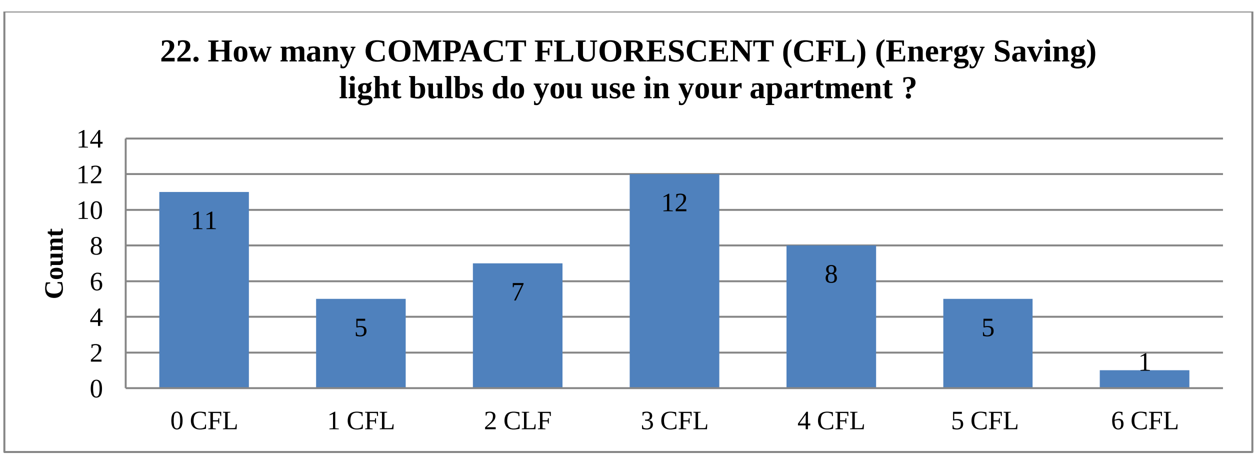

21.5 Do you use timer controls to control your electrical devices ?
Count
30
25
20
15
10
5
0
3
8
3
6
1
28
No reponse
Always
Between always and I don't know
I don't know
Between I don't know and never
Never

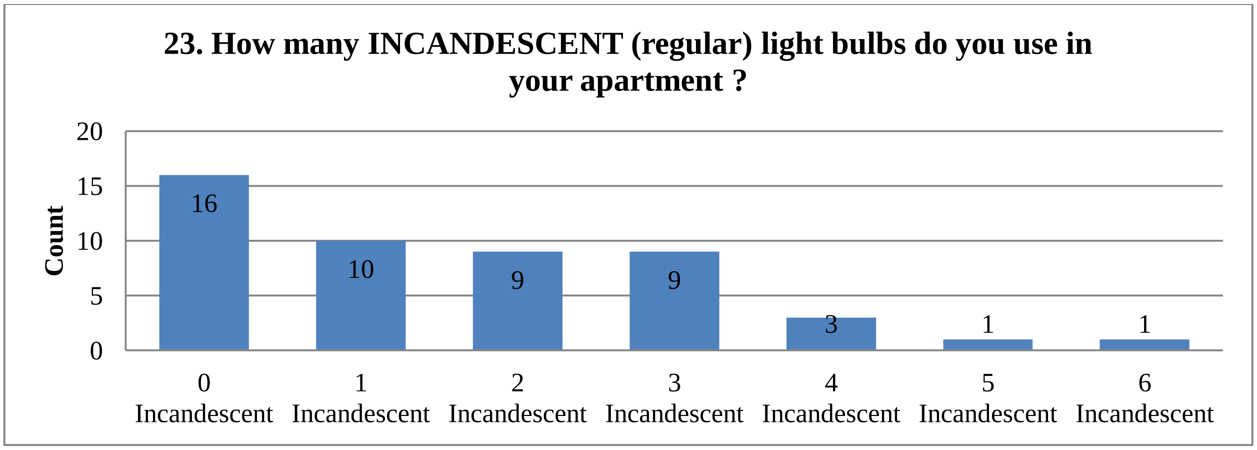

21.6 Do you turn off (shut down) computer when not in use ?
Count
25
20
15
10
5
0
23
17
4
2
2
No reponse
Always
I don't know
Between I don't know and never
Never

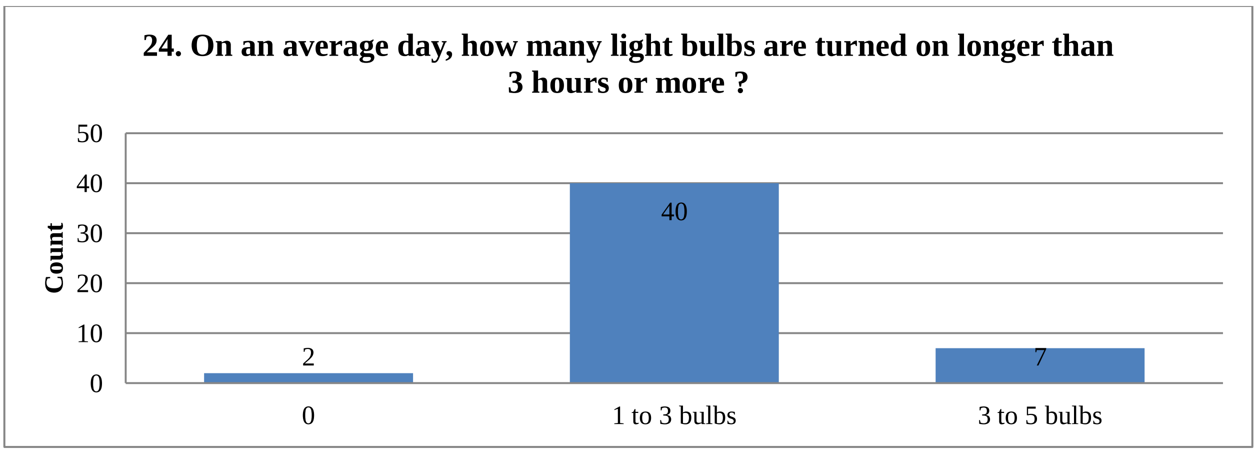


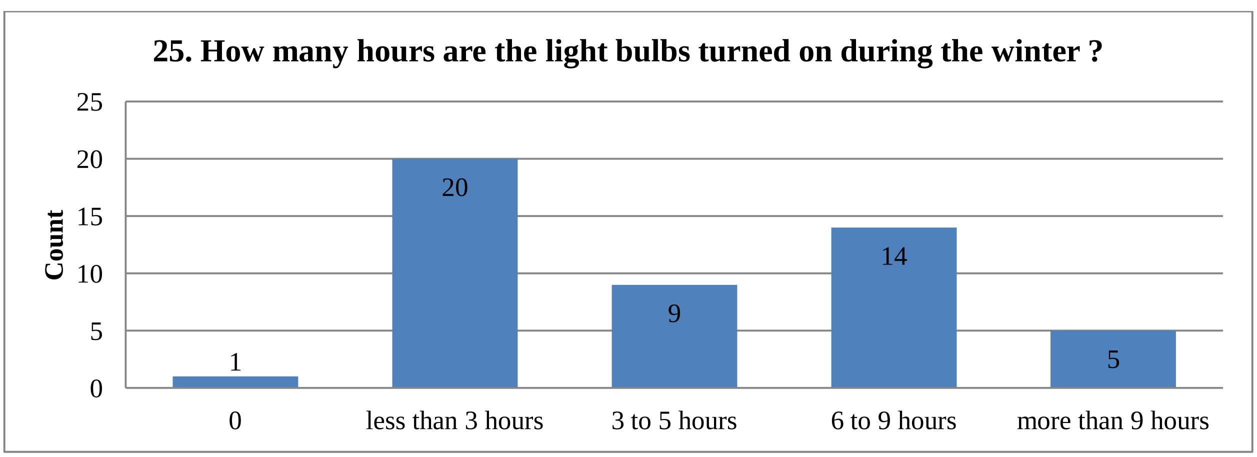



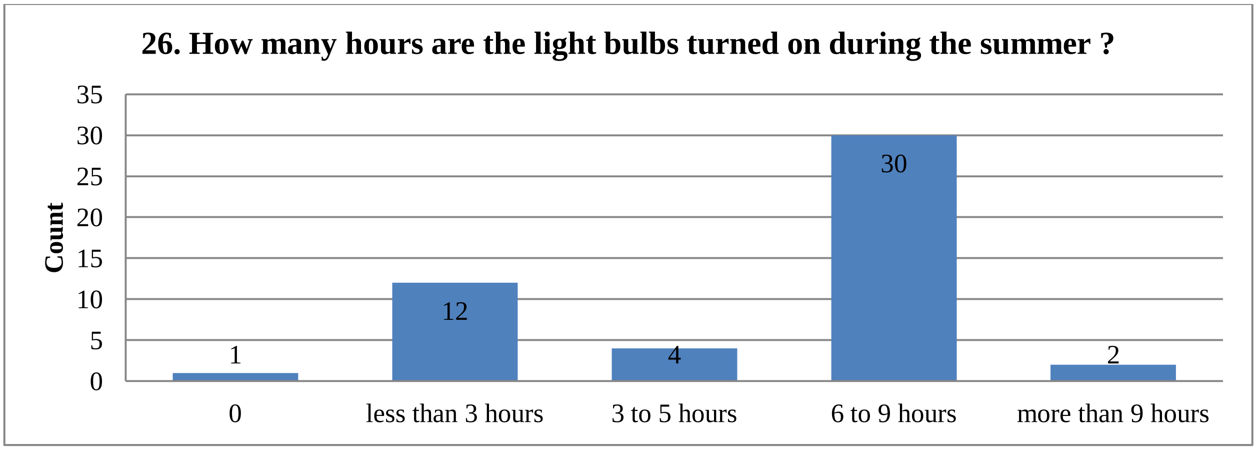

## Part 5: Lighting

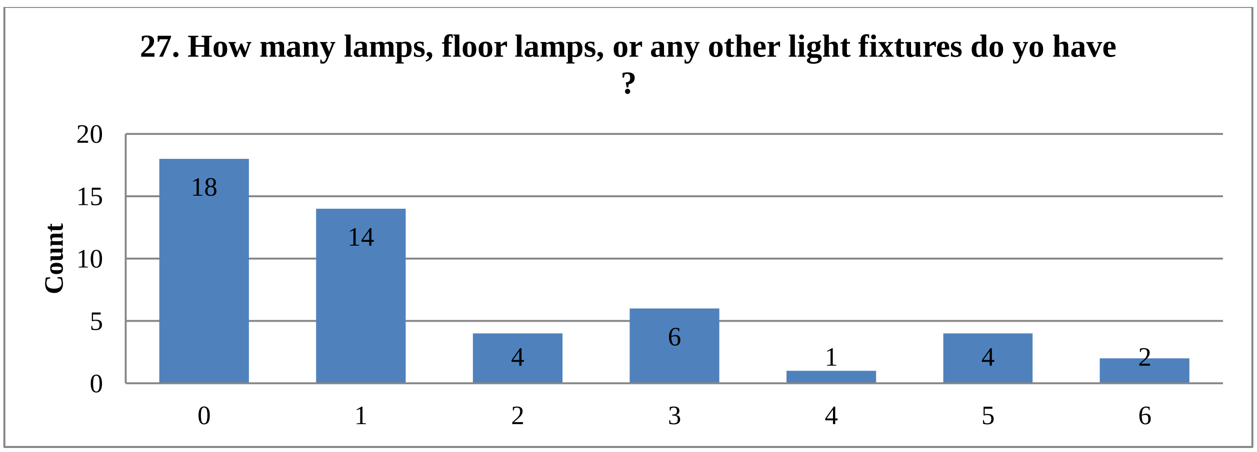



23. How many INCANDESCENT (regular) light bulbs do you use in your apartment ?
Count
20
15
10
5
0
16
10
9
9
3
1
1
0 Incandescent
1 Incandescent
2 Incandescent
3 Incandescent
4 Incandescent
5 Incandescent
6 Incandescent

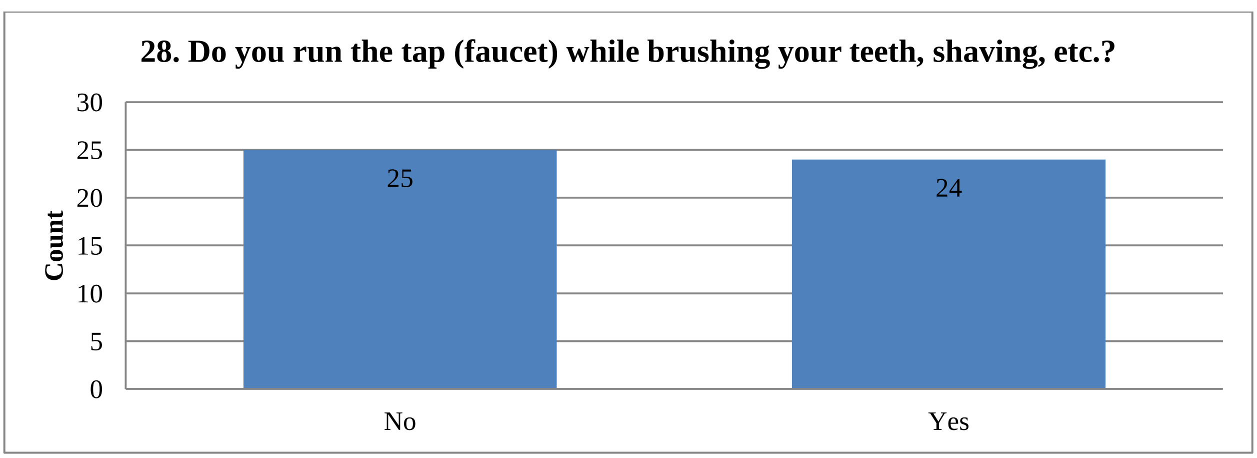

24. On an average day, how many light bulbs are turned on longer than 3 hours or more ?
Count
50
40
30
20
10
0
2
40
7
0
1 to 3 bulbs
3 to 5 bulbs

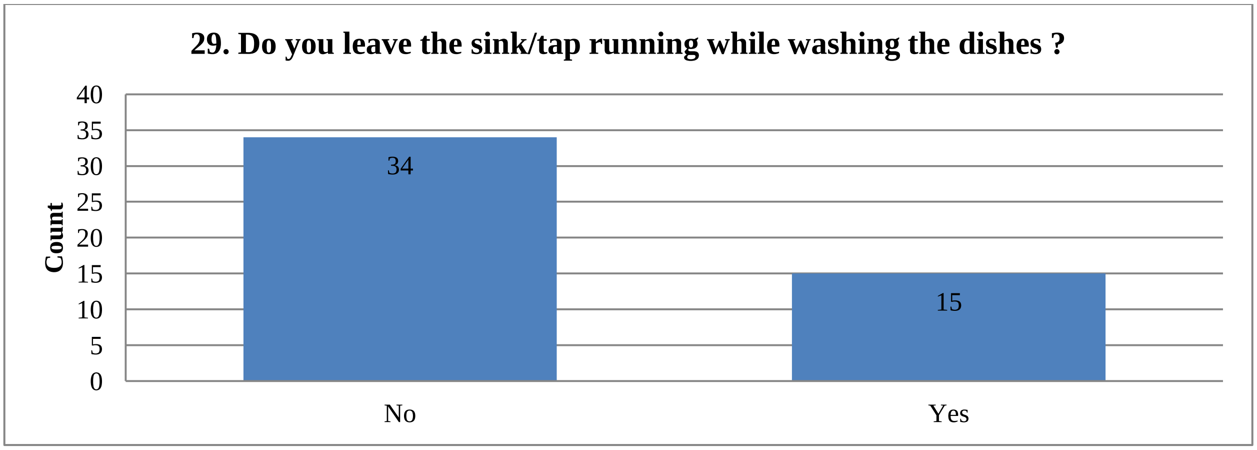

25. How many hours are the light bulbs turned on during the winter ?
Count
25
20
15
10
5
0
1
20
9
14
5
0
less than 3 hours
3 to 5 hours
6 to 9 hours
more than 9 hours



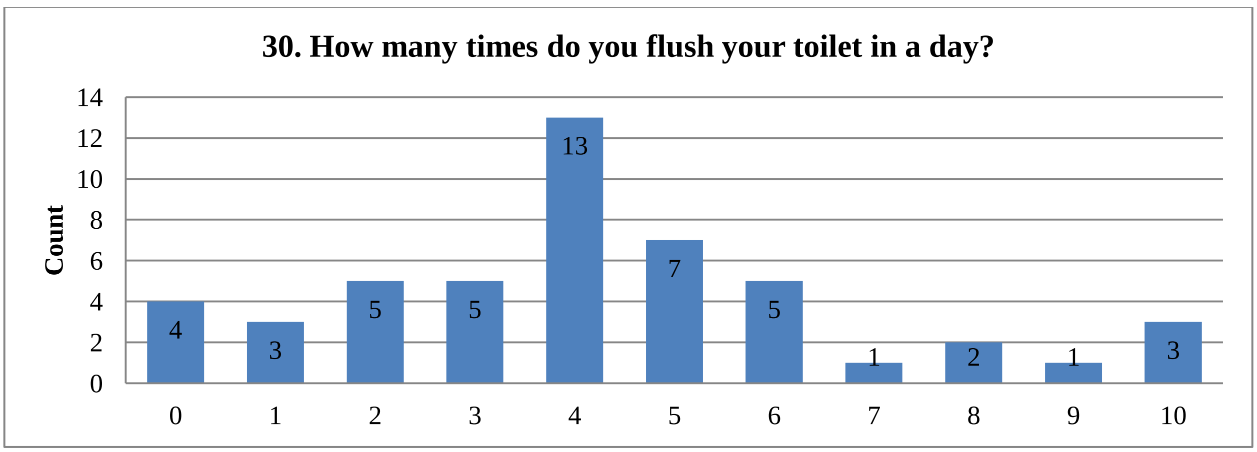




## Part 6: Water Usage

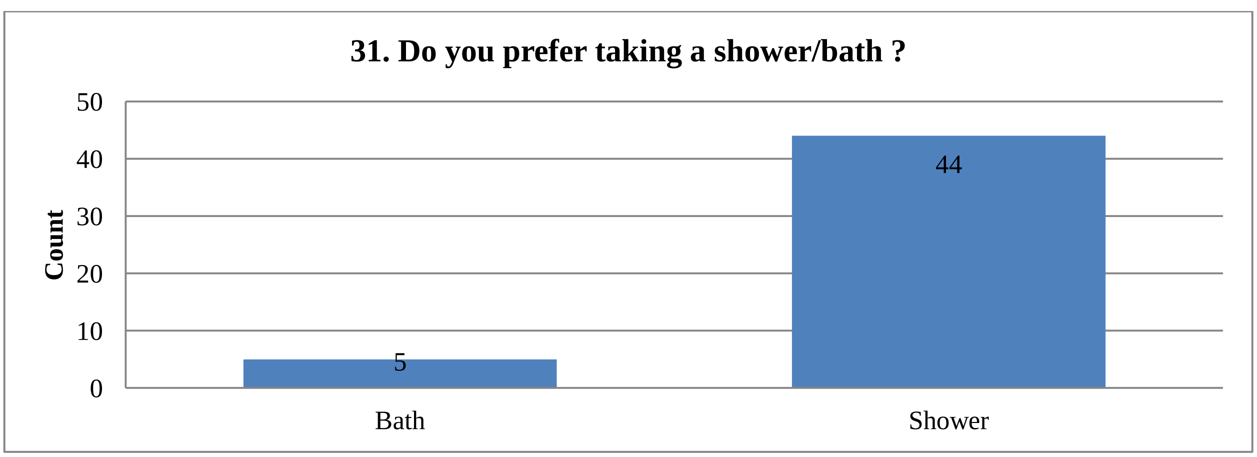




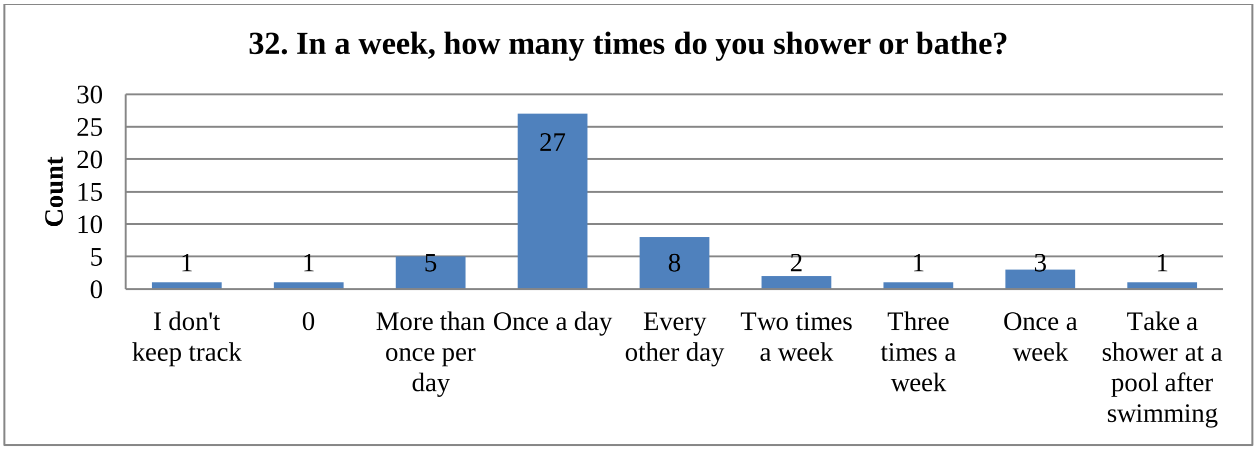
29. Do you leave the sink/tap running while washing the dishes ?
Count
40
35
30
25
20
15
10
5
0
34
15
No
Yes

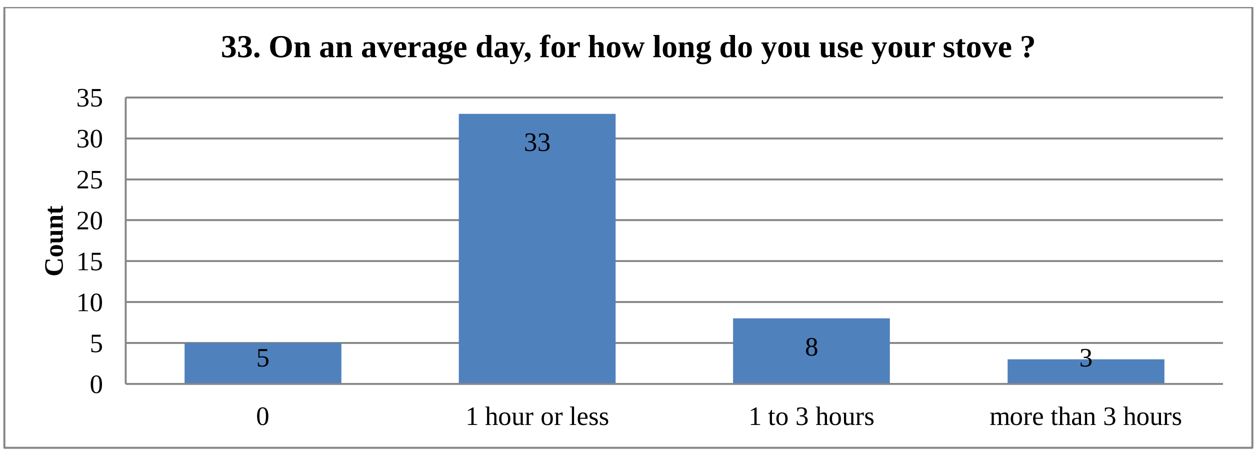
30. How many times do you flush your toilet in a day?
Count
14
12
10
8
6
4
2
0
4
3
5
5
13
7
5
1
2
1
3
0
1
2
3
4
5
6
7
8
9
10

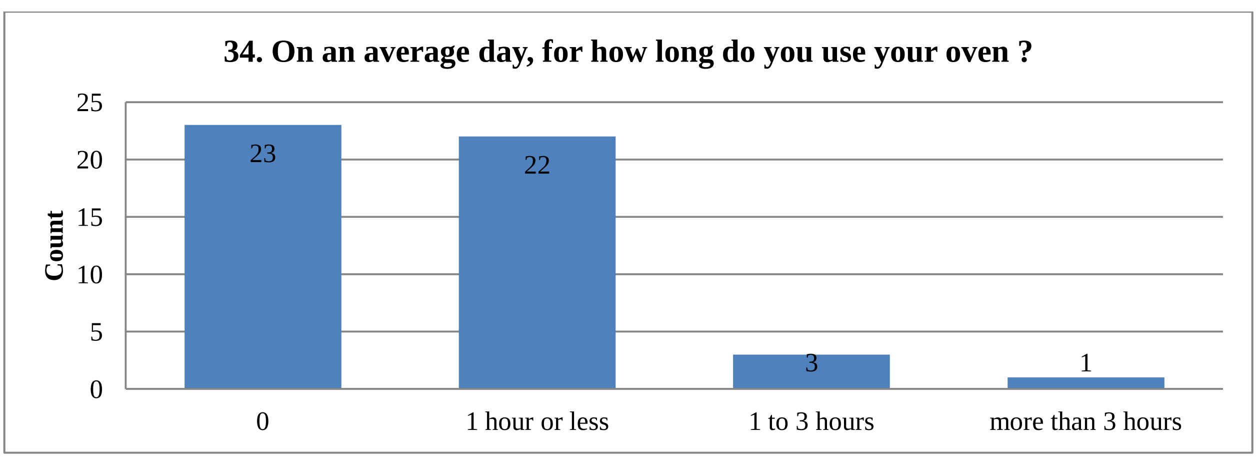



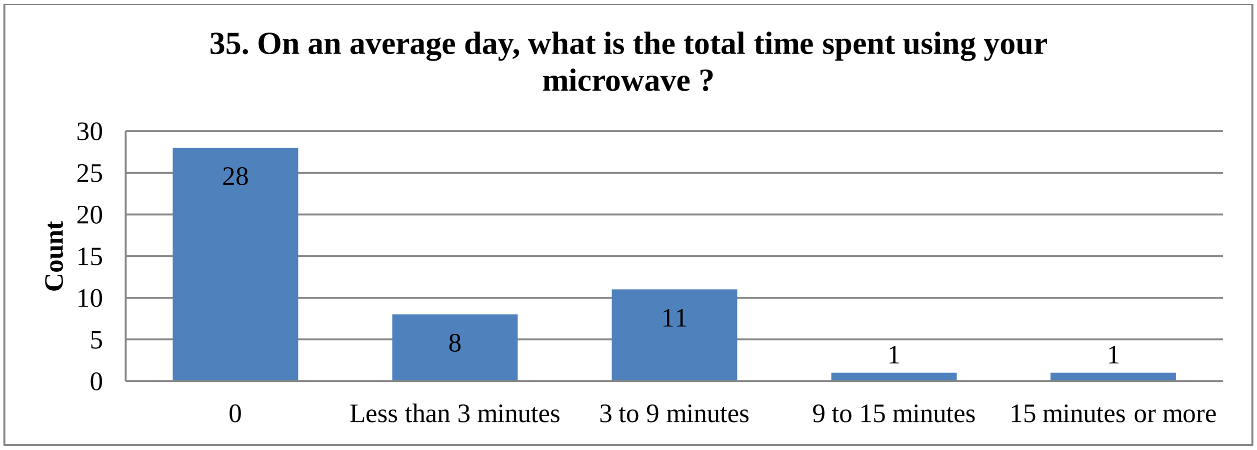
31. Do you prefer taking a shower/bath ?
Count
50
40
30
20
10
0
5
44
Bath
Shower



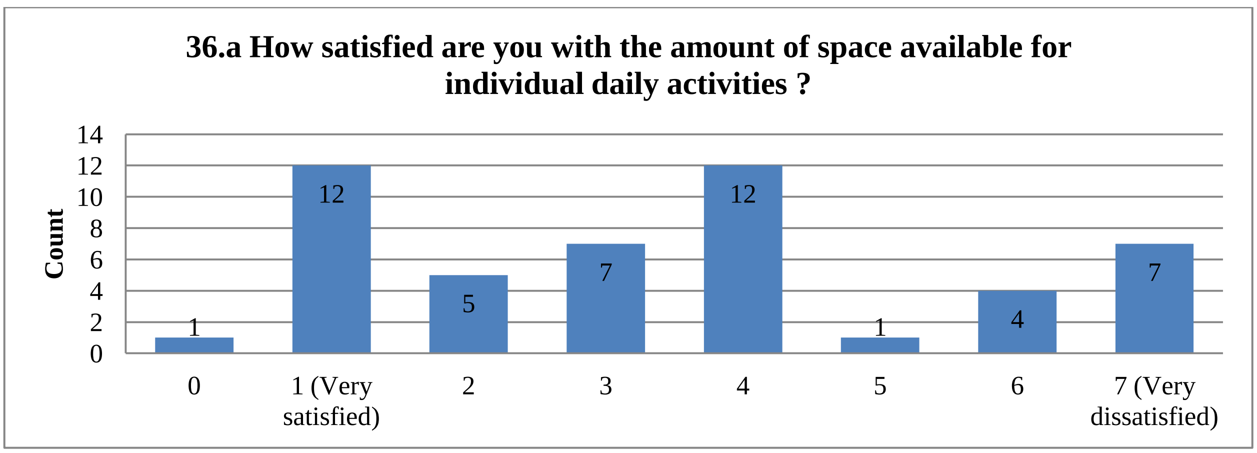

## Part 7: Household Activities

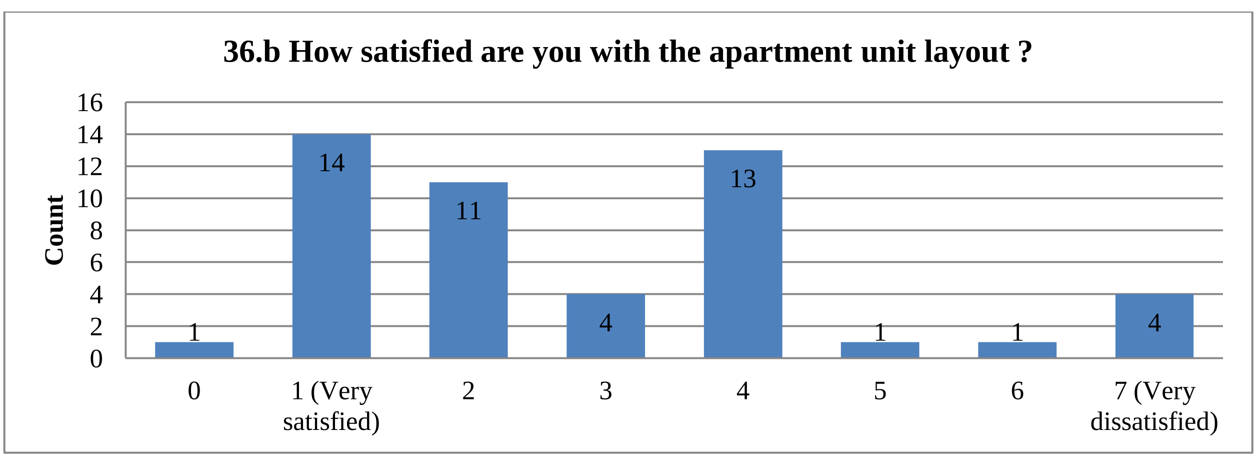


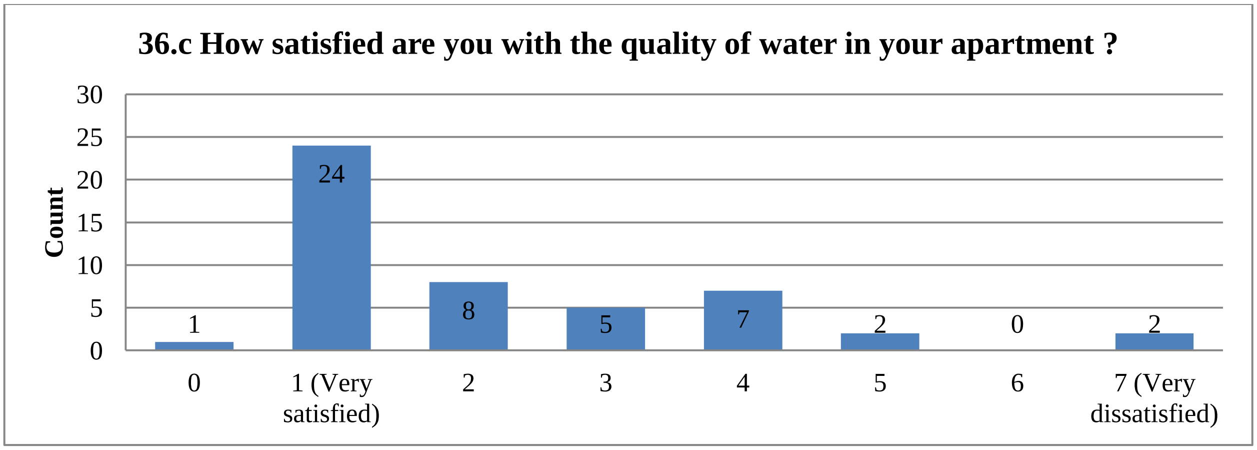



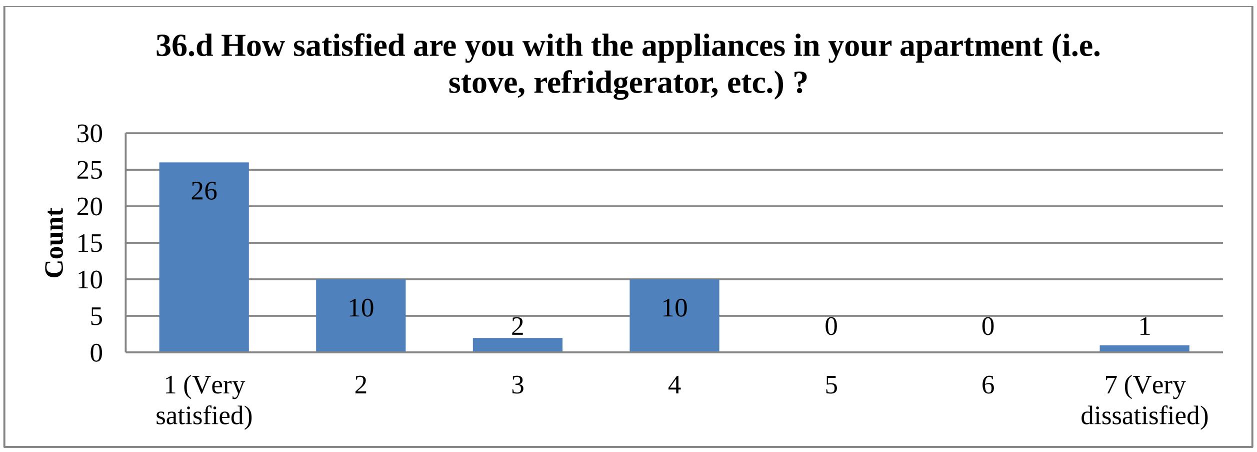


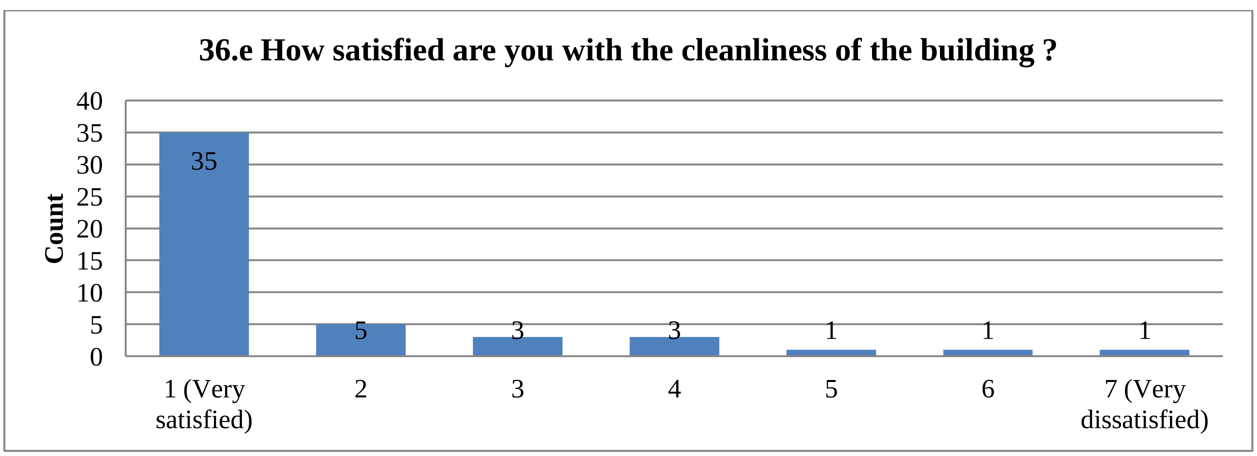

## Part 8: Indoor Environment Satisfaction and Thermal Comfort

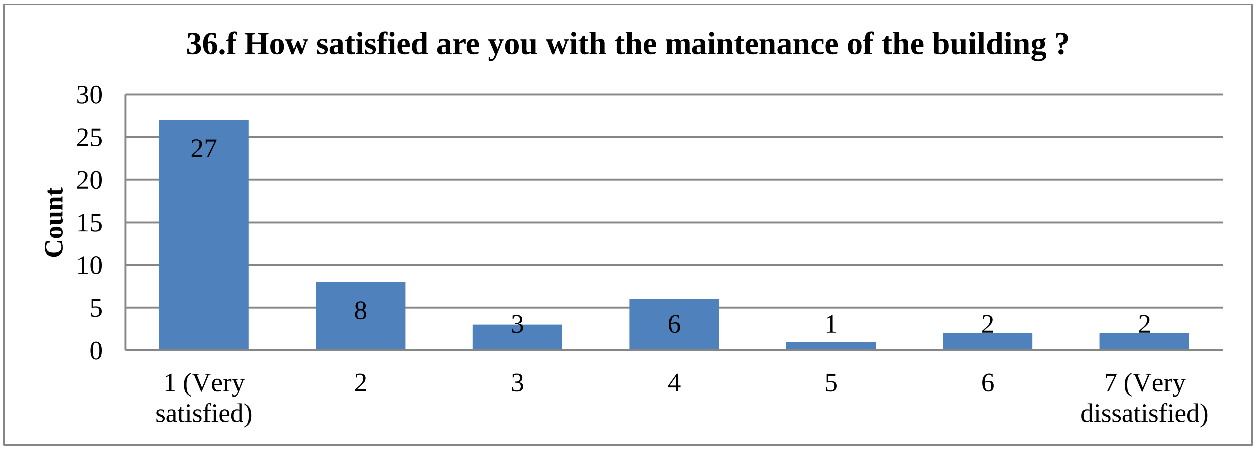


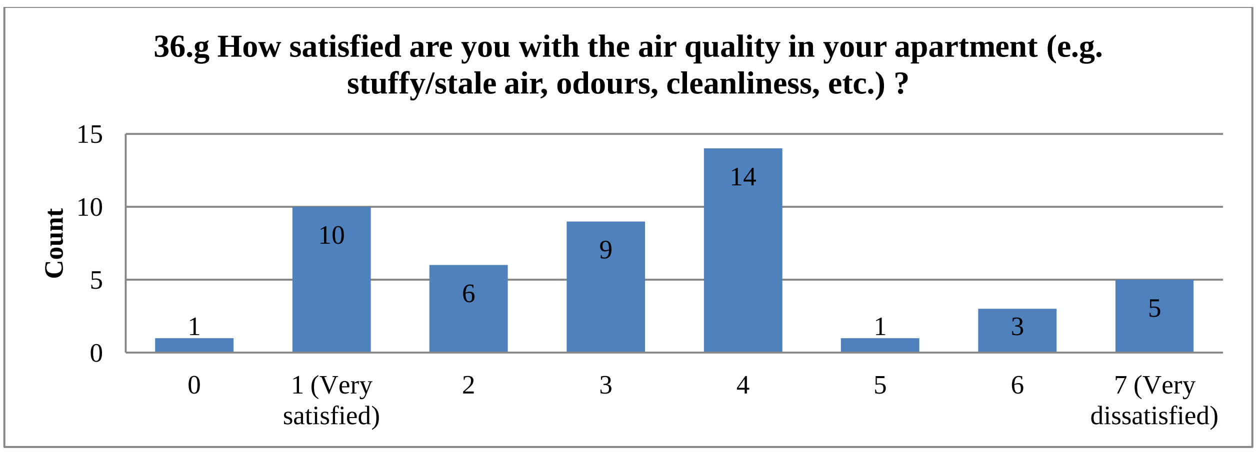



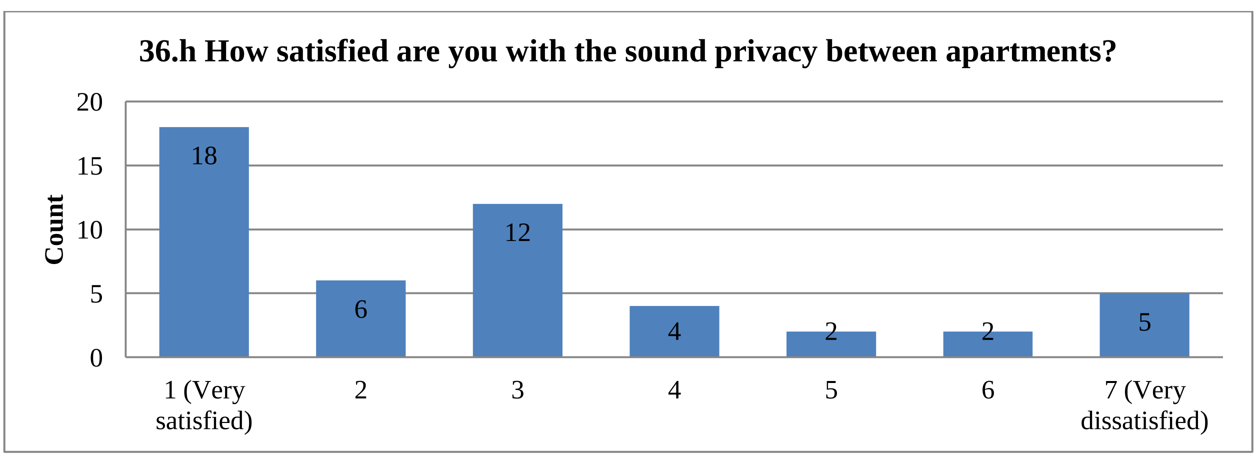

36.c How satisfied are you with the quality of water in your apartment ?
Count
30
25
20
15
10
5
0
1
24
8
5
7
2
0
2
0
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)

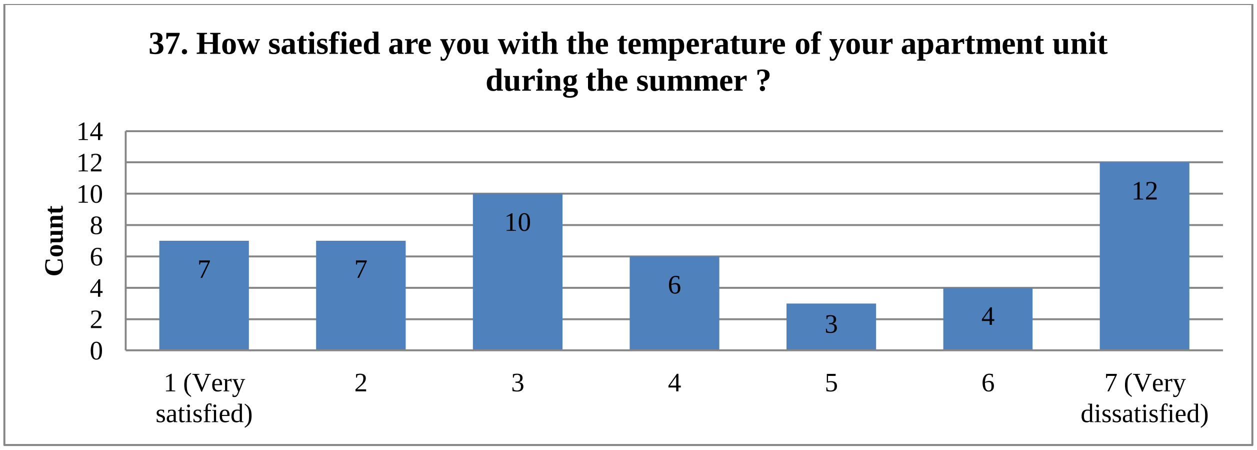

36.d How satisfied are you with the appliances in your apartment (i.e. stove, refridgerator, etc.) ?
Count
30
25
20
15
10
5
0
26
10
2
10
0
0
1
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)

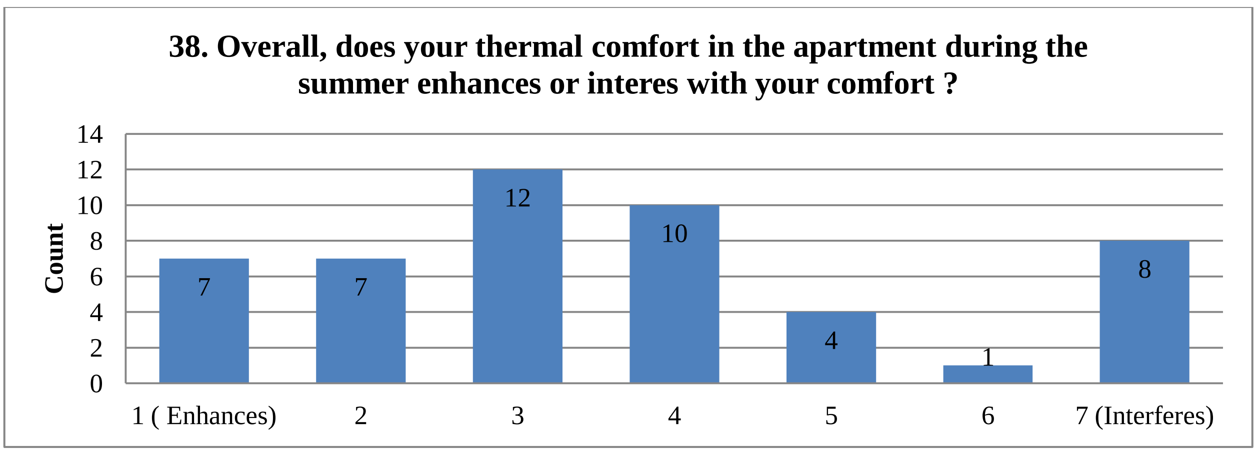

36.e How satisfied are you with the cleanliness of the building ?
Count
40
35
30
25
20
15
10
5
0
35
5
3
3
1
1
1
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)

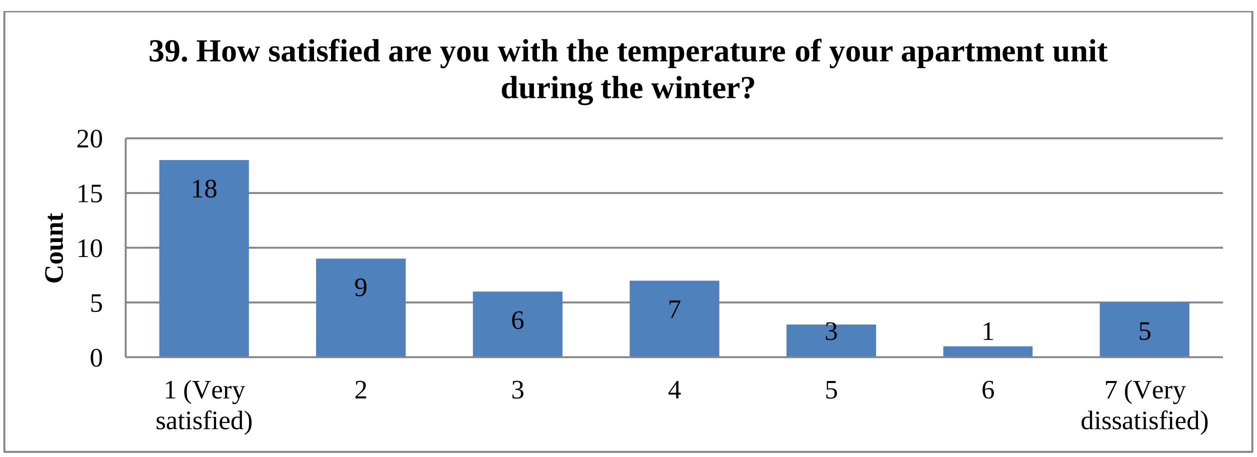

36.f How satisfied are you with the maintenance of the building ?
Count
30
25
20
15
10
5
0
27
8
3
6
1
2
2
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)

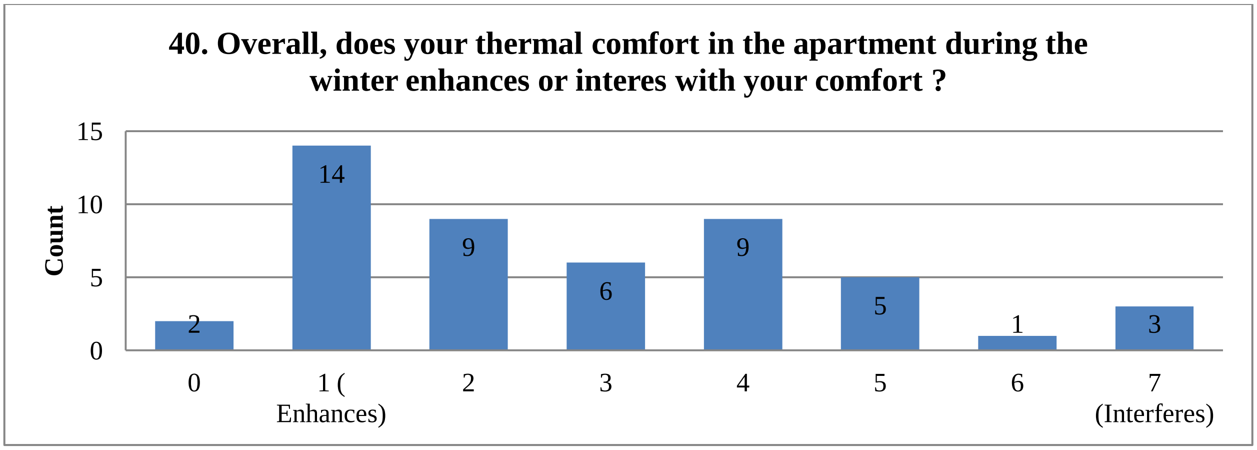

36.g How satisfied are you with the air quality in your apartment (e.g. stuffy/stale air, odours, cleanliness, etc.) ?
Count
15
10
5
0
1
10
6
9
14
1
3
5
0
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)

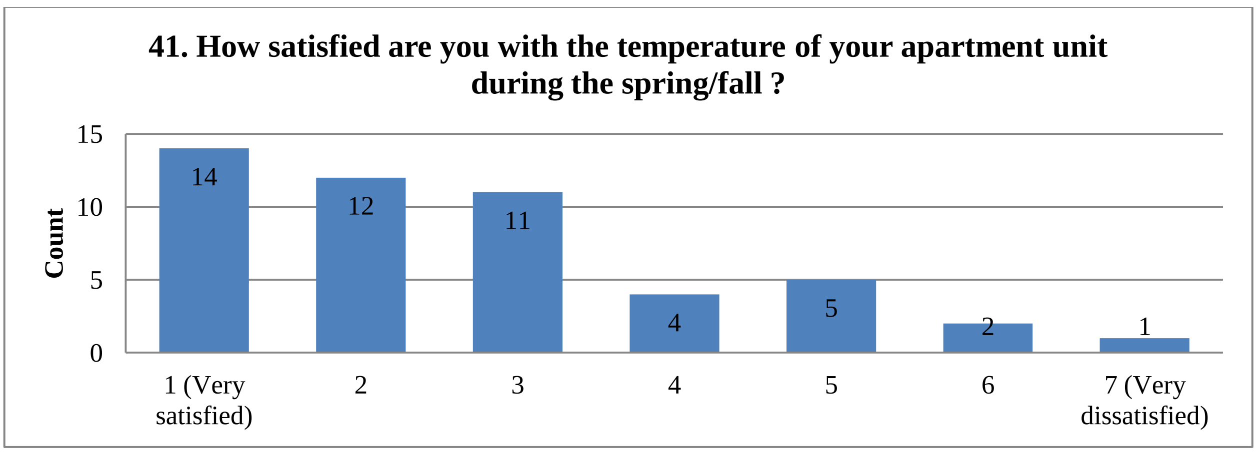

36.h How satisfied are you with the sound privacy between apartments?
Count
20
15
10
5
0
18
6
12
4
2
2
5
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)

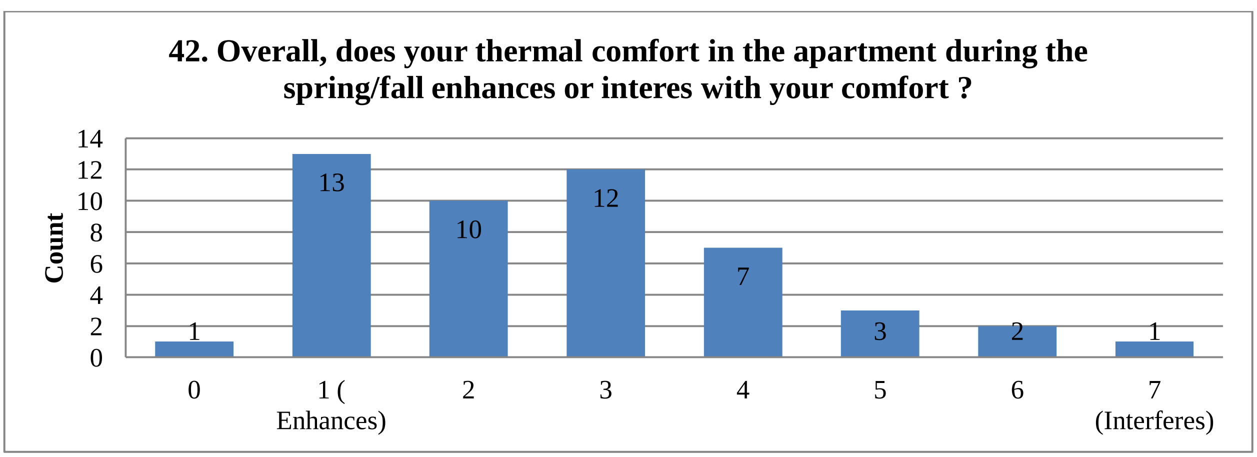

37. How satisfied are you with the temperature of your apartment unit during the summer ?
Count
14
12
10
8
6
4
2
0
7
7
10
6
3
4
12
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)

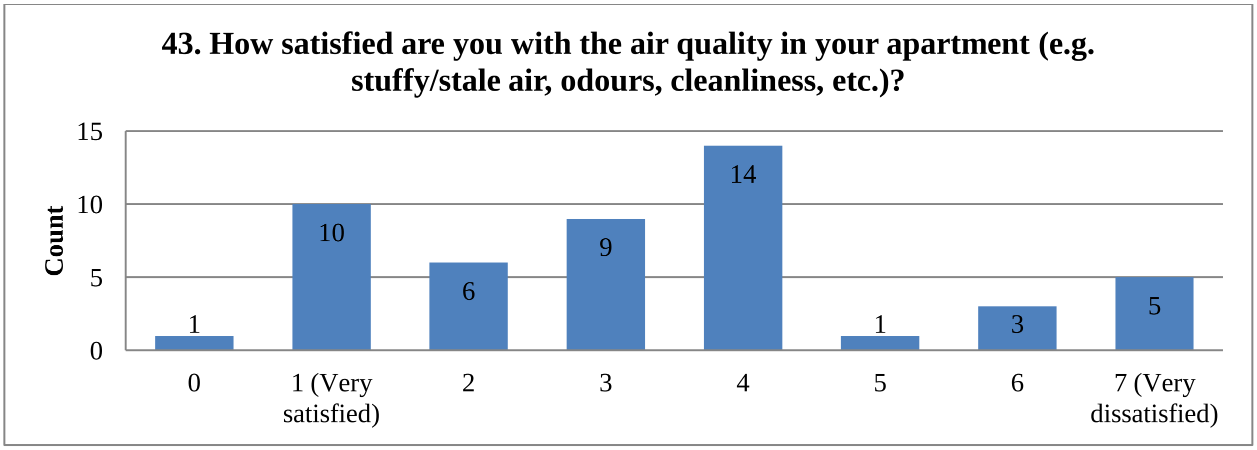

38. Overall, does your thermal comfort in the apartment during the summer enhances or interes with your comfort ?
Count
14
12
10
8
6
4
2
0
7
7
12
10
4
1
8
1 ( Enhances)
2
3
4
5
6
7 (Interferes)

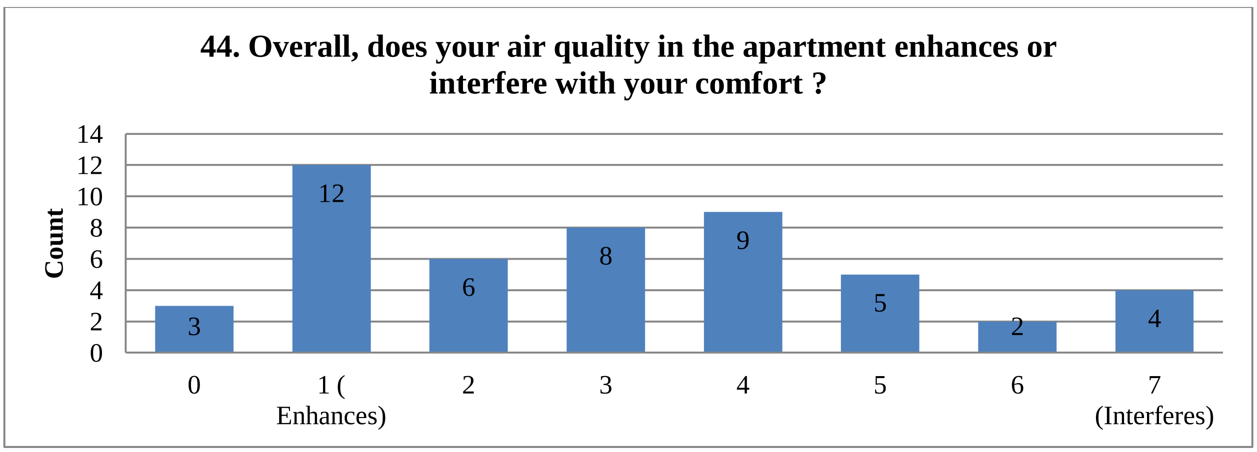

39. How satisfied are you with the temperature of your apartment unit during the winter?
Count
20
15
10
5
0
18
9
6
7
3
1
5
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)

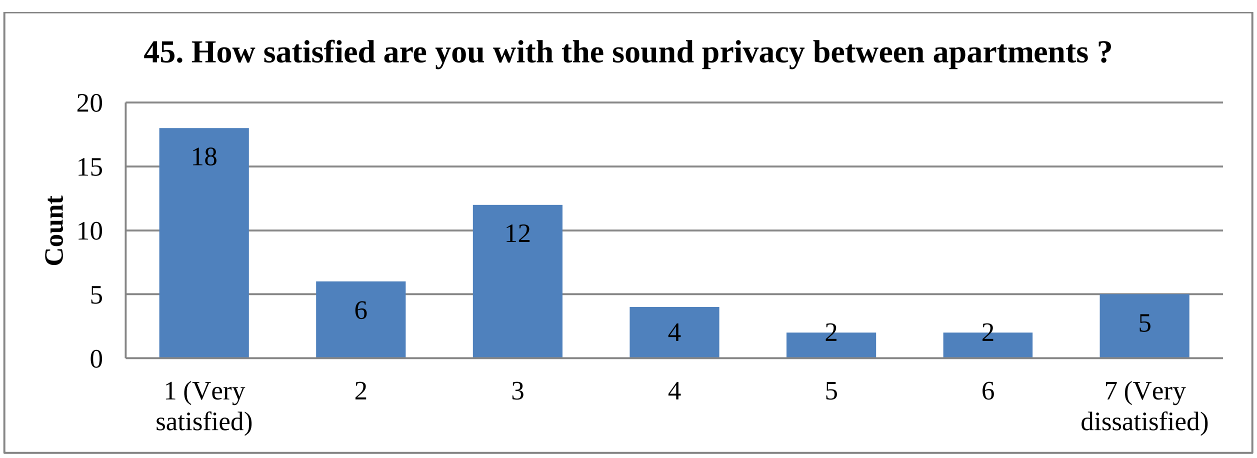

40. Overall, does your thermal comfort in the apartment during the winter enhances or interes with your comfort ?
Count
15
10
5
0
2
14
9
6
9
5
1
3
0
1 ( Enhances)
2
3
4
5
6
7 (Interferes)

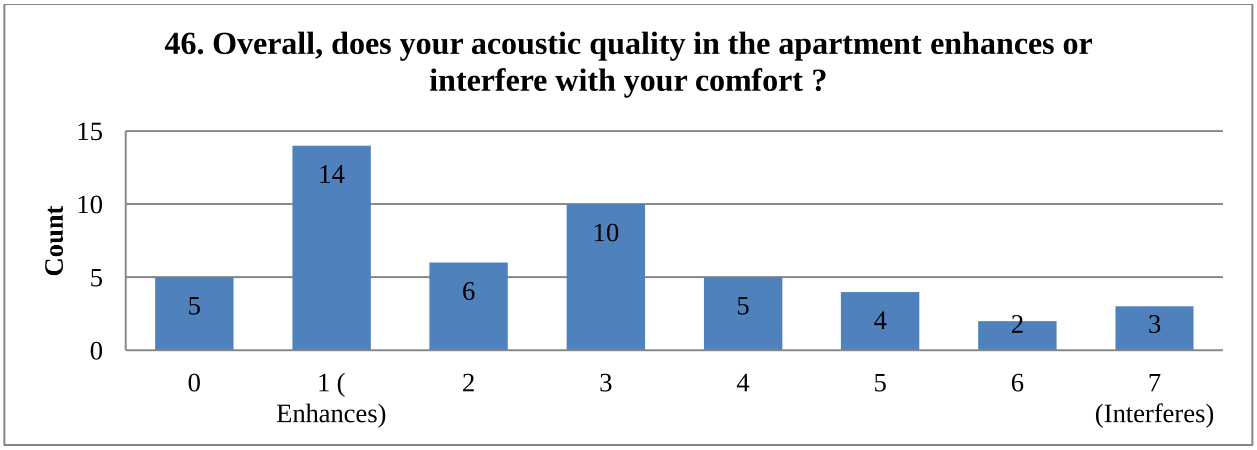

41. How satisfied are you with the temperature of your apartment unit during the spring/fall ?
Count
15
10
5
0
14
12
11
4
5
2
1
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)

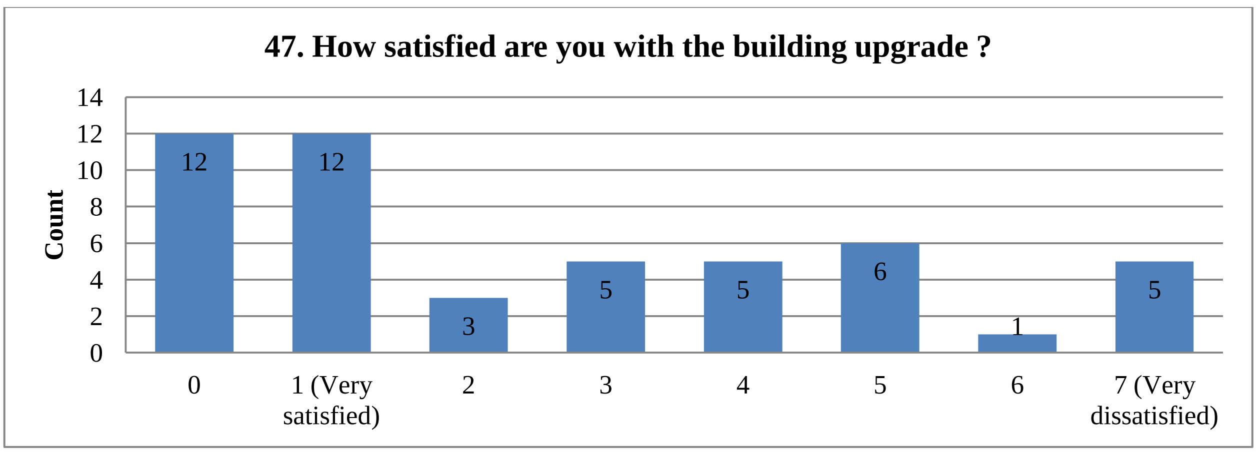

42. Overall, does your thermal comfort in the apartment during the spring/fall enhances or interes with your comfort ?
Count
14
12
10
8
6
4
2
0
1
13
10
12
7
3
2
1
0
1 ( Enhances)
2
3
4
5
6
7 (Interferes)

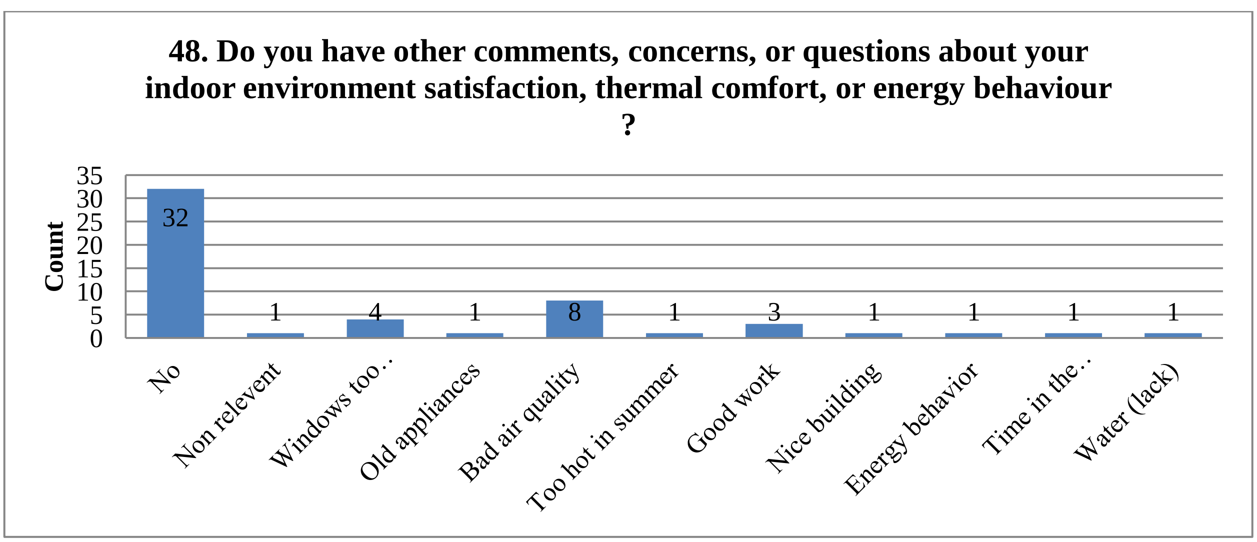

43. How satisfied are you with the air quality in your apartment (e.g. stuffy/stale air, odours, cleanliness, etc.)?
Count
15
10
5
0
1
10
6
9
14
1
3
5
0
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)

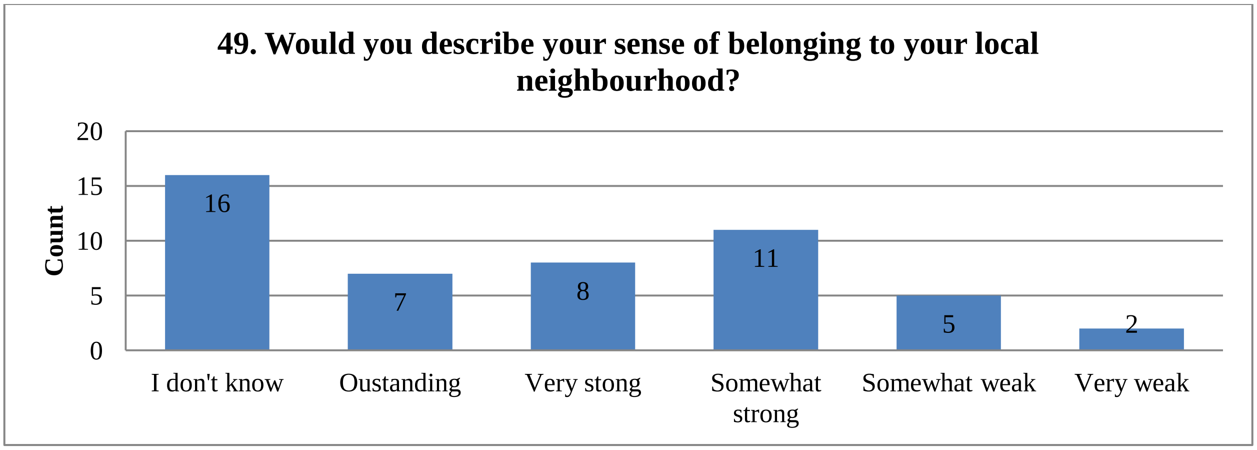

44. Overall, does your air quality in the apartment enhances or interfere with your comfort ?
Count
14
12
10
8
6
4
2
0
3
12
6
8
9
5
2
4
0
1 ( Enhances)
2
3
4
5
6
7 (Interferes)

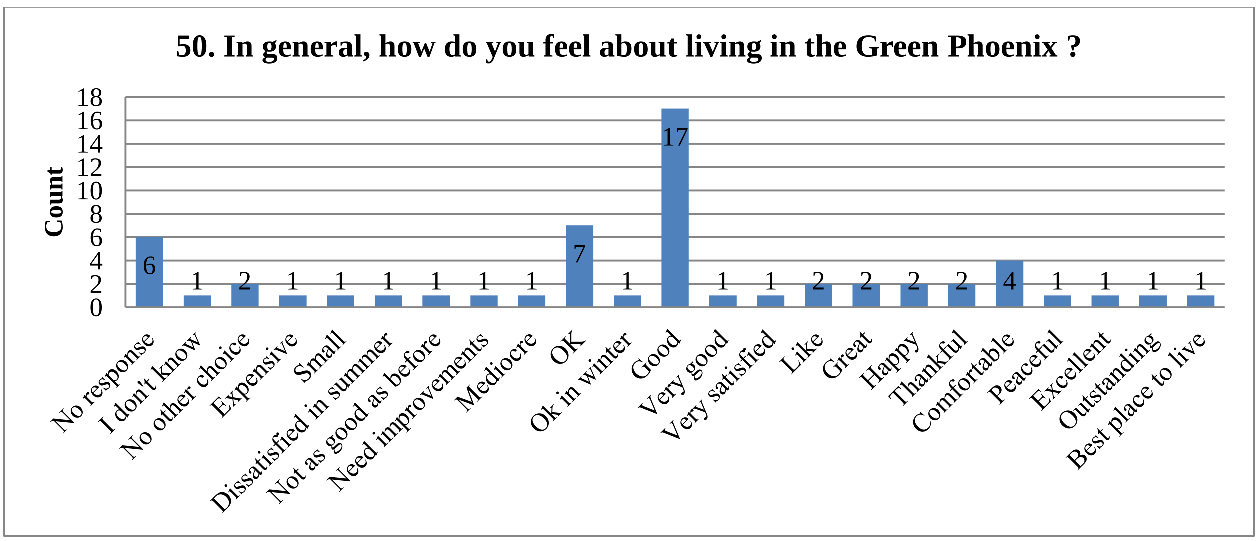

45. How satisfied are you with the sound privacy between apartments ?
Count
20
15
10
5
0
18
6
12
4
2
2
5
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)

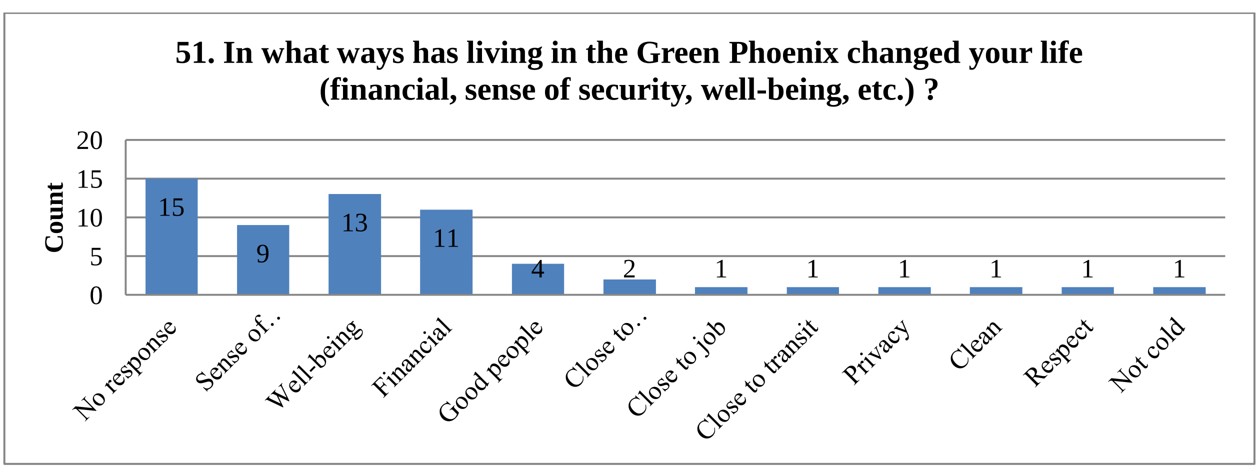

46. Overall, does your acoustic quality in the apartment enhances or interfere with your comfort ?
Count
15
10
5
0
14
10
5
6
5
4
2
3
0
1 ( Enhances)
2
3
4
5
6
7 (Interferes)


47. How satisfied are you with the building upgrade ?
Count
14
12
10
8
6
4
2
0
12
12
3
5
5
6
1
5
0
1 (Very satisfied)
2
3
4
5
6
7 (Very dissatisfied)


48. Do you have other comments, concerns, or questions about your indoor environment satisfaction, thermal comfort, or energy behaviour ?
Count
35
30
25
20
15
10
5
0
32
1
4
1
8
1
3
1
1
1
1
No
Non relevent
Windows too…
Old appliances
Bad air quality
Too hot in summer
Good work
Nice building
Energy behavior
Time in the…
Water (lack)


49. Would you describe your sense of belonging to your local neighbourhood?
Count
20
15
10
5
0
16
7
8
11
5
2
I don't know
Oustanding
Very stong
Somewhat strong
Somewhat weak
Very weak


50. In general, how do you feel about living in the Green Phoenix ?
Count
18
16
14
12
10
8
6
4
2
0
6
1
2
1
1
1
1
1
1
7
1
17
1
1
2
2
2
2
4
1
1
1
1
No response
I don't know
No other choice
Expensive
Small
Dissatisfied in summer
Not as good as before
Need improvements
Mediocre
OK
Ok in winter
Good
Very good
Very satisfied
Like
Great
Happy
Thankful
Comfortable
Peaceful
Excellent
Outstanding
Best place to live


51. In what ways has living in the Green Phoenix changed your life (financial, sense of security, well-being, etc.) ?
Count
20
15
10
5
0
15
9
13
11
4
2
1
1
1
1
1
1
No response
Sense of…
Well-being
Financial
Good people
Close to…
Close to job
Close to transit
Privacy
Clean
Respect
Not cold

# Appendix F: Correlation - Indoor Environment Satisfaction and Thermal Comfort

| Spearson's correlation | | How satisfied are you with the amount of space available for individual daily activities? | How satisfied are you with the apartment unit layout? | How satisfied are you with the quality of water in your apartment? | How satisfied are you with the appliances in your apartment (i.e. stove, refrigerator, etc.)? | How satisfied are you with the cleanliness of the building? | How satisfied are you with the maintenance of the building? | How satisfied are you with the temperature of your apartment unit during the summer? | Overall, does your thermal comfort in the apartment during the summer enhances or interferes with your comfort? | How satisfied are you with the temperature of your apartment unit during the winter? | Overall, does your thermal comfort in the apartment during the winter enhances or interferes with your comfort? | How satisfied are you with the temperature of your apartment unit during the spring/fall? | Overall, does your thermal comfort in the apartment during the spring/fall enhances or interferes with your comfort? | How satisfied are you with the air quality in your apartment (e.g. stuffy/stale air, odors, cleanliness, etc.)? | Overall, does your air quality in the apartment enhances or interfere with your comfort? | How satisfied are you with the sound privacy between apartments? | Overall, does your acoustic quality in the apartment enhances or interfere with your comfort? | How satisfied are you with the building upgrade? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| How satisfied are you with the amount of space available for individual daily activities? | Correlation Coefficient | 1 | .775** | .426** | 429** | 318* | 376** | 378** | 354* | 319* | 486** | 406** | 430** | 378** | 477** | 0 .151 | 0 .22 | 0 .294 |
| | Sig. (2-tailed) | . | 0 | 0.003 | 0 .002 | 0 .028 | 0 .008 | 0 .008 | 0 .014 | 0 .027 | 0 .001 | 0 .004 | 0 .003 | 0 .009 | 0 .001 | 0 .304 | 0 .156 | 0 .082 |
| How satisfied are you with the apartment unit layout? | Correlation Coefficient | 775** | 1 | .484** | 581** | 398** | 480** | 434** | 404** | 0 .136 | 330* | 418** | 418** | 384** | 466** | 0 .255 | 354* | 500** |
| | Sig. (2-tailed) | 0 | . | 0 | 0 | 0 .005 | 0 .001 | 0 .002 | 0 .004 | 0 .355 | 0 .025 | 0 .003 | 0 .003 | 0 .008 | 0 .001 | 0 .08 | 0 .02 | 0 .002 |
| How satisfied are you with the quality of water in your apartment? | Correlation Coefficient | 426** | .484** | 1 | 483** | 351* | 429** | 385** | 475** | 0 .255 | 386** | 460** | 451** | 369* | 327* | 0 .173 | 0 .121 | 578** |
| | Sig. (2-tailed) | 0 .003 | 0 | . | 0 .001 | 0 .015 | 0 .002 | 0 .007 | 0 .001 | 0 .08 | 0 .008 | 0 .001 | 0 .001 | 0 .011 | 0 .028 | 0 .239 | 0 .439 | 0 |
| How satisfied are you with the appliances in your apartment (i.e. stove, refrigerator, etc.)? | Correlation Coefficient | 429** | .581** | .483** | 1 | 545** | 602** | 0 .243 | 0 .193 | 0 .102 | 371* | 409** | 443** | 289* | 344* | 387** | 464** | 456** |
| | Sig. (2-tailed) | 0 .002 | 0 | 0.001 | . | 0 | 0 | 0 .093 | 0 .183 | 0 .484 | 0 .01 | 0 .004 | 0 .002 | 0 .046 | 0 .019 | 0 .006 | 0 .002 | 0 .005 |
| How satisfied are you with the cleanliness of the building? | Correlation Coefficient | 318* | .398** | .351* | 545** | 1 | 722** | 296* | 369** | 0 .275 | 420** | 373** | 412** | 286* | 457** | 422** | 494** | 451** |
| | Sig. (2-tailed) | 0 .028 | 0.005 | 0.015 | 0 | . | 0 | 0 .039 | 0 .009 | 0 .055 | 0 .003 | 0 .008 | 0 .004 | 0 .049 | 0 .001 | 0 .003 | 0 .001 | 0 .005 |
| How satisfied are you with the maintenance of the building? | Correlation Coefficient | 376** | .480** | .429** | 602** | 722** | 1 | 410** | 494** | 0 .155 | 400** | 0 .245 | 292* | 0 .259 | 350* | 420** | 435** | 506** |
| | Sig. (2-tailed) | 0 .008 | 0.001 | 0.002 | 0 | 0 | . | 0 .003 | 0 | 0 .287 | 0 .005 | 0 .09 | 0 .044 | 0 .075 | 0 .017 | 0 .003 | 0 .003 | 0 .001 |
| How satisfied are you with the temperature of your apartment unit during the | Correlation Coefficient | 378** | .434** | .385** | 0 .243 | 296* | 410** | 1 | 884** | 351* | 330* | 481** | 414** | 324* | 411** | 305* | 0 .259 | 568** |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| summer? | Sig. (2-tailed) | 0 .008 | 0.002 | 0.007 | 0 .093 | 0 .039 | 0 .003 | . | 0 | 0 .013 | 0 .024 | 0 | 0 .003 | 0 .025 | 0 .005 | 0 .033 | 0 .09 | 0 |
| Overall, does your thermal comfort in the apartment during the summer enhances or interferes with your comfort? | Correlation Coefficient | 354* | .404** | .475** | 0 .193 | 369** | 494** | 884** | 1 | 308* | 0 .263 | 429** | 360* | 422** | 474** | 306* | 0 .275 | 642** |
| | Sig. (2-tailed) | 0 .014 | 0.004 | 0.001 | 0 .183 | 0 .009 | 0 | 0 | . | 0 .031 | 0 .074 | 0 .002 | 0 .012 | 0 .003 | 0 .001 | 0 .033 | 0 .071 | 0 |
| How satisfied are you with...The temperature of your apartment unit during the winter? | Correlation Coefficient | 319* | 0.136 | 0.255 | 0 .102 | 0 .275 | 0 .155 | 351* | 308* | 1 | 749** | 634** | 577** | 338* | 424** | 0 .228 | 0 .105 | 0 .157 |
| | Sig. (2-tailed) | 0 .027 | 0.355 | 0.08 | 0 .484 | 0 .055 | 0 .287 | 0 .013 | 0 .031 | . | 0 | 0 | 0 | 0 .019 | 0 .003 | 0 .114 | 0 .497 | 0 .353 |
| Overall, does your thermal comfort in the apartment during the winter enhances or interferes with your comfort? | Correlation Coefficient | 486** | .330* | .386** | 371* | 420** | 400** | 330* | 0 .263 | 749** | 1 | 672** | 714** | 330* | 551** | 0 .237 | 0 .167 | 0 .223 |
| | Sig. (2-tailed) | 0 .001 | 0.025 | 0.008 | 0 .01 | 0 .003 | 0 .005 | 0 .024 | 0 .074 | 0 | . | 0 | 0 | 0 .025 | 0 | 0 .108 | 0 .284 | 0 .198 |
| How satisfied are you with the temperature of your apartment unit during the spring/fall? | Correlation Coefficient | 406** | .418** | .460** | 409** | 373** | 0 .245 | 481** | 429** | 634** | 672** | 1 | 937** | 457** | 554** | 468** | 422** | 432** |
| | Sig. (2-tailed) | 0 .004 | 0.003 | 0.001 | 0 .004 | 0 .008 | 0 .09 | 0 | 0 .002 | 0 | 0 | . | 0 | 0 .001 | 0 | 0 .001 | 0 .004 | 0 .008 |
| Overall, does your thermal comfort in the apartment during the spring/fall enhances or interferes with your comfort? | Correlation Coefficient | 430** | .418** | .451** | 443** | 412** | 292* | 414** | 360* | 577** | 714** | 937** | 1 | 342* | 541** | 452** | 474** | 412* |
| | Sig. (2-tailed) | 0 .003 | 0.003 | 0.001 | 0 .002 | 0 .004 | 0 .044 | 0 .003 | 0 .012 | 0 | 0 | 0 | . | 0 .019 | 0 | 0 .001 | 0 .001 | 0 .013 |
| How satisfied are you with the air quality in your apartment (e.g. stuffy/stale air, odors, cleanliness, etc.)? | Correlation Coefficient | 378** | .384** | .369* | 289* | 286* | 0 .259 | 324* | 422** | 338* | 330* | 457** | 342* | 1 | 794** | 395** | 475** | 451** |
| | Sig. (2-tailed) | 0 .009 | 0.008 | 0.011 | 0 .046 | 0 .049 | 0 .075 | 0 .025 | 0 .003 | 0 .019 | 0 .025 | 0 .001 | 0 .019 | . | 0 | 0 .005 | 0 .001 | 0 .006 |
| Overall, does your air quality in the apartment enhances or interfere with your comfort? | Correlation Coefficient | 477** | .466** | .327* | 344* | 457** | 350* | 411** | 474** | 424** | 551** | 554** | 541** | 794** | 1 | 478** | 571** | 562** |
| | Sig. (2-tailed) | 0 .001 | 0.001 | 0.028 | 0 .019 | 0 .001 | 0 .017 | 0 .005 | 0 .001 | 0 .003 | 0 | 0 | 0 | 0 | . | 0 .001 | 0 | 0 .001 |
| How satisfied are you with the sound privacy between apartments? | Correlation Coefficient | 0 .151 | 0.255 | 0.173 | 387** | 422** | 420** | 305* | 306* | 0 .228 | 0 .237 | 468** | 452** | 395** | 478** | 1 | 922** | 448** |
| | Sig. (2-tailed) | 0 .304 | 0.08 | 0.239 | 0 .006 | 0 .003 | 0 .003 | 0 .033 | 0 .033 | 0 .114 | 0 .108 | 0 .001 | 0 .001 | 0 .005 | 0 .001 | . | 0 | 0 .005 |
| Overall, does your acoustic quality in the apartment enhances or interfere with your comfort? | Correlation Coefficient | 0 .22 | .354* | 0.121 | 464** | 494** | 435** | 0 .259 | 0 .275 | 0 .105 | 0 .167 | 422** | 474** | 475** | 571** | 922** | 1 | 408* |
| | Sig. (2-tailed) | 0 .156 | 0.02 | 0.439 | 0 .002 | 0 .001 | 0 .003 | 0 .09 | 0 .071 | 0 .497 | 0 .284 | 0 .004 | 0 .001 | 0 .001 | 0 | 0 | . | 0 .018 |
| How satisfied are you with the building upgrade? | Correlation Coefficient | 0 .294 | .500** | .578** | 456** | 451** | 506** | 568** | 642** | 0 .157 | 0 .223 | 432** | 412* | 451** | 562** | 448** | 408* | 1 |
| | Sig. (2-tailed) | 0 .082 | 0.002 | 0 | 0 .005 | 0 .005 | 0 .001 | 0 | 0 | 0 .353 | 0 .198 | 0 .008 | 0 .013 | 0 .006 | 0 .001 | 0 .005 | 0 .018 | . |
| **. Correlation is significant at the 0.01 level (2-tailed). | | | *. Correlation is significant at the 0.05 level (2-tailed). | | | | | | | | | | | | | | | |

## Appendix G: Occupant Predictors of Household Energy Use – Gender, Age, Income, Hours per day

# INTERPRETING CROSS-TABULATIONS

Title of the survey section

Number of respondents of the question

**Percentage of the respondents of the question**

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| **Part 2: Electrical Devices** | | | | | | | | | | | | | | | | | |
| **8. How OLD is your TELEVISION ?** | I don't have a TV | 10 | 20% | 80% | 20% | 10% | 50% | 30% | 10% | 10% | 70% | 10% | 10% | 20% | 60% | 20% | 0% |
| | 5 years or less | 28 | 57% | 75% | 25% | 11% | 25% | 29% | 36% | 36% | 25% | 18% | 21% | 29% | 39% | 14% | 18% |
| | 6 to 10 years | 6 | 12% | 83% | 17% | 17% | 33% | 33% | 17% | 33% | 33% | 0% | 33% | 33% | 67% | 0% | 0% |
| | 11 to 15 years | 4 | 8% | 100% | 0% | 0% | 25% | 25% | 50% | 25% | 25% | 25% | 25% | 0% | 75% | 0% | 25% |
| | 16 years and more | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 100% |
| **9. How many hours a day do you leave your TELEVISION turned on ?** | I don't have a TV | 10 | 20% | 80% | 20% | 10% | 50% | 30% | 10% | 10% | 70% | 10% | 10% | 20% | 60% | 20% | 0% |
| | 1 hour or less | 6 | 12% | 50% | 50% | 0% | 33% | 17% | 50% | 67% | 0% | 0% | 33% | 50% | 17% | 17% | 17% |
| | 1 to 3 hours | 16 | 33% | 88% | 13% | 19% | 38% | 31% | 13% | 19% | 44% | 31% | 6% | 25% | 75% | 0% | 0% |
| | 4 to 8 hours | 12 | 24% | 83% | 17% | 8% | 17% | 17% | 58% | 25% | 33% | 0% | 42% | 17% | 33% | 25% | 25% |
| | 9 to 13 hours | 4 | 8% | 75% | 25% | 0% | 0% | 75% | 25% | 50% | 0% | 25% | 25% | 25% | 25% | 0% | 50% |
| | 14 hours or more | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |

Survey question

**This means that 50% of the people who reply "I use my TV 1 hour or a less a day" are female.**

**This means that 67% of the people who reply "My TV is 6 to 10 years old" spend 9 to 13 hours in their apartment per day.**

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| Part 1: General Information | | | | | | | | | | | | | | | | | |
| 2.Are you a male or female ? | Male | 39 | 80% | | | 8% | 33% | 31% | 28% | 23% | 38% | 18% | 21% | 28% | 46% | 15% | 10% |
| | Female | 10 | 20% | | | 20% | 20% | 20% | 40% | 50% | 30% | 0% | 4% | 10% | 60% | 0% | 30% |
| 3. What is your age | Between 18 and 30 years old | 5 | 10% | 60% | 40% | | | | | 40% | 20% | 0% | 40% | 20% | 80% | 0% | 0% |
| | Between 31 and 45 years old | 15 | 31% | 87% | 13% | | | | | 20% | 53% | 13% | 13% | 33% | 60% | 7% | 0% |
| | Between 46 to 60 years old | 14 | 29% | 86% | 14% | | | | | 29% | 36% | 29% | 7% | 21% | 64% | 7% | 7% |
| | Over 60 years old | 15 | 31% | 73% | 27% | | | | | 33% | 27% | 7% | 33% | 20% | 13% | 27% | 40% |
| 4. What part of the world did you grow up in? | Canada | 15 | 31% | 73% | 27% | 0% | 13% | 27% | 60% | 27% | 40% | 7% | 27% | 20% | 33% | 13% | 33% |
| | USA | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| | Europe | 4 | 8% | 100% | 0% | 25% | 0% | 50% | 25% | 50% | 25% | 25% | 0% | 0% | 50% | 25% | 25% |
| | South or central America | 4 | 8% | 100% | 0% | 0% | 0% | 50% | 50% | 25% | 25% | 25% | 25% | 50% | 0% | 50% | 0% |
| | East Asia | 2 | 4% | 50% | 50% | 50% | 0% | 0% | 50% | 0% | 0% | 50% | 50% | 0% | 100% | 0% | 0% |
| | West Asia and Middle East | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| | Africa | 22 | 45% | 77% | 23% | 14% | 55% | 27% | 5% | 27% | 41% | 14% | 18% | 32% | 64% | 5% | 0% |
| 5. How many years have you been living in the Toronto MURB | 0 to 1 year | 6 | 12% | 83% | 17% | 33% | 50% | 17% | 0% | 17% | 33% | 0% | 50% | 17% | 83% | 0% | 0% |
| | 2 to 4 years | 16 | 33% | 75% | 25% | 19% | 38% | 31% | 13% | 25% | 50% | 25% | 0% | 25% | 63% | 13% | 0% |
| | 5 to 7 years | 5 | 10% | 60% | 40% | 0% | 20% | 60% | 20% | 60% | 20% | 0% | 20% | 40% | 40% | 0% | 20% |
| | more than 7 years | 22 | 45% | 86% | 14% | 0% | 23% | 23% | 55% | 27% | 32% | 14% | 27% | 23% | 32% | 18% | 27% |
| 6. On an average day, how many hours do you spend in you apartment unit (includes sleeping)? | 8 hours or less | 12 | 24% | 92% | 8% | 8% | 42% | 25% | 25% | 25% | 42% | 17% | 17% | | | | |
| | 9 to 13 hours | 24 | 49% | 75% | 25% | 17% | 38% | 38% | 8% | 25% | 42% | 17% | 17% | | | | |
| | 14 to 18 hours | 6 | 12% | 100% | 0% | 0% | 17% | 17% | 67% | 0% | 33% | 17% | 50% | | | | |
| | more than 18 hours | 7 | 14% | 57% | 43% | 0% | 0% | 14% | 86% | 71% | 14% | 0% | 14% | | | | |
| 7. What is your total income ? | Between $0 and $14,999 | 14 | 29% | 64% | 36% | 14% | 21% | 29% | 36% | | | | | 21% | 43% | 0% | 36% |
| | Between $15,000 and $29,999 | 18 | 37% | 83% | 17% | 6% | 44% | 28% | 11% | | | | | 28% | 56% | 11% | 6% |
| | Between $30,000 and $49,999 | 7 | 14% | 100% | 0% | 0% | 29% | 57% | 14% | | | | | 29% | 57% | 14% | 0% |
| | Preferred not to say | 10 | 20% | 80% | 20% | 20% | 20% | 10% | 50% | | | | | 20% | 40% | 30% | 10% |

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| Part 2: Electrical Devices | | | | | | | | | | | | | | | | | |
| 8. How OLD is your TELEVISION ? | I don't have a TV | 10 | 20% | 80% | 20% | 10% | 50% | 30% | 10% | 10% | 70% | 10% | 10% | 20% | 60% | 20% | 0% |
| | 5 years or less | 28 | 57% | 75% | 25% | 11% | 25% | 29% | 36% | 36% | 25% | 18% | 21% | 29% | 39% | 14% | 18% |
| | 6 to 10 years | 6 | 12% | 83% | 17% | 17% | 33% | 33% | 17% | 33% | 33% | 0% | 33% | 33% | 67% | 0% | 0% |
| | 11 to 15 years | 4 | 8% | 100% | 0% | 0% | 25% | 25% | 50% | 25% | 25% | 25% | 25% | 0% | 75% | 0% | 25% |
| | 16 years and more | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 100% |
| 9. How many hours a day do you leave your TELEVISION turned on ? | I don't have a TV | 10 | 20% | 80% | 20% | 10% | 50% | 30% | 10% | 10% | 70% | 10% | 10% | 20% | 60% | 20% | 0% |
| | 1 hour or less | 6 | 12% | 50% | 50% | 0% | 33% | 17% | 50% | 67% | 0% | 0% | 33% | 50% | 17% | 17% | 17% |
| | 1 to 3 hours | 16 | 33% | 88% | 13% | 19% | 38% | 31% | 13% | 19% | 44% | 31% | 6% | 25% | 75% | 0% | 0% |
| | 4 to 8 hours | 12 | 24% | 83% | 17% | 8% | 17% | 17% | 58% | 25% | 33% | 0% | 42% | 17% | 33% | 25% | 25% |
| | 9 to 13 hours | 4 | 8% | 75% | 25% | 0% | 0% | 75% | 25% | 50% | 0% | 25% | 25% | 25% | 25% | 0% | 50% |
| | 14 hours or more | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| 10. What TYPE of TELEVISION do you have? | I don't have a TV | 10 | 20% | 80% | 20% | 10% | 50% | 30% | 10% | 10% | 70% | 10% | 10% | 20% | 60% | 20% | 0% |
| | LCD / LED | 16 | 33% | 106% | 6% | 0% | 38% | 31% | 31% | 25% | 38% | 13% | 25% | 13% | 50% | 25% | 13% |
| | Plasma | 9 | 18% | 56% | 44% | 33% | 11% | 22% | 33% | 67% | 22% | 11% | 0% | 33% | 44% | 0% | 22% |
| | Regular (tube) | 14 | 29% | 79% | 21% | 7% | 21% | 29% | 43% | 21% | 21% | 21% | 36% | 36% | 43% | 0% | 21% |
| 11. Do you turn off the cable box when you are done watching television ? | I haven't cable box | 28 | 57% | 75% | 25% | 7% | 39% | 32% | 21% | 25% | 43% | 14% | 18% | 21% | 57% | 11% | 11% |
| | Always turn off | 12 | 24% | 100% | 0% | 0% | 25% | 33% | 42% | 17% | 25% | 25% | 33% | 42% | 25% | 25% | 8% |
| | Leave on all the time | 7 | 14% | 57% | 43% | 43% | 0% | 14% | 43% | 57% | 29% | 0% | 14% | 14% | 57% | 0% | 29% |
| | Sometimes turn it off | 2 | 4% | 100% | 0% | 0% | 50% | 0% | 50% | 50% | 50% | 0% | 0% | 0% | 50% | 0% | 50% |
| 12. Do you have a laptop, desktop, or both? | None | 26 | 53% | 77% | 23% | 4% | 23% | 23% | 50% | 19% | 42% | 12% | 27% | 27% | 38% | 19% | 15% |
| | Laptop | 16 | 33% | 81% | 19% | 25% | 50% | 25% | 0% | 31% | 38% | 13% | 19% | 25% | 69% | 6% | 0% |
| | Desktop | 5 | 10% | 100% | 0% | 0% | 0% | 80% | 20% | 40% | 20% | 40% | 0% | 20% | 40% | 40% | 0% |
| | Both | 2 | 4% | 50% | 50% | 0% | 50% | 0% | 50% | 100% | 0% | 0% | 0% | 0% | 50% | 0% | 50% |
| 13. How many hours a day do you use your | I don't have a computer or I don't use it | 28 | 57% | 79% | 21% | 4% | 25% | 25% | 46% | 18% | 43% | 14% | 25% | 29% | 39% | 18% | 14% |
| | 1 hour or less | 3 | 6% | 67% | 33% | 33% | 33% | 0% | 33% | 33% | 0% | 33% | 33% | 33% | 33% | 0% | 33% |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **COMPUTER?** | **1 to 3 hours** | **7** | **14%** | **86%** | **14%** | **0%** | **57%** | **43%** | **0%** | **43%** | **14%** | **14%** | **29%** | **0%** | **86%** | **14%** | **0%** |
| | **4 to 8 hours** | **9** | **18%** | **78%** | **22%** | **33%** | **22%** | **33%** | **11%** | **56%** | **33%** | **11%** | **0%** | **33%** | **44%** | **22%** | **0%** |
| | **9 hours or more** | **2** | **4%** | **100%** | **0%** | **0%** | **50%** | **50%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** |
| **14. How old is you computer ?** | **I don't have a computer** | **26** | **53%** | **77%** | **23%** | **4%** | **23%** | **23%** | **50%** | **19%** | **42%** | **12%** | **27%** | **27%** | **38%** | **19%** | **15%** |
| | **5 years or less** | **21** | **43%** | **86%** | **14%** | **19%** | **38%** | **38%** | **5%** | **33%** | **33%** | **19%** | **14%** | **24%** | **62%** | **5%** | **10%** |
| | **6 to 10 years** | **2** | **4%** | **50%** | **50%** | **0%** | **50%** | **0%** | **50%** | **100%** | **0%** | **0%** | **0%** | **0%** | **50%** | **0%** | **50%** |
| **15. On an average day, how long do you spend on the Internet ?** | **I do not have internet** | **28** | **57%** | **79%** | **21%** | **4%** | **25%** | **25%** | **46%** | **18%** | **43%** | **14%** | **25%** | **29%** | **39%** | **18%** | **14%** |
| | **1 hour or less** | **3** | **6%** | **67%** | **33%** | **33%** | **33%** | **0%** | **33%** | **33%** | **0%** | **33%** | **33%** | **33%** | **33%** | **0%** | **33%** |
| | **1 to 3 hours** | **7** | **14%** | **86%** | **14%** | **0%** | **57%** | **43%** | **0%** | **43%** | **14%** | **14%** | **29%** | **0%** | **86%** | **14%** | **0%** |
| | **4 to 8 hours** | **9** | **18%** | **78%** | **22%** | **33%** | **22%** | **33%** | **11%** | **56%** | **33%** | **11%** | **0%** | **33%** | **44%** | **0%** | **22%** |
| | **8 to 14 hours** | **0** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** |
| | **14 hours or more** | **2** | **4%** | **100%** | **0%** | **0%** | **50%** | **50%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** |

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| 16. What appliances do you have at home ? | Cell phone charger | 36 | 73% | 72% | 28% | 14% | 36% | 28% | 22% | 33% | 33% | 14% | 19% | 25% | 56% | 8% | 11% |
| | Home phone | 19 | 39% | 84% | 16% | 5% | 11% | 47% | 37% | 37% | 16% | 21% | 21% | 21% | 37% | 21% | 21% |
| | VHS player | 6 | 12% | 83% | 17% | 0% | 33% | 33% | 33% | 17% | 50% | 17% | 17% | 67% | 17% | 0% | 17% |
| | DVD player | 25 | 51% | 100% | 20% | 8% | 32% | 32% | 28% | 28% | 36% | 20% | 16% | 20% | 52% | 12% | 16% |
| | Game console | 1 | 2% | 100% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 0% |
| | Printer | 10 | 20% | 100% | 0% | 30% | 30% | 40% | 0% | 40% | 20% | 30% | 10% | 40% | 50% | 0% | 10% |
| | Speakers | 13 | 27% | 85% | 15% | 8% | 54% | 23% | 15% | 23% | 38% | 23% | 15% | 31% | 46% | 8% | 15% |
| | Clock | 17 | 35% | 100% | 0% | 12% | 18% | 41% | 29% | 29% | 29% | 24% | 18% | 24% | 47% | 18% | 12% |
| | Radio / stereo | 25 | 51% | 84% | 16% | 4% | 28% | 32% | 36% | 16% | 40% | 24% | 20% | 16% | 44% | 20% | 20% |
| | Slow cooker | 5 | 10% | 80% | 20% | 0% | 20% | 40% | 40% | 0% | 20% | 40% | 40% | 40% | 40% | 0% | 20% |
| | Rice cooker | 6 | 12% | 67% | 33% | 17% | 50% | 17% | 17% | 17% | 33% | 17% | 33% | 0% | 83% | 0% | 17% |
| | Iron | 21 | 43% | 62% | 38% | 10% | 24% | 43% | 24% | 38% | 33% | 10% | 19% | 14% | 67% | 5% | 14% |
| | Vacuum cleaner | 12 | 24% | 92% | 8% | 0% | 8% | 33% | 58% | 42% | 25% | 8% | 25% | 17% | 25% | 25% | 33% |
| | Humidifier / Dehumidifier | 3 | 6% | 67% | 33% | 0% | 33% | 33% | 33% | 33% | 33% | 33% | 0% | 33% | 33% | 0% | 33% |
| | Toaster | 5 | 10% | 80% | 20% | 20% | 40% | 20% | 20% | 20% | 60% | 0% | 20% | 0% | 80% | 0% | 20% |
| | Coffee maker | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| | Fan | 2 | 4% | 100% | 0% | 0% | 0% | 50% | 50% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| | Air conditioner | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| | Battery clock | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 100% |
| | Broiler | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| | Microwave | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| | Electric kettle | 1 | 2% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| | Refrigerator | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% |
| | Teapot | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
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| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| Part 3: Heating and Cooling | | | | | | | | | | | | | | | | | |
| 17. During the winter, what temperature do you set your heating/cooling equipment at ? | 0 | 19 | 39% | 68% | 26% | 5% | 47% | 26% | 16% | 21% | 37% | 11% | 26% | 21% | 63% | 0% | 11% |
| | 0-16 | 7 | 14% | 86% | 14% | 0% | 14% | 57% | 29% | 29% | 43% | 29% | 0% | 71% | 14% | 0% | 14% |
| | 16-20 | 9 | 18% | 78% | 22% | 11% | 33% | 33% | 22% | 33% | 44% | 11% | 11% | 22% | 56% | 11% | 11% |
| | over 20 | 14 | 29% | 86% | 14% | 21% | 14% | 7% | 57% | 36% | 21% | 14% | 29% | 7% | 36% | 36% | 21% |
| | other | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| 18. During the summer, what temperature do you set your heating/cooling equipment at ? | 0 | 24 | 49% | 75% | 25% | 8% | 38% | 21% | 33% | 29% | 38% | 13% | 21% | 38% | 46% | 0% | 17% |
| | 0-16 | 6 | 12% | 100% | 0% | 17% | 0% | 50% | 33% | 50% | 0% | 33% | 17% | 17% | 50% | 17% | 17% |
| | 16-20 | 13 | 27% | 69% | 31% | 8% | 38% | 31% | 23% | 31% | 46% | 8% | 15% | 8% | 54% | 23% | 15% |
| | over 20 | 5 | 10% | 100% | 0% | 20% | 20% | 20% | 40% | 0% | 40% | 20% | 40% | 20% | 40% | 40% | 0% |
| | other | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| 19. Which of the following do you use to adjust your thermal comfort ? | Open / close windows | 39 | 80% | 77% | 23% | 13% | 33% | 31% | 23% | 31% | 33% | 15% | 21% | 23% | 56% | 8% | 13% |
| | Open / close doors | 14 | 29% | 86% | 14% | 14% | 36% | 21% | 29% | 43% | 29% | 29% | 0% | 21% | 64% | 0% | 14% |
| | Adjust thermostat | 13 | 27% | 77% | 23% | 8% | 31% | 31% | 31% | 46% | 8% | 15% | 31% | 8% | 54% | 23% | 15% |
| | Turn on personal heater | 3 | 6% | 67% | 33% | 0% | 67% | 0% | 33% | 33% | 33% | 33% | 0% | 0% | 100% | 0% | 0% |
| | Turn on personal fan | 14 | 29% | 93% | 7% | 0% | 0% | 43% | 57% | 36% | 29% | 14% | 21% | 7% | 36% | 29% | 29% |
| | Put on / remove clothing | 23 | 47% | 74% | 26% | 13% | 17% | 35% | 35% | 26% | 35% | 22% | 17% | 17% | 48% | 13% | 22% |
| | Close blinds / drapes | 21 | 43% | 76% | 24% | 5% | 14% | 38% | 43% | 38% | 29% | 10% | 24% | 14% | 48% | 14% | 24% |
| | Other | 1 | 2% | 0% | 100% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
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| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| Part 4: Energy Behaviour | | | | | | | | | | | | | | | | | |
| 20.a Do you turn off the lights when you are not at home ? | No response | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% |
| | Always | 42 | 86% | 79% | 21% | 10% | 29% | 31% | 31% | 26% | 38% | 14% | 21% | 21% | 52% | 12% | 14% |
| | Between always and I don't know | 4 | 8% | 75% | 25% | 25% | 25% | 25% | 25% | 50% | 25% | 25% | 0% | 50% | 25% | 0% | 25% |
| | I don't know | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| | Between I don't know and never | 0 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | Never | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% |
| 20.b Do you turn off the lights when not in use ? | Always | 35 | 71% | 77% | 23% | 6% | 31% | 29% | 34% | 17% | 46% | 14% | 23% | 23% | 51% | 14% | 11% |
| | Between always and I don't know | 10 | 20% | 90% | 10% | 20% | 20% | 40% | 20% | 50% | 10% | 20% | 20% | 40% | 30% | 10% | 20% |
| | I don't know | 3 | 6% | 100% | 0% | 33% | 67% | 0% | 0% | 67% | 33% | 0% | 0% | 0% | 100% | 0% | 0% |
| | Between I don't know and never | 0 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | Never | 1 | 2% | 0% | 100% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| 20.c Do you turn off electronics when you are not at home? | No response | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| | Always | 40 | 82% | 75% | 25% | 10% | 30% | 23% | 38% | 33% | 33% | 13% | 23% | 18% | 50% | 15% | 10% |
| | Between always and I don't know | 5 | 10% | 100% | 0% | 0% | 40% | 60% | 0% | 0% | 40% | 40% | 20% | 40% | 60% | 0% | 0% |
| | I don't know | 2 | 4% | 100% | 0% | 0% | 50% | 50% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% |
| | Between I don't know and never | 0 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | Never | 1 | 2% | 100% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% |
| 20.d Do you turn off the electronics when not in use ? | No response | 2 | 4% | 100% | 0% | 0% | 0% | 50% | 50% | 0% | 100% | 0% | 0% | 0% | 50% | 50% | 0% |
| | Always | 37 | 76% | 78% | 22% | 8% | 35% | 24% | 32% | 27% | 35% | 14% | 24% | 24% | 49% | 14% | 14% |
| | Between always and I don't know | 5 | 10% | 80% | 20% | 0% | 20% | 60% | 20% | 20% | 20% | 40% | 20% | 20% | 60% | 0% | 20% |
| | I don't know | 3 | 6% | 100% | 0% | 33% | 33% | 33% | 0% | 33% | 67% | 0% | 0% | 33% | 67% | 0% | 0% |
| | Between I don't know and never | 0 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | Never | 2 | 4% | 50% | 50% | 50% | 0% | 0% | 50% | 100% | 0% | 0% | 0% | 50% | 0% | 0% | 50% |
| 20.e Do | No response | 3 | 6% | 100% | 0% | 0% | 0% | 67% | 33% | 0% | 33% | 33% | 33% | 33% | 67% | 0% | 0% |

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| you use timer controls to control your electrical devices ? | Always | 8 | 16% | 88% | 13% | 13% | 38% | 25% | 25% | 25% | 38% | 13% | 25% | 50% | 25% | 13% | 13% |
| | Between always and I don't know | 3 | 6% | 100% | 0% | 0% | 33% | 67% | 0% | 33% | 33% | 33% | 0% | 67% | 33% | 0% | 0% |
| | I don't know | 6 | 12% | 100% | 0% | 0% | 50% | 17% | 33% | 0% | 33% | 17% | 50% | 33% | 50% | 17% | 0% |
| | Between I don't know and never | 1 | 2% | 100% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% |
| | Never | 28 | 57% | 68% | 32% | 11% | 29% | 25% | 36% | 39% | 39% | 11% | 11% | 11% | 54% | 14% | 21% |
| 20.f Do you turn off (shut down) computer when not in use ? | No response | 23 | 47% | 74% | 26% | 0% | 22% | 26% | 52% | 22% | 39% | 17% | 22% | 22% | 39% | 22% | 17% |
| | Always | 17 | 35% | 82% | 18% | 24% | 47% | 29% | 0% | 29% | 35% | 12% | 24% | 24% | 71% | 6% | 0% |
| | Between always and I don't know | 4 | 8% | 75% | 25% | 0% | 50% | 25% | 25% | 50% | 50% | 0% | 0% | 0% | 50% | 0% | 50% |
| | I don't know | 3 | 6% | 100% | 0% | 33% | 0% | 33% | 33% | 33% | 0% | 33% | 33% | 100% | 0% | 0% | 0% |
| | Between I don't know and never | 0 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | Never | 2 | 4% | 100% | 0% | 0% | 0% | 50% | 50% | 50% | 50% | 0% | 0% | 0% | 50% | 0% | 50% |
| 20.g Do you turn off (shut down) computer when not at home ? | No response | 24 | 49% | 75% | 25% | 0% | 21% | 25% | 54% | 21% | 38% | 17% | 25% | 25% | 38% | 21% | 17% |
| | Always | 20 | 41% | 80% | 20% | 25% | 45% | 25% | 5% | 35% | 35% | 10% | 20% | 25% | 60% | 5% | 10% |
| | Between always and I don't know | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 0% |
| | I don't know | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% | 0% |
| | Between I don't know and never | 0 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | Never | 3 | 6% | 100% | 0% | 0% | 0% | 67% | 33% | 33% | 67% | 0% | 0% | 0% | 67% | 0% | 33% |

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
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| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| 20. h Do you buy green appliances/devices (e.g. energy saving bulbs and EnergyStar appliances) ? | No response | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| | Always | 24 | 49% | 83% | 17% | 4% | 17% | 38% | 42% | 21% | 42% | 21% | 17% | 25% | 42% | 21% | 13% |
| | Between always and I don't know | 5 | 10% | 100% | 0% | 0% | 60% | 40% | 0% | 40% | 40% | 20% | 0% | 40% | 40% | 0% | 20% |
| | I don't know | 6 | 12% | 100% | 0% | 0% | 67% | 17% | 17% | 17% | 33% | 17% | 33% | 0% | 83% | 17% | 0% |
| | Between I don't know and never | 0 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | Never | 13 | 27% | 54% | 46% | 31% | 31% | 15% | 23% | 38% | 31% | 0% | 31% | 31% | 54% | 0% | 15% |
| 21. How many COMPACT FLUORESCENT (CFL) (Energy Saving) light bulbs do you use in your apartment ? | 0 CFL | 11 | 22% | 55% | 45% | 18% | 36% | 18% | 27% | 36% | 45% | 0% | 18% | 9% | 55% | 0% | 36% |
| | 1 CFL | 5 | 10% | 80% | 20% | 40% | 40% | 0% | 20% | 20% | 20% | 0% | 60% | 20% | 80% | 0% | 0% |
| | 2 CFL | 7 | 14% | 86% | 14% | 0% | 43% | 0% | 57% | 43% | 29% | 0% | 29% | 43% | 29% | 14% | 14% |
| | 3 CFL | 12 | 24% | 83% | 17% | 8% | 33% | 42% | 17% | 33% | 42% | 25% | 0% | 25% | 50% | 8% | 17% |
| | 4 CFL | 8 | 16% | 88% | 13% | 0% | 25% | 63% | 13% | 25% | 38% | 25% | 13% | 38% | 50% | 13% | 0% |
| | 5 CFL | 5 | 10% | 100% | 0% | 0% | 0% | 20% | 80% | 0% | 40% | 20% | 40% | 0% | 40% | 60% | 0% |
| | 6 CFL | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% | 0% |
| 22. How many INCANDESCENT (regular) light bulbs do you use in your apartment ? | 0 incandescent | 16 | 33% | 94% | 6% | 0% | 25% | 50% | 25% | 19% | 38% | 31% | 13% | 25% | 56% | 13% | 6% |
| | 1 incandescent | 10 | 20% | 60% | 40% | 10% | 20% | 20% | 50% | 30% | 40% | 0% | 30% | 10% | 40% | 30% | 20% |
| | 2 incandescent | 9 | 18% | 100% | 0% | 11% | 44% | 11% | 33% | 11% | 56% | 0% | 33% | 56% | 44% | 0% | 0% |
| | 3 incandescent | 9 | 18% | 78% | 22% | 33% | 56% | 11% | 0% | 44% | 33% | 11% | 11% | 11% | 78% | 11% | 0% |
| | 4 incandescent | 3 | 6% | 33% | 67% | 0% | 0% | 33% | 67% | 67% | 0% | 33% | 0% | 33% | 0% | 0% | 67% |
| | 5 incandescent | 1 | 2% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% |
| | 6 incandescent | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| 23. On an average day, how many light bulbs are turned on longer than 3 hours or more ? | 0 | 2 | 4% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 50% | 50% | 0% | 0% |
| | 1 to 3 bulbs | 40 | 82% | 78% | 23% | 13% | 33% | 23% | 33% | 35% | 35% | 10% | 20% | 25% | 50% | 10% | 15% |
| | 3 to 5 bulbs | 7 | 14% | 86% | 14% | 0% | 0% | 71% | 29% | 0% | 29% | 43% | 29% | 14% | 43% | 29% | 14% |
| 24. How many hours are the light bulbs turned on during the winter ? | 0 | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% |
| | less than 3 hours | 14 | 29% | 64% | 36% | 14% | 29% | 29% | 29% | 36% | 36% | 14% | 14% | 29% | 57% | 7% | 7% |
| | 3 to 5 hours | 20 | 41% | 85% | 15% | 15% | 45% | 15% | 25% | 30% | 45% | 5% | 20% | 30% | 55% | 5% | 10% |
| | 6 to 9 hours | 9 | 18% | 89% | 11% | 0% | 11% | 56% | 33% | 11% | 33% | 22% | 33% | 0% | 56% | 22% | 22% |
| | more than 9 hours | 5 | 10% | 80% | 20% | 0% | 0% | 40% | 60% | 40% | 0% | 40% | 20% | 20% | 0% | 40% | 40% |
| 25. How many hours are the light bulbs turned on | 0 | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% |
| | less than 3 hours | 30 | 61% | 70% | 30% | 13% | 27% | 27% | 33% | 33% | 40% | 7% | 20% | 30% | 50% | 7% | 13% |

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| during the summer ? | 3 to 5 hours | 12 | 24% | 100% | 0% | 8% | 42% | 25% | 25% | 17% | 33% | 25% | 25% | 8% | 58% | 25% | 8% |
| | 6 to 9 hours | 4 | 8% | 75% | 25% | 0% | 25% | 50% | 25% | 25% | 25% | 25% | 25% | 25% | 50% | 0% | 25% |
| | more than 9 hours | 2 | 4% | 100% | 0% | 100% | 100% | 50% | 50% | 50% | 0% | 50% | 0% | 0% | 0% | 50% | 50% |
| 26. How many lamps, floor lamps, or any other light fixtures do yo have ? | 0 | 18 | 37% | 67% | 33% | 6% | 44% | 33% | 17% | 39% | 33% | 17% | 11% | 28% | 61% | 6% | 6% |
| | 1 | 14 | 29% | 86% | 14% | 7% | 14% | 36% | 43% | 21% | 29% | 21% | 29% | 29% | 43% | 7% | 21% |
| | 2 | 4 | 8% | 75% | 25% | 25% | 0% | 25% | 50% | 75% | 0% | 0% | 25% | 25% | 0% | 0% | 75% |
| | 3 | 6 | 12% | 83% | 17% | 33% | 50% | 0% | 17% | 0% | 83% | 0% | 17% | 17% | 67% | 17% | 0% |
| | 4 | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% |
| | 5 | 4 | 8% | 100% | 0% | 0% | 50% | 25% | 25% | 25% | 50% | 0% | 25% | 0% | 75% | 25% | 0% |
| | 6 | 2 | 4% | 100% | 0% | 0% | 0% | 50% | 50% | 0% | 50% | 50% | 0% | 50% | 0% | 50% | 0% |

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
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| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| Part 6: Water Usage | | | | | | | | | | | | | | | | | |
| 27. Do you run the tap while brushing your teeth, shaving, ? | No | 25 | 51% | 72% | 28% | 8% | 36% | 20% | 36% | 32% | 24% | 16% | 28% | 24% | 48% | 12% | 16% |
| | Yes | 24 | 49% | 88% | 13% | 13% | 25% | 38% | 25% | 25% | 50% | 13% | 13% | 25% | 50% | 13% | 13% |
| 28. Do you leave the sink/tap running while washing the dishes ? | No | 34 | 69% | 88% | 12% | 9% | 32% | 26% | 32% | 18% | 44% | 15% | 24% | 26% | 50% | 12% | 12% |
| | Yes | 15 | 31% | 60% | 40% | 13% | 27% | 33% | 27% | 53% | 20% | 13% | 13% | 20% | 47% | 13% | 20% |
| 29. How many times do you flush your toilet in a day? | 0 | 4 | 8% | 75% | 25% | 0% | 0% | 75% | 25% | 25% | 25% | 0% | 50% | 50% | 50% | 0% | 0% |
| | 1 | 3 | 6% | 100% | 0% | 0% | 33% | 0% | 67% | 0% | 67% | 0% | 33% | 67% | 0% | 33% | 0% |
| | 2 | 5 | 10% | 100% | 0% | 0% | 60% | 20% | 20% | 20% | 20% | 40% | 20% | 40% | 40% | 0% | 20% |
| | 3 | 5 | 10% | 100% | 0% | 0% | 40% | 40% | 20% | 20% | 60% | 20% | 0% | 60% | 40% | 0% | 0% |
| | 4 | 13 | 27% | 69% | 31% | 8% | 38% | 31% | 23% | 38% | 23% | 8% | 31% | 8% | 62% | 15% | 15% |
| | 5 | 7 | 14% | 71% | 29% | 29% | 14% | 14% | 43% | 43% | 43% | 14% | 0% | 14% | 57% | 14% | 14% |
| | 6 | 5 | 10% | 60% | 40% | 20% | 20% | 20% | 40% | 20% | 40% | 0% | 40% | 0% | 60% | 20% | 20% |
| | 7 | 1 | 2% | 100% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 0% |
| | 8 | 2 | 4% | 100% | 0% | 0% | 0% | 0% | 100% | 50% | 50% | 0% | 0% | 0% | 0% | 0% | 100% |
| | 9 | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| | 10 | 3 | 6% | 67% | 33% | 0% | 33% | 67% | 0% | 0% | 33% | 67% | 0% | 33% | 33% | 33% | 0% |
| 30. Do you prefer taking a shower/bath ? | Bath | 5 | 10% | 80% | 20% | 0% | 0% | 60% | 40% | 40% | 0% | 20% | 40% | 20% | 20% | 20% | 40% |
| | Shower | 44 | 90% | 80% | 20% | 11% | 34% | 25% | 30% | 27% | 41% | 14% | 18% | 25% | 52% | 11% | 11% |
| 31. In a week, how many times do you shower or bathe? | 0 | 1 | 2% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% |
| | I don't keep track | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| | More than once per day | 5 | 10% | 80% | 20% | 40% | 20% | 20% | 20% | 40% | 60% | 0% | 0% | 80% | 20% | 0% | 0% |
| | Once a day | 27 | 55% | 81% | 19% | 7% | 41% | 41% | 11% | 33% | 26% | 22% | 19% | 19% | 59% | 15% | 7% |
| | Every other day | 8 | 16% | 75% | 25% | 13% | 38% | 13% | 38% | 13% | 50% | 0% | 38% | 25% | 50% | 0% | 25% |
| | Two times a week | 2 | 4% | 50% | 50% | 0% | 0% | 0% | 100% | 0% | 50% | 0% | 50% | 50% | 50% | 0% | 0% |
| | Three times a week | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% |
| | Once a week | 3 | 6% | 100% | 0% | 0% | 0% | 67% | 33% | 0% | 100% | 0% | 0% | 0% | 33% | 67% | 0% |
| | Take a shower at a pool after swimming | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% |

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| **Part 7: Household Activities** | | | | | | | | | | | | | | | | | |
| 32. On an average day, for how long do you use your stove ? | 0 | 5 | 10% | 100% | 0% | 20% | 40% | 40% | 0% | 20% | 60% | 20% | 0% | 40% | 60% | 0% | 0% |
| | 1 hour or less | 33 | 67% | 79% | 21% | 9% | 36% | 21% | 33% | 30% | 33% | 12% | 24% | 21% | 48% | 12% | 18% |
| | 1 to 3 hours | 8 | 16% | 75% | 25% | 13% | 13% | 50% | 25% | 25% | 38% | 25% | 13% | 25% | 50% | 25% | 0% |
| | more than 3 hours | 3 | 6% | 67% | 33% | 0% | 0% | 33% | 67% | 33% | 33% | 0% | 33% | 33% | 33% | 0% | 33% |
| 33. On an average day, for how long do you use your oven ? | 0 | 23 | 47% | 74% | 26% | 4% | 35% | 26% | 35% | 22% | 35% | 17% | 26% | 26% | 52% | 9% | 13% |
| | 1 hour or less | 22 | 45% | 82% | 18% | 14% | 27% | 32% | 27% | 36% | 41% | 9% | 14% | 14% | 50% | 18% | 18% |
| | 1 to 3 hours | 3 | 6% | 100% | 0% | 33% | 33% | 33% | 0% | 33% | 33% | 33% | 0% | 67% | 33% | 0% | 0% |
| | more than 3 hours | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% |
| 34. On an average day, what is the total time spent using your microwave ? | 0 | 28 | 57% | 68% | 32% | 7% | 36% | 21% | 36% | 25% | 46% | 4% | 25% | 29% | 46% | 14% | 11% |
| | Less than 3 minutes | 8 | 16% | 88% | 13% | 13% | 38% | 13% | 38% | 25% | 38% | 13% | 25% | 0% | 63% | 13% | 25% |
| | 3 to 9 minutes | 11 | 22% | 100% | 0% | 9% | 18% | 55% | 18% | 36% | 18% | 36% | 9% | 18% | 55% | 9% | 18% |
| | 9 to 15 minutes | 1 | 2% | 100% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% |
| | 15 minutes or more | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% | 0% |

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| **Part 8: Indoor Environment Satisfaction and Thermal Comfort** | | | | | | | | | | | | | | | | | |
| 35.a How satisfied are you with the amount of space available for individual daily activities ? | 0 | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% |
| | 1 (Very satisfied) | 12 | 24% | 83% | 17% | 17% | 17% | 33% | 33% | 0% | 58% | 25% | 17% | 25% | 42% | 25% | 8% |
| | 2 | 5 | 10% | 80% | 20% | 0% | 80% | 0% | 20% | 20% | 60% | 0% | 20% | 40% | 20% | 20% | 20% |
| | 3 | 7 | 14% | 100% | 0% | 0% | 14% | 43% | 43% | 29% | 14% | 29% | 29% | 14% | 71% | 14% | 0% |
| | 4 | 12 | 24% | 83% | 17% | 0% | 17% | 33% | 50% | 42% | 25% | 8% | 25% | 17% | 42% | 8% | 33% |
| | 5 | 1 | 2% | 0% | 100% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| | 6 | 4 | 8% | 50% | 50% | 50% | 0% | 25% | 25% | 75% | 0% | 0% | 25% | 0% | 75% | 0% | 25% |
| | 7 (Very dissatisfied) | 7 | 14% | 71% | 29% | 14% | 57% | 29% | 0% | 43% | 43% | 14% | 0% | 57% | 43% | 0% | 0% |
| 35.b How satisfied are you with the apartment unit layout ? | 0 | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% |
| | 1 (Very satisfied) | 14 | 29% | 79% | 21% | 14% | 21% | 29% | 36% | 14% | 50% | 21% | 14% | 29% | 36% | 21% | 14% |
| | 2 | 11 | 22% | 82% | 18% | 0% | 45% | 36% | 18% | 18% | 55% | 18% | 9% | 18% | 73% | 9% | 0% |
| | 3 | 4 | 8% | 50% | 50% | 0% | 25% | 25% | 50% | 25% | 25% | 0% | 50% | 0% | 50% | 25% | 25% |
| | 4 | 13 | 27% | 77% | 23% | 8% | 23% | 31% | 38% | 46% | 8% | 15% | 31% | 23% | 38% | 8% | 31% |
| | 5 | 1 | 2% | 100% | 0% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% |
| | 6 | 1 | 2% | 100% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 0% |
| | 7 (Very dissatisfied) | 4 | 8% | 100% | 0% | 25% | 50% | 25% | 0% | 25% | 75% | 0% | 0% | 50% | 50% | 0% | 0% |
| 35.c How satisfied are you with the quality of water in your apartment ? | 0 | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% |
| | 1 (Very satisfied) | 24 | 49% | 75% | 25% | 13% | 17% | 33% | 38% | 17% | 38% | 25% | 21% | 25% | 46% | 21% | 8% |
| | 2 | 8 | 16% | 100% | 0% | 0% | 50% | 38% | 13% | 38% | 38% | 0% | 25% | 13% | 63% | 13% | 13% |
| | 3 | 5 | 10% | 40% | 60% | 0% | 40% | 0% | 60% | 60% | 20% | 0% | 20% | 20% | 40% | 0% | 40% |
| | 4 | 7 | 14% | 86% | 14% | 29% | 29% | 14% | 29% | 57% | 14% | 14% | 14% | 29% | 43% | 0% | 29% |
| | 5 | 2 | 4% | 100% | 0% | 0% | 50% | 50% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% |
| | 6 | 0 | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% | 0% |
| | 7 (Very dissatisfied) | 2 | 4% | 100% | 0% | 0% | 50% | 50% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% |
| 35.d How satisfied are you with the | 1 (Very satisfied) | 26 | 53% | 69% | 31% | 12% | 27% | 27% | 35% | 19% | 46% | 15% | 19% | 27% | 38% | 19% | 15% |
| | 2 | 10 | 20% | 100% | 0% | 0% | 50% | 30% | 20% | 30% | 30% | 20% | 20% | 10% | 70% | 10% | 10% |

| | | | | | | | | | | | | | | | | | |
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| **appliances in your apartment (i.e. stove, refrigerator, etc.) ?** | **3** | **2** | **4%** | **100%** | **0%** | **0%** | **50%** | **50%** | **0%** | **50%** | **50%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** |
| | **4** | **10** | **20%** | **80%** | **20%** | **20%** | **20%** | **30%** | **30%** | **50%** | **20%** | **10%** | **20%** | **30%** | **50%** | **0%** | **20%** |
| | **5** | **0** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** |
| | **6** | **0** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** |
| | **7 (Very dissatisfied)** | **1** | **2%** | **100%** | **0%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **100%** | **100%** | **0%** | **0%** | **0%** |
| **35.e How satisfied are you with the cleanliness of the building ?** | **1 (Very satisfied)** | **35** | **71%** | **80%** | **20%** | **6%** | **31%** | **29%** | **34%** | **20%** | **49%** | **11%** | **20%** | **29%** | **40%** | **17%** | **14%** |
| | **2** | **5** | **10%** | **80%** | **20%** | **0%** | **60%** | **20%** | **20%** | **80%** | **20%** | **0%** | **0%** | **0%** | **60%** | **0%** | **40%** |
| | **3** | **3** | **6%** | **67%** | **33%** | **33%** | **0%** | **33%** | **33%** | **0%** | **0%** | **67%** | **33%** | **0%** | **100%** | **0%** | **0%** |
| | **4** | **3** | **6%** | **100%** | **0%** | **0%** | **33%** | **33%** | **33%** | **33%** | **0%** | **33%** | **33%** | **67%** | **33%** | **0%** | **0%** |
| | **5** | **1** | **2%** | **100%** | **0%** | **100%** | **0%** | **0%** | **0%** | **0%** | **0%** | **0%** | **100%** | **0%** | **100%** | **0%** | **0%** |
| | **6** | **1** | **2%** | **0%** | **100%** | **0%** | **0%** | **100%** | **0%** | **100%** | **0%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** |
| | **7 (Very dissatisfied)** | **1** | **2%** | **100%** | **0%** | **100%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** |

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| 35.f How satisfied are you with the maintenance of the building ? | 1 (Very satisfied) | 27 | 55% | 78% | 22% | 4% | 26% | 30% | 41% | 22% | 44% | 15% | 19% | 30% | 33% | 19% | 19% |
| | 2 | 8 | 16% | 88% | 13% | 0% | 38% | 25% | 38% | 38% | 25% | 25% | 13% | 13% | 50% | 13% | 25% |
| | 3 | 3 | 6% | 67% | 33% | 33% | 33% | 33% | 0% | 67% | 0% | 0% | 33% | 0% | 100% | 0% | 0% |
| | 4 | 6 | 12% | 83% | 17% | 17% | 33% | 33% | 17% | 17% | 50% | 0% | 33% | 33% | 67% | 0% | 0% |
| | 5 | 1 | 2% | 100% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% |
| | 6 | 2 | 4% | 50% | 50% | 0% | 50% | 50% | 0% | 50% | 0% | 50% | 0% | 50% | 50% | 0% | 0% |
| | 7 (Very dissatisfied) | 2 | 4% | 100% | 0% | 50% | 50% | 0% | 0% | 50% | 50% | 0% | 0% | 0% | 100% | 0% | 0% |
| 35.g How satisfied are you with the air quality in your apartment (e.g. stuffy/stale air, odours, cleanliness, etc.) ? | 0 | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% |
| | 1 (Very satisfied) | 10 | 20% | 100% | 0% | 10% | 10% | 40% | 40% | 20% | 40% | 20% | 20% | 20% | 40% | 10% | 30% |
| | 2 | 6 | 12% | 67% | 33% | 17% | 17% | 33% | 33% | 17% | 50% | 17% | 17% | 17% | 50% | 33% | 0% |
| | 3 | 9 | 18% | 67% | 33% | 0% | 44% | 11% | 44% | 11% | 33% | 11% | 44% | 11% | 44% | 22% | 22% |
| | 4 | 14 | 29% | 86% | 14% | 14% | 36% | 21% | 29% | 43% | 29% | 14% | 14% | 29% | 64% | 7% | 0% |
| | 5 | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% |
| | 6 | 3 | 6% | 33% | 67% | 0% | 33% | 33% | 33% | 67% | 33% | 0% | 0% | 0% | 33% | 0% | 67% |
| | 7 (Very dissatisfied) | 5 | 10% | 80% | 20% | 20% | 60% | 20% | 0% | 40% | 40% | 20% | 0% | 60% | 40% | 0% | 0% |
| 35.h How satisfied are you with the sound privacy between apartments ? | 1 (Very satisfied) | 18 | 37% | 78% | 22% | 11% | 17% | 39% | 33% | 28% | 39% | 17% | 17% | 22% | 44% | 11% | 22% |
| | 2 | 6 | 12% | 83% | 17% | 0% | 50% | 17% | 33% | 17% | 67% | 17% | 0% | 17% | 67% | 0% | 17% |
| | 3 | 12 | 24% | 83% | 17% | 8% | 50% | 17% | 25% | 33% | 33% | 8% | 25% | 25% | 42% | 17% | 17% |
| | 4 | 4 | 8% | 100% | 0% | 25% | 0% | 50% | 25% | 25% | 25% | 25% | 25% | 25% | 75% | 0% | 0% |
| | 5 | 2 | 4% | 50% | 50% | 0% | 50% | 0% | 50% | 100% | 0% | 0% | 0% | 50% | 50% | 0% | 0% |
| | 6 | 2 | 4% | 50% | 50% | 0% | 50% | 50% | 0% | 50% | 0% | 0% | 50% | 0% | 50% | 50% | 0% |
| | 7 (Very dissatisfied) | 5 | 10% | 80% | 20% | 20% | 40% | 0% | 40% | 0% | 40% | 20% | 40% | 40% | 40% | 20% | 0% |
| 36. Overall, does your acoustic quality in the apartment enhances or interferes with your | 0 | 5 | 10% | 100% | 0% | 20% | 20% | 20% | 40% | 20% | 40% | 0% | 40% | 20% | 60% | 20% | 0% |
| | 1 ( Enhances) | 14 | 29% | 79% | 21% | 0% | 29% | 36% | 36% | 29% | 57% | 14% | 0% | 21% | 36% | 14% | 29% |
| | 2 | 6 | 12% | 50% | 50% | 17% | 33% | 17% | 33% | 0% | 33% | 17% | 50% | 0% | 83% | 0% | 17% |
| | 3 | 10 | 20% | 90% | 10% | 10% | 40% | 30% | 20% | 40% | 30% | 20% | 10% | 40% | 30% | 10% | 20% |
| | 4 | 5 | 10% | 100% | 0% | 0% | 20% | 40% | 40% | 40% | 20% | 20% | 20% | 40% | 60% | 0% | 0% |

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| comfort ? | 5 | 4 | 8% | 75% | 25% | 25% | 25% | 25% | 25% | 50% | 25% | 0% | 25% | 0% | 75% | 25% | 0% |
| | 6 | 2 | 4% | 50% | 50% | 0% | 50% | 50% | 0% | 50% | 0% | 0% | 50% | 0% | 50% | 50% | 0% |
| | 7 (interferes) | 3 | 6% | 67% | 33% | 33% | 33% | 0% | 33% | 0% | 33% | 33% | 33% | 67% | 33% | 0% | 0% |
| 37. How satisfied are you with the temperature of your apartment unit during the summer ? | 1 (Very satisfied) | 7 | 14% | 71% | 29% | 0% | 29% | 14% | 57% | 29% | 29% | 29% | 14% | 29% | 14% | 29% | 29% |
| | 2 | 7 | 14% | 86% | 14% | 0% | 43% | 14% | 43% | 14% | 43% | 14% | 29% | 14% | 43% | 29% | 14% |
| | 3 | 10 | 20% | 80% | 20% | 10% | 20% | 40% | 30% | 20% | 30% | 30% | 20% | 30% | 50% | 10% | 10% |
| | 4 | 6 | 12% | 67% | 33% | 33% | 17% | 33% | 17% | 67% | 17% | 0% | 17% | 17% | 67% | 0% | 17% |
| | 5 | 3 | 6% | 100% | 0% | 0% | 33% | 33% | 33% | 67% | 0% | 0% | 33% | 33% | 67% | 0% | 0% |
| | 6 | 4 | 8% | 75% | 25% | 25% | 25% | 25% | 25% | 75% | 0% | 0% | 25% | 0% | 50% | 0% | 50% |
| | 7 (Very dissatisfied) | 12 | 24% | 83% | 17% | 8% | 42% | 33% | 17% | 0% | 75% | 8% | 17% | 33% | 58% | 8% | 0% |

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| 38. Overall, does your thermal comfort in the apartment during the summer enhances or interferes with your comfort ? | 1 ( Enhances) | 7 | 14% | 71% | 29% | 0% | 29% | 14% | 57% | 29% | 29% | 29% | 14% | 29% | 14% | 29% | 29% |
| | 2 | 7 | 14% | 100% | 0% | 0% | 29% | 43% | 29% | 14% | 43% | 29% | 14% | 29% | 29% | 29% | 14% |
| | 3 | 12 | 24% | 75% | 25% | 8% | 25% | 25% | 42% | 8% | 33% | 17% | 42% | 17% | 67% | 8% | 8% |
| | 4 | 10 | 20% | 80% | 20% | 20% | 20% | 30% | 30% | 70% | 20% | 0% | 10% | 30% | 50% | 0% | 20% |
| | 5 | 4 | 8% | 100% | 0% | 25% | 25% | 25% | 25% | 25% | 25% | 0% | 50% | 0% | 75% | 25% | 0% |
| | 6 | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 0% |
| | 7 (interferes) | 8 | 16% | 75% | 25% | 13% | 50% | 38% | 0% | 13% | 75% | 13% | 0% | 38% | 50% | 0% | 13% |
| 39. How satisfied are you with the temperature of your apartment unit during the winter? | 1 (Very satisfied) | 18 | 37% | 78% | 22% | 11% | 33% | 17% | 39% | 17% | 44% | 11% | 28% | 6% | 61% | 17% | 17% |
| | 2 | 9 | 18% | 89% | 11% | 0% | 11% | 67% | 22% | 44% | 11% | 33% | 11% | 11% | 44% | 22% | 22% |
| | 3 | 6 | 12% | 100% | 0% | 17% | 33% | 17% | 33% | 17% | 50% | 0% | 33% | 50% | 33% | 17% | 0% |
| | 4 | 7 | 14% | 86% | 14% | 14% | 29% | 29% | 29% | 57% | 29% | 0% | 14% | 43% | 43% | 0% | 14% |
| | 5 | 3 | 6% | 33% | 67% | 33% | 0% | 0% | 67% | 33% | 0% | 33% | 33% | 0% | 67% | 0% | 33% |
| | 6 | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% |
| | 7 (Very dissatisfied) | 5 | 10% | 60% | 40% | 0% | 60% | 40% | 0% | 20% | 60% | 20% | 0% | 60% | 40% | 0% | 0% |
| 40. Overall, does your thermal comfort in the apartment during the winter enhances or interferes with your comfort ? | 0 | 2 | 4% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 100% | 0% | 0% | 0% |
| | 1 ( Enhances) | 14 | 29% | 64% | 36% | 7% | 14% | 36% | 43% | 29% | 43% | 14% | 14% | 7% | 50% | 21% | 21% |
| | 2 | 9 | 18% | 100% | 0% | 0% | 44% | 44% | 11% | 22% | 22% | 33% | 22% | 11% | 56% | 22% | 11% |
| | 3 | 6 | 12% | 100% | 0% | 17% | 33% | 17% | 33% | 33% | 50% | 0% | 17% | 33% | 33% | 17% | 17% |
| | 4 | 9 | 18% | 67% | 33% | 22% | 22% | 22% | 33% | 44% | 33% | 0% | 22% | 33% | 44% | 0% | 22% |
| | 5 | 5 | 10% | 100% | 0% | 20% | 20% | 40% | 20% | 20% | 40% | 20% | 20% | 0% | 100% | 0% | 0% |
| | 6 | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% |
| | 7 (interferes) | 3 | 6% | 33% | 67% | 0% | 100% | 0% | 0% | 33% | 33% | 33% | 0% | 67% | 33% | 0% | 0% |
| 41. How satisfied are you with the temperature of your apartment unit during the spring/fall ? | 1 (Very satisfied) | 14 | 29% | 71% | 29% | 7% | 29% | 21% | 43% | 21% | 50% | 14% | 14% | 21% | 36% | 21% | 21% |
| | 2 | 12 | 24% | 83% | 17% | 8% | 33% | 42% | 17% | 25% | 25% | 25% | 25% | 17% | 75% | 8% | 0% |
| | 3 | 11 | 22% | 91% | 9% | 18% | 27% | 27% | 27% | 27% | 27% | 9% | 36% | 18% | 45% | 18% | 18% |
| | 4 | 4 | 8% | 75% | 25% | 25% | 0% | 25% | 50% | 75% | 25% | 0% | 0% | 25% | 25% | 0% | 50% |
| | 5 | 5 | 10% | 80% | 20% | 0% | 20% | 40% | 40% | 40% | 40% | 0% | 20% | 40% | 60% | 0% | 0% |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **6** | **2** | **4%** | **50%** | **50%** | **0%** | **100%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** | **50%** | **50%** | **0%** | **0%** |
| | **7 (Very dissatisfied)** | **1** | **2%** | **100%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **0%** | **100%** | **0%** | **100%** | **0%** | **0%** | **0%** |
| **42. Overall, does your thermal comfort in the apartment during the spring/fall enhances or interferes with your comfort ?** | **0** | **1** | **2%** | **100%** | **0%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **100%** | **100%** | **0%** | **0%** | **0%** |
| | **1 ( Enhances)** | **13** | **27%** | **69%** | **31%** | **8%** | **23%** | **31%** | **38%** | **23%** | **54%** | **15%** | **8%** | **15%** | **38%** | **23%** | **15%** |
| | **2** | **10** | **20%** | **80%** | **20%** | **0%** | **40%** | **40%** | **20%** | **30%** | **30%** | **30%** | **10%** | **20%** | **80%** | **0%** | **0%** |
| | **3** | **12** | **24%** | **92%** | **8%** | **17%** | **33%** | **17%** | **33%** | **33%** | **25%** | **8%** | **33%** | **25%** | **33%** | **25%** | **17%** |
| | **4** | **7** | **14%** | **71%** | **29%** | **14%** | **0%** | **57%** | **29%** | **43%** | **29%** | **0%** | **29%** | **14%** | **57%** | **0%** | **29%** |
| | **5** | **3** | **6%** | **100%** | **0%** | **33%** | **33%** | **0%** | **33%** | **33%** | **33%** | **0%** | **33%** | **33%** | **67%** | **0%** | **0%** |
| | **6** | **2** | **4%** | **50%** | **50%** | **0%** | **100%** | **0%** | **0%** | **0%** | **100%** | **0%** | **0%** | **50%** | **50%** | **0%** | **0%** |
| | **7 (interferes)** | **1** | **2%** | **100%** | **0%** | **0%** | **100%** | **0%** | **0%** | **0%** | **0%** | **100%** | **0%** | **100%** | **0%** | **0%** | **0%** |

| Questions | | # | % | Gender | | Age | | | | Income | | | | Hours per day | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Male | Female | Between 18 and 30 years old | Between 31 and 45 years old | Between 46 to 60 years old | Over 60 years old | Between $0 and $14,999 | Between $15,000 and $29,999 | Between $30,000 and $49,999 | Preferred not to say | 8 hours or less | 9 to 13 hours | 14 to 18 hours | more than 18 hours |
| 43. How satisfied are you with the air quality in your apartment (e.g. stuffy/stale air, odours, cleanliness, etc.)? | 0 | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 100% | 0% | 100% | 0% | 0% |
| | 1 (Very satisfied) | 10 | 20% | 100% | 0% | 10% | 10% | 40% | 40% | 20% | 40% | 20% | 20% | 20% | 40% | 10% | 30% |
| | 2 | 6 | 12% | 67% | 33% | 17% | 17% | 33% | 33% | 17% | 50% | 17% | 17% | 17% | 50% | 33% | 0% |
| | 3 | 9 | 18% | 67% | 33% | 0% | 44% | 11% | 44% | 11% | 33% | 11% | 44% | 11% | 44% | 22% | 22% |
| | 4 | 14 | 29% | 86% | 14% | 14% | 36% | 21% | 29% | 43% | 29% | 14% | 14% | 29% | 64% | 7% | 0% |
| | 5 | 1 | 2% | 100% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 100% | 0% | 0% | 0% |
| | 6 | 3 | 6% | 33% | 67% | 0% | 33% | 33% | 33% | 67% | 33% | 0% | 0% | 0% | 33% | 0% | 67% |
| | 7 (Very dissatisfied) | 5 | 10% | 80% | 20% | 20% | 60% | 20% | 0% | 40% | 40% | 20% | 0% | 60% | 40% | 0% | 0% |
| 44. Overall, does your air quality in the apartment enhances or interferes with your comfort ? | 0 | 3 | 6% | 67% | 33% | 0% | 0% | 33% | 67% | 0% | 0% | 0% | 100% | 33% | 33% | 0% | 33% |
| | 1 ( Enhances) | 12 | 24% | 92% | 8% | 0% | 25% | 33% | 42% | 33% | 50% | 17% | 0% | 8% | 42% | 17% | 33% |
| | 2 | 6 | 12% | 67% | 33% | 0% | 17% | 50% | 33% | 33% | 33% | 17% | 17% | 17% | 67% | 17% | 0% |
| | 3 | 8 | 16% | 88% | 13% | 13% | 38% | 38% | 13% | 0% | 38% | 25% | 38% | 25% | 50% | 25% | 0% |
| | 4 | 9 | 18% | 78% | 22% | 22% | 33% | 22% | 22% | 11% | 56% | 11% | 22% | 22% | 67% | 11% | 0% |
| | 5 | 5 | 10% | 60% | 40% | 20% | 40% | 0% | 40% | 80% | 20% | 0% | 0% | 20% | 60% | 0% | 20% |
| | 6 | 2 | 4% | 100% | 0% | 50% | 0% | 0% | 50% | 50% | 0% | 0% | 50% | 100% | 0% | 0% | 0% |
| | 7 (interferes) | 4 | 8% | 75% | 25% | 0% | 75% | 25% | 0% | 50% | 25% | 25% | 0% | 50% | 25% | 0% | 25% |
| 47. How satisfied are you with the building upgrade ? | 0 | 12 | 24% | 75% | 25% | 25% | 42% | 25% | 8% | 25% | 58% | 8% | 8% | 25% | 67% | 8% | 0% |
| | 1 (Very satisfied) | 12 | 24% | 67% | 33% | 0% | 17% | 25% | 58% | 33% | 33% | 17% | 17% | 17% | 33% | 17% | 33% |
| | 2 | 3 | 6% | 67% | 33% | 0% | 67% | 33% | 0% | 33% | 67% | 0% | 0% | 33% | 67% | 0% | 0% |
| | 3 | 5 | 10% | 100% | 0% | 0% | 20% | 20% | 60% | 20% | 40% | 0% | 40% | 60% | 40% | 0% | 0% |
| | 4 | 5 | 10% | 100% | 0% | 20% | 0% | 20% | 60% | 40% | 0% | 0% | 40% | 0% | 40% | 40% | 20% |
| | 5 | 6 | 12% | 67% | 33% | 17% | 17% | 50% | 17% | 33% | 17% | 33% | 17% | 33% | 50% | 0% | 17% |
| | 6 | 1 | 2% | 100% | 0% | 0% | 100% | 0% | 0% | 0% | 0% | 0% | 100% | 0% | 0% | 100% | 0% |
| | 7 (Very dissatisfied) | 5 | 10% | 100% | 0% | 0% | 60% | 40% | 0% | 20% | 80% | 0% | 0% | 20% | 60% | 0% | 20% |

# Appendix H: Difference between Prediction and Actual Energy Consumption

Appendix H contains the detailed energy consumptions of 48 households (Case #). The appendix shows the difference between the predictions of the "Before Survey" model and actual energy consumption from May 2012 to September 2012.

| Case # | Month | Year | Prediction | Actual | Difference |
|---|---|---|---|---|---|
| 1 | May | 2012 | 101.62 | 123.70 | -22.08 |
| | June | 2012 | 105.53 | 152.00 | -46.47 |
| | July | 2012 | 109.20 | 127.70 | -18.50 |
| | August | 2012 | 119.89 | 110.10 | 9.79 |
| | September | 2012 | 115.39 | 159.90 | -44.51 |
| 2 | May | 2012 | 111.39 | 94.70 | 16.69 |
| | June | 2012 | 116.50 | 98.70 | 17.80 |
| | July | 2012 | 146.78 | 102.80 | 43.98 |
| | August | 2012 | 153.03 | 101.50 | 51.53 |
| | September | 2012 | 108.05 | 101.10 | 6.95 |
| 3 | May | 2012 | 90.82 | 82.00 | 8.82 |
| | June | 2012 | 91.09 | 80.90 | 10.19 |
| | July | 2012 | 92.68 | 100.70 | -8.02 |
| | August | 2012 | 92.97 | 89.60 | 3.37 |
| | September | 2012 | 98.33 | 81.40 | 16.93 |
| 4 | May | 2012 | 129.97 | 137.60 | -7.63 |
| | June | 2012 | 123.06 | 143.00 | -19.94 |
| | July | 2012 | 128.16 | 180.60 | -52.44 |
| | August | 2012 | 135.95 | 192.30 | -56.35 |
| | September | 2012 | 138.62 | 146.10 | -7.48 |
| 5 | May | 2012 | 103.82 | 73.20 | 30.62 |
| | June | 2012 | 109.54 | 74.80 | 34.74 |
| | July | 2012 | 110.14 | 103.90 | 6.24 |
| | August | 2012 | 121.32 | 106.00 | 15.32 |
| | September | 2012 | 114.93 | 86.40 | 28.53 |
| 6 | May | 2012 | 49.61 | 50.6 | -0.99 |
| | June | 2012 | 53.03 | 51.7 | 1.33 |
| | July | 2012 | 64.71 | 60.1 | 4.61 |
| | August | 2012 | 70.35 | 57.3 | 13.05 |
| | September | 2012 | 49.59 | 53.2 | -3.61 |

| | | | | | |
|---|---|---|---|---|---|
| 7 | May | 2012 | 61.50 | 57.2 | 4.30 |
| | June | 2012 | 69.91 | 63.3 | 6.61 |
| | July | 2012 | 84.11 | 82.9 | 1.21 |
| | August | 2012 | 101.84 | 80.2 | 21.64 |
| | September | 2012 | 59.72 | 64.2 | -4.48 |
| 8 | May | 2012 | 115.98 | 76.1 | 39.88 |
| | June | 2012 | 124.21 | 92.1 | 32.11 |
| | July | 2012 | 155.21 | 69.1 | 86.11 |
| | August | 2012 | 140.62 | 73.1 | 67.52 |
| | September | 2012 | 113.74 | 93 | 20.74 |
| 9 | May | 2012 | 217.98 | 312.8 | -94.82 |
| | June | 2012 | 245.43 | 388.6 | -143.17 |
| | July | 2012 | 295.70 | 237 | 58.70 |
| | August | 2012 | 217.90 | 351.9 | -134.00 |
| | September | 2012 | 244.80 | 628 | -383.20 |
| 10 | May | 2012 | 149.80 | 187.8 | -38.00 |
| | June | 2012 | 198.01 | 181.1 | 16.91 |
| | July | 2012 | 257.47 | 164.7 | 92.77 |
| | August | 2012 | 178.37 | 148.3 | 30.07 |
| | September | 2012 | 151.70 | 128.9 | 22.80 |
| 11 | May | 2012 | 114.99 | 114.8 | 0.19 |
| | June | 2012 | 99.59 | 107.6 | -8.01 |
| | July | 2012 | 113.70 | 143.6 | -29.90 |
| | August | 2012 | 152.10 | 153.2 | -1.10 |
| | September | 2012 | 120.22 | 132.9 | -12.68 |
| 12 | May | 2012 | 157.71 | 161 | -3.29 |
| | June | 2012 | 163.91 | 169.1 | -5.19 |
| | July | 2012 | 164.49 | 193.9 | -29.41 |
| | August | 2012 | 163.11 | 162.1 | 1.01 |
| | September | 2012 | 163.40 | 146.1 | 17.30 |
| 13 | May | 2012 | 71.12 | 79.6 | -8.48 |
| | June | 2012 | 76.12 | 72.1 | 4.02 |
| | July | 2012 | 86.78 | 97.8 | -11.02 |
| | August | 2012 | 89.09 | 97.3 | -8.21 |
| | September | 2012 | 73.13 | 81.8 | -8.67 |
| 14 | May | 2012 | 111.88 | 89.4 | 22.48 |
| | June | 2012 | 108.30 | 90.7 | 17.60 |
| | July | 2012 | 121.48 | 148.3 | -26.82 |
| | August | 2012 | 122.55 | 161 | -38.45 |
| | September | 2012 | 115.96 | 149.3 | -33.34 |
| 15 | May | 2012 | 194.48 | 148.6 | 45.88 |

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|---|---|---|---|---|---|
| | June | 2012 | 204.41 | 155.4 | 49.01 |
| | July | 2012 | 239.84 | 171.1 | 68.74 |
| | August | 2012 | 226.11 | 108.7 | 117.41 |
| | September | 2012 | 202.85 | 85.7 | 117.15 |
| 16 | May | 2012 | 70.81 | 65.8 | 5.01 |
| | June | 2012 | 68.11 | 58.5 | 9.61 |
| | July | 2012 | 84.02 | 56.5 | 27.52 |
| | August | 2012 | 109.18 | 30.3 | 78.88 |
| | September | 2012 | 72.04 | 36.7 | 35.34 |
| 17 | May | 2012 | 121.86 | 144.1 | -22.24 |
| | June | 2012 | 116.86 | 147.6 | -30.74 |
| | July | 2012 | 113.10 | 182.7 | -69.60 |
| | August | 2012 | 122.16 | 166.5 | -44.34 |
| | September | 2012 | 145.02 | 152.3 | -7.28 |
| 18 | May | 2012 | 115.35 | 120.4 | -5.05 |
| | June | 2012 | 118.13 | 129.5 | -11.37 |
| | July | 2012 | 127.59 | 159.8 | -32.21 |
| | August | 2012 | 154.90 | 160.9 | -6.00 |
| | September | 2012 | 115.69 | 131.6 | -15.91 |
| 19 | May | 2012 | 116.50 | 119.8 | -3.30 |
| | June | 2012 | 121.55 | 121.3 | 0.25 |
| | July | 2012 | 115.46 | 135.1 | -19.64 |
| | August | 2012 | 118.35 | 140 | -21.65 |
| | September | 2012 | 137.67 | 129.8 | 7.87 |
| 20 | May | 2012 | 157.34 | 82.9 | 74.44 |
| | June | 2012 | 163.35 | 81.9 | 81.45 |
| | July | 2012 | 166.87 | 138.8 | 28.07 |
| | August | 2012 | 167.15 | 146.7 | 20.45 |
| | September | 2012 | 168.07 | 139 | 29.07 |
| 21 | May | 2012 | 177.81 | 105.4 | 72.41 |
| | June | 2012 | 217.34 | 112.4 | 104.94 |
| | July | 2012 | 245.40 | 100.8 | 144.60 |
| | August | 2012 | 220.30 | 110.2 | 110.10 |
| | September | 2012 | 183.98 | 103.8 | 80.18 |
| 22 | May | 2012 | 139.20 | 272 | -132.80 |
| | June | 2012 | 135.78 | 309.6 | -173.82 |
| | July | 2012 | 153.76 | 344.6 | -190.84 |
| | August | 2012 | 164.51 | 342.2 | -177.69 |
| | September | 2012 | 142.64 | 349.8 | -207.16 |
| 23 | May | 2012 | 94.50 | 165.4 | -70.90 |
| | June | 2012 | 99.25 | 134 | -34.75 |

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|---|---|---|---|---|---|
| | July | 2012 | 114.91 | 154.4 | -39.49 |
| | August | 2012 | 104.64 | 72.3 | 32.34 |
| | September | 2012 | 111.22 | 117.4 | -6.18 |
| 24 | May | 2012 | 88.96 | 108.1 | -19.14 |
| | June | 2012 | 90.43 | 98.9 | -8.47 |
| | July | 2012 | 104.44 | 144.5 | -40.06 |
| | August | 2012 | 111.01 | 119.6 | -8.59 |
| | September | 2012 | 84.79 | 65.2 | 19.59 |
| 25 | May | 2012 | 95.64 | 81.9 | 13.74 |
| | June | 2012 | 96.53 | 155.6 | -59.07 |
| | July | 2012 | 119.40 | 236.7 | -117.30 |
| | August | 2012 | 135.73 | 175.1 | -39.37 |
| | September | 2012 | 101.51 | 113.4 | -11.89 |
| 26 | May | 2012 | 120.38 | 119.1 | 1.28 |
| | June | 2012 | 111.71 | 112.8 | -1.09 |
| | July | 2012 | 123.63 | 86.6 | 37.03 |
| | August | 2012 | 134.31 | 78.4 | 55.91 |
| | September | 2012 | 114.18 | 97.8 | 16.38 |
| 27 | May | 2012 | 103.79 | 68.9 | 34.89 |
| | June | 2012 | 96.94 | 76.6 | 20.34 |
| | July | 2012 | 101.07 | 104.2 | -3.13 |
| | August | 2012 | 107.87 | 72.4 | 35.47 |
| | September | 2012 | 93.30 | 73.9 | 19.40 |
| 28 | May | 2012 | 91.13 | 74.2 | 16.93 |
| | June | 2012 | 113.76 | 72.4 | 41.36 |
| | July | 2012 | 133.84 | 77.1 | 56.74 |
| | August | 2012 | 101.47 | 68.6 | 32.87 |
| | September | 2012 | 92.46 | 63 | 29.46 |
| 29 | May | 2012 | 158.26 | 171.4 | -13.14 |
| | June | 2012 | 147.39 | 148.6 | -1.21 |
| | July | 2012 | 165.48 | 168.2 | -2.72 |
| | August | 2012 | 192.08 | 152.7 | 39.38 |
| | September | 2012 | 209.98 | 175.4 | 34.58 |
| 30 | May | 2012 | 318.36 | 102 | 216.36 |
| | June | 2012 | 330.81 | 83 | 247.81 |
| | July | 2012 | 323.82 | 116.5 | 207.32 |
| | August | 2012 | 285.33 | 131 | 154.33 |
| | September | 2012 | 336.15 | 91.1 | 245.05 |
| 31 | May | 2012 | 85.39 | 90.5 | -5.11 |
| | June | 2012 | 86.55 | 86.8 | -0.25 |
| | July | 2012 | 88.44 | 123.2 | -34.76 |

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|---|---|---|---|---|---|
| | August | 2012 | 89.08 | 42.6 | 46.48 |
| | September | 2012 | 93.94 | 63 | 30.94 |
| 32 | May | 2012 | 113.70 | 186.5 | -72.80 |
| | June | 2012 | 120.21 | 194.9 | -74.69 |
| | July | 2012 | 122.06 | 211.2 | -89.14 |
| | August | 2012 | 121.65 | 205.6 | -83.95 |
| | September | 2012 | 124.05 | 181 | -56.95 |
| 33 | May | 2012 | 131.24 | 125.3 | 5.94 |
| | June | 2012 | 128.08 | 113.1 | 14.98 |
| | July | 2012 | 132.30 | 132.5 | -0.20 |
| | August | 2012 | 165.95 | 108.1 | 57.85 |
| | September | 2012 | 142.35 | 125.9 | 16.45 |
| 34 | May | 2012 | 79.52 | 76.7 | 2.82 |
| | June | 2012 | 90.14 | 57.8 | 32.34 |
| | July | 2012 | 142.95 | 44.5 | 98.45 |
| | August | 2012 | 125.13 | 105.4 | 19.73 |
| | September | 2012 | 84.52 | 89.3 | -4.78 |
| 35 | May | 2012 | 103.32 | 94.1 | 9.22 |
| | June | 2012 | 105.63 | 93.9 | 11.73 |
| | July | 2012 | 108.62 | 166 | -57.38 |
| | August | 2012 | 117.35 | 154.4 | -37.05 |
| | September | 2012 | 115.75 | 128.3 | -12.55 |
| 36 | May | 2012 | 122.39 | 108 | 14.39 |
| | June | 2012 | 133.12 | 116.8 | 16.32 |
| | July | 2012 | 136.93 | 201.5 | -64.57 |
| | August | 2012 | 143.74 | 206 | -62.26 |
| | September | 2012 | 136.71 | 166.1 | -29.39 |
| 37 | May | 2012 | 213.43 | 218.5 | -5.07 |
| | June | 2012 | 205.52 | 196 | 9.52 |
| | July | 2012 | 208.46 | 164.6 | 43.86 |
| | August | 2012 | 205.47 | 169.9 | 35.57 |
| | September | 2012 | 232.96 | 220.5 | 12.46 |
| 38 | May | 2012 | 92.46 | 89.4 | 3.06 |
| | June | 2012 | 72.43 | 90.7 | -18.27 |
| | July | 2012 | 75.00 | 148.3 | -73.30 |
| | August | 2012 | 118.40 | 161 | -42.60 |
| | September | 2012 | 95.12 | 149.3 | -54.18 |
| 39 | May | 2012 | 152.00 | 134.3 | 17.70 |
| | June | 2012 | 185.72 | 125.1 | 60.62 |
| | July | 2012 | 218.78 | 163 | 55.78 |
| | August | 2012 | 185.75 | 136.6 | 49.15 |

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|---|---|---|---|---|---|
| | September | 2012 | 150.37 | 108.4 | 41.97 |
| 40 | May | 2012 | 280.59 | 153.3 | 127.29 |
| | June | 2012 | 286.17 | 169.6 | 116.57 |
| | July | 2012 | 291.75 | 215.2 | 76.55 |
| | August | 2012 | 266.71 | 217.4 | 49.31 |
| | September | 2012 | 304.20 | 162.8 | 141.40 |
| 41 | May | 2012 | 78.94 | 74.8 | 4.14 |
| | June | 2012 | 87.94 | 72.4 | 15.54 |
| | July | 2012 | 107.98 | 74.1 | 33.88 |
| | August | 2012 | 103.72 | 67.5 | 36.22 |
| | September | 2012 | 82.25 | 75.1 | 7.15 |
| 42 | May | 2012 | 115.40 | 93.7 | 21.70 |
| | June | 2012 | 124.38 | 92.9 | 31.48 |
| | July | 2012 | 132.52 | 169.5 | -36.98 |
| | August | 2012 | 148.79 | 133.6 | 15.19 |
| | September | 2012 | 122.91 | 97.2 | 25.71 |
| 43 | May | 2012 | 105.95 | 85.5 | 20.45 |
| | June | 2012 | 100.53 | 85.5 | 15.03 |
| | July | 2012 | 118.20 | 105.6 | 12.60 |
| | August | 2012 | 121.78 | 95.1 | 26.68 |
| | September | 2012 | 114.75 | 87.6 | 27.15 |
| 44 | May | 2012 | 149.49 | 76.1 | 73.39 |
| | June | 2012 | 154.11 | 92.1 | 62.01 |
| | July | 2012 | 173.99 | 69.1 | 104.89 |
| | August | 2012 | 180.96 | 73.1 | 107.86 |
| | September | 2012 | 136.91 | 93 | 43.91 |
| 45 | May | 2012 | 69.35 | 81.1 | -11.75 |
| | June | 2012 | 71.12 | 72.8 | -1.68 |
| | July | 2012 | 85.63 | 81.3 | 4.33 |
| | August | 2012 | 96.50 | 89.1 | 7.40 |
| | September | 2012 | 64.35 | 88.9 | -24.55 |
| 46 | May | 2012 | 76.29 | 69.9 | 6.39 |
| | June | 2012 | 77.23 | 69.9 | 7.33 |
| | July | 2012 | 86.30 | 88 | -1.70 |
| | August | 2012 | 94.74 | 86.2 | 8.54 |
| | September | 2012 | 78.87 | 75.3 | 3.57 |
| 47 | May | 2012 | 82.85 | 83.4 | -0.55 |
| | June | 2012 | 88.89 | 82.2 | 6.69 |
| | July | 2012 | 107.52 | 123.6 | -16.08 |
| | August | 2012 | 103.46 | 99.8 | 3.66 |
| | September | 2012 | 85.03 | 89.1 | -4.07 |

| | | | | | |
|---|---|---|---|---|---|
| 48 | May | 2012 | 154.74 | 88.1 | 66.64 |
| | June | 2012 | 182.08 | 105.9 | 76.18 |
| | July | 2012 | 211.40 | 145.7 | 65.70 |
| | August | 2012 | 236.24 | 130.9 | 105.34 |
| | September | 2012 | 157.13 | 130.5 | 26.63 |
| | | | **Sum of the Predicted Energy Consumption** | **Actual Energy Consumption** | |
| | | | 32328.93 | 30170.80 | 7% |

# References

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.

Abrahamse, W., Steg, L. V., & Rothengatter, T. (2007). The effect of tailored information, goal setting, and tailored feedback on household energy use, energy-related behaviours, and behavioural antecedents. *Journal of Environmental Psychology.* , 27: pp. 265-276.

Ajzen, I. (1991). The Theory of Planned Behavior. *Organizational Behaviour and Human Decision Processes*. 50: pp. 179-211.

Alahmad, M. A., Wheeler, P.G., Schwer, A., Eiden, J., Brumbaugh, A. (2012). A Comparative Study of Three Feedback Devices for Residential Real-Time Energy Monitoring. *IEEE Transactions on Industrial Electronics.* 59(4): pp. 2002-2013.

Allcott, H. Social norms and energy conservation. *Journal of Public Economics*. 95: pp. 1082-1095.

Alyuda Research Company (2003). Alyuda NeuroIntelligence User Manual Version 2.1.

American Council for an Energy-Efficient Economy (ACEEE). (2007). Quantifying the Effects of Market Failures in the End Use of Energy. Final Draft Report for the International Energy Agency. Washington, D.C.: ACEEE.

Anstett, M., and Kreider, J. F. (1993) Application of Neural Networking Models to Predict Energy Use. *ASHRAE Transactions*. 99 (1): pp.505-517.

Anwar, S. (2009). Determinants of Pricing Individual Depositor's Rate of Return in Indonesian Islamic Bank: A Case-study of PT Bank Syariah Mandiri. APIEMS2009, December 14-16.

Argyrou, A. (2006). Predicting Financial Distress Using Neural Networks: Another Episode to the Serial? Thesis - *Swedish School Economics and Business Administation*.

Aydinalp, M., Ugursal, V. I., Fung, A. S. (2002). Modeling of the appliance, lighting, and space-cooling energy consumptions in the residential sector using neural networks. *Journal of Applied Energy*. 71: pp. 87-110.

Aydinalp, M. (2002). A New Approach for Modeling of Residential Energy Consumption. ProQuest Dissertations & Theses (PQDT). Dissertation/thesis number NQ77588 - Dalhousie University.

Aydinalp, M., Ugursal, V. I., Fung, A. S. (2003). Modelling of residential energy consumption at the national level. *International Journal of Energy Research*. 27: pp. 441-453.

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.

Aydinalp, M., Ismet Ugursal, V., Fung, A. S. (2004). Modeling of the space and domestic hot-water heating energy-consumption in the residential sector using neural networks. *Journal of Applied Energy*. 79: pp. 159-178.

Aydinalp-Koksal, M., Ugursal, V. I. (2008). Comparison of neural network, conditional demand analysis, and engineering approaches for modeling end-use energy consumption in the residential sector. *Journal of Applied Energy*. 85: pp. 271-296.

Bartels, R., Fiebig, D. G. (1990). Integrating Direct Metering and Conditional Demand Analysis for Estimating End-Use Loads. *The Energy Journey*. 11: pp.79-97.

Baxter, L. (1998). Electricity policies for low-income households. *Energy Policy* , 26 (3): pp. 247-256.

Benders, R. M., Kok, R., Moll, H. C., Wiersma, G., & Noorman, K. J. (2006). New approaches for household energy conservation - In search of personal household energy budgets and energy reducations options. *Journal on Energy Policy* , 34:pp. 3612-3622.

Bonino, D., Corno, F., De Russis, L. (2012). Home energy consumption feedback: A user survey. *Journal of Energy and Buildings*. 47: pp. 383-393.

Boulaire, F., Higgins, A., Foliente, G., McNamara, C. (2013). Statistical modelling of district-level residential electricity use in NSW, Austrailia. *In Proceedings of Journal of Sustainability Science*.

Brandon, G., Lewis, A., 1999. Reducing household energy consumption: a qualitative and quantitative field study. *Journal of Environmental Psychology.* 19:pp. 75–85.

Canada Mortgage Housing Corporation. (1997). Field Investigations of Indoor Environment and Energy Usage in Mid-Rise Residential Buildings.

Canada Mortgage Housing Corporation. (2002). *Research Highlights.* Retrieved February 2012, from Analysis of the Annual Energy and Water Consumption of Apartment Buildings in the CMHC HiSTAR Database: http://www.cmhc-schl.gc.ca/publications/en/rh-pr/tech/01-142e.pdf

Canadian Mortgage and Housing Corporation, C. (2012). Government Assisted Housing, 1996 – 2012 CMHC-SCHL. Retrieved September 23 2011, from http://www.cmhc-schl.gc.ca/en/co/buho/seca/seca_001.cfm

Caves, D . W., Herriges, J. A., Train, K. A.,Windle, R. J. (1987). A Bayesian Approach to Combining Conditional Demand and Engineering Models of Electricity Usage. *The Review of Economics and Statistics*. 69: pp. 438-448.

Cavusgil, S., Elvey-Kirk, L. (1998) Mail survey response behavior - A conceptualization of motivating factors and an empirical study. *European Journal of Marketing*. 32(11-12): pp.1165-1192.

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

Center for the Built Environment (CBE). (2012). Occupant Indoor Environmental Quality (IEQ)TM. Retrieved on December 11, 2011, weblink: http://www.cbe.berkeley.edu/research/survey.htm

City of Toronto. (2011a) Retrieved October 22, 2011, from http://www.toronto.ca/city_manager/tower_renewal.htm

City of Toronto. (2011b). Tower Renewal implementation book Retrieved October 22, 2011, from http://www.toronto.ca/city_manager/pdf/tr_implementation_book.pdf

Community Champion Program by Globe. (2011). Community Champion Program by GLOBE (Toronto, Canada). Weblink: http://www.globeservices.ca/index.php/our-services/community-champion-program/; http://www.globeservices.ca/index.php/globe-and-shsc-finalist-in-energy-conservation-at-2011-green-toronto-awards/

Cook, S. W., Berrenberg, J. L. (1981). Approaches to Encouraging Conservation Behavior: A review and Conceptual Framework. *Journal of Social Issues.* 37 (2): pp. 73-107.

Dayhoff, J. E., DeLeo, J. M. (2001). Artificial Neural Networks: Opening the Black Box. *Conference on Prognostic Factors and Staging in Cancer Management: Contributions of Artificial Neural Networks and Other Statistical Methods*: pp. 1615-1635.

Dombayci, O. A. (2010). The prediction of heating energy consumption in a model house by using artificial neural networks in Denizli-Turkey. *Advances in Engineering Software*: 41: pp. 141-147.

Enermodal Engineering Limited. (2001). Analysis of the annual energy and water consumption of apartment buildings in the CMHC HiSTAR database. Kitchener.

Environment Canada (2012). National Climate Data and Information Archive. Retrieved on web link: http://www.climate.weatheroffice.gc.ca.

Erdos, P.L. (1974). "Data collection methods: mail surveys", in Ferber, R. (Ed.), *Handbook of Marketing Research..* 2: pp. 90 –104.

Ermis, K., Midilli, A., Dincer, I., Rosen, M.A. (2007). Artificial neural network analysis of world green energy use. *Journal of Energy Policy*. 35: pp. 1731-1743.

Farahbakhsh, H., Ugursal, V. I., Fung, A. S. (1998). A Residential End-Use Energy Consumption Model For Canada. *International Journal of Energy Research*. 22: pp. 1998.

Geller, E. S. (1981). Evaluating energy conservation programs: Is verbal report enough? . *Journal of Consumer Research.* 8: pp. 1049-1066.

Gronhoj, A., Thogersen, J. (2011). Feedback on household electricity consumption: learning and social influence processes. *International Journal of Consumer Studies*. 35: pp. 138-145.

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.

Ehrhardt-Martinez, K., Donnolly, K. A., Laitner, J.A. (2010). Advanced Metering Initiatives and Residential Feedback Programs: A Meta-Review of Household Electricity-Saving Opportunities. American Council of an Energy Efficient Economy.

Farqui, A., Sergici, S., & Sharif, A. (2010). The impact of informational feedback on energy consumption - A survey of the experimental evidence. *Journal of Energy*. pp. 1598 - 1608.

Fischer, C. (2008). Feedback on household electricity consumption: a tool for saving energy? *Energy Efficiency*. 1: pp. 79-104.

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.

Gorrie, P. (2008). Brahms work in concert for savings. Toronto Star - article #414394. Retrieved on July 23, 2011. Weblink: http://www.thestar.com/article/414394.

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.

Haldi, F., Robinson, D. (2011). The impact of occupants' behaviour on building energy demand. *Journal of Building Performance Simulation.* 4 (4): pp.323-338.

Heinz, S. (2011). Mathematical Modelling. *Published by Springer Heidelberg Dordrecht*. New York. pp. 1.

Hsiao, C., Mountain, C., Ho Illman, K. (1995). A Bayesian Integration of End-Use Metering and Conditional-Demand Analysis. *Journal of Business & Economic Statistics*. 13 (3): pp. 315-326.

Huang, Y. (2012). Energy Benchmarking and Energy Saving Assessment in High-rise Multi-Unit Residential Buildings. Thesis from Ryerson University.

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.

Independent Statistics & Analysis: U.S. Energy Information Administration (EIA) (2012). Residential Energy Consumption Survey. Retrieved on 2012, weblink: http://www.eia.gov/consumption/residential/data/2009/

Jacobson, S., McDuff, M., & Monroe, M. (2006). Conservation Education and Outreach Techniques. New York: Oxford University Press.

Janda, K. B. (2011) Buildings don't use energy: people do. *Journal of Architectural Science*. 54(1): pp. 15-22.

Johnson Controls. (2012). Series B Vertical Floor Fan Coil Unit. Retrieved weblink: http://www.enviro-tec.com/pdf/iom/ET115.24-NOM9.pdf

Katzev, R. D., & Johnson, T. R. (1983). A social-psychological analysis of residential electricity consumption: The impact of minimal justification techniques. *Journal of Economic Pyschology*. 3: pp. 267-284.

Kavgic, M., Mavrogianni, A., Mumovic, D., Summerfield, A, Stevanovic, Z., Djurovic-Petrovic, M. (2010). A review of bottom-up building stock models for energy consumption in the residential sector. *Journal of Building and Environment*. 45: pp. 1683-1697.

Kurz, T., Donaghue, N., & Walker, I. (2005). Utilizing a Social-Ecological Framework to Promote Water and Energy Conservation: A Field Experiment. . *Journal of Applied Social Psychology*. 35(6):pp. 1281-1300.

Laquatra. (1992). Rural landlords and rental housing energy efficiency. *Energy Policy*. pp.815-824.

Levinson, A., & Niemann, S. (2006). Energy use by apartment tenants when landloards pay for utilities. *Resource and Energy Economics*. 26: pp. 51-75.

Li., J., Dackermann, U., Xu, Y., Samali, B. (2011). Damage identification in civil engineering structures utilizing PCA-compressed residual frequency response functions and neural network ensembles. *Structure Control and Health Monitoring.* 18: pp. 207-226.

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

Low-Income Energy Network (LIEN). (2011). Working to End Energy Poverty in Ontario - A Tool Kit. Retrieved on July 24, 2011. Weblink: http://www.lowincomeenergy.ca/wp-content/uploads/2011/05/LIWN_manual_May-27_FINAL.pdf.

Mahmoud, M. A., Alajmi, A. F. (2010). Quantitative assessment of energy conservation due to public awareness campaigns using neural networks. *Journal of Applied Energy*. 87: pp. 220-228.

Maruejols, L., & Young, D. (2010). Energy use in Canadian multi-family dwellings.

Maruejols, L., Young, D. (2011). Split incentives and energy efficiency in Canadian multi-family dwellings. *Journal of Energy Policy*. pp. 3655-3668.

McCalley, L.T., Midden, C.J.H. (2002). Energy conservation through product-integrated feedback: The roles of goal-setting and social orientation. *Journal of Economic Psychology*. 23: pp. 589-603.

McClelland, L., Cook, S. W. (1980). Energy Conservation in University Buildings: Encouraging and Evaluating Reductions in Occupants' Electricity Use. *Evaluation Review*. 4 (1): pp. 119-133.

McDougall, G., & Keller, G. (1979). A Survey of the Canadian Public's Attitudes Towards the Energy Situation. *Consumer Research and Evaluation Branch: Summary Report (Volume Two)*.

McKenzie-Mohr, D. (2011). Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing. Gabriola: New Society Publishers.

McMaking, A., Malone, E., Lundgren, R.E. (2002). Motivating Residents to Conserve Energy Without Financial Incentives. *Journal of Environment and Behaviour*. 34 (6): pp. 848-863.

Michelis-Tzanakou, E. (2011). Artificial Neural Networks: An Overview. *Network: Computation in Neural Systems*. 22 (1-4): pp. 208-230.

Midden, C., Meter, J. F., Weenig, H., & Zieverink, H. J. (1983). Using Feedback, Reinforcement and Information to Reduce Energy Consumption in Households: A Field-Experiment. *Journal of Economic Psychology*. 3: pp. 65-86.

Mountain, D. C. (2006). The Impact of Real-Time Feedback on Residential Electricity Consumption: The Hydro One Pilot. Hydro One: Mountain Economic Consulting and Associates Inc.

Mountain, D. C. (2010). Conservation and Customer Perceptions: The Power Cost Monitor Pilot of Dominion Virginia Power. *Mountain Economic Consulting and Associates Inc*: pp.1-40.

Nair, J., Nair, S. S., Kashani, J. H., Reid, J. C., Mistry, S. I., Vargas, V. G. (1999). Analysis of the symptoms of depression - a neural network approach. *Journal of Psychiatry Research*. 87: pp. 193-201.

Natural Resources Canada. (1994). *200-House Audit Project*, Natural Resources Canada, Ottawa.

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

Natural Resources Canada. (2011a). *Energy Efficiency Trends in Canada: 1990 to 2008*. From Natural Resources Canada: www.nrcan.gc.ca/eneene/index-eng.php

Natural Resources Canada (2011b). Energy Efficiency Ratings: Search - EnerGuide. Retrieved on weblink: http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.welcome-bienvenue&language_langue=en

Natural Resources Canada (2012). *Office of Energy Efficiency*. Compare Product Models' Energy Efficiency. Retrieved September 23, 2012: http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.welcome-bienvenue

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.

Paco, A., Varejao, L. (2010). Factors affective energy saving behaviour: a prospective research. *Journal of Environmental Planning and Management*. 53 (8): pp.963-976.

Pallak, M. S., & Cummings, N. (1976). Commitment and voluntary energy conservation. *Personality and Social Psychology Bulletin*. 2(1): 27–31.

Parti M, Parti, C. (1980). The total and appliance-specific conditional demand for electricity in the household sector. *Journal of Economics*. 11: pp. 309–321.

Poulad, M. E., Naylor, D., Fung, A. S. (2010). Prediction of Local Heat Transfer in a Vertical Cavity Using Artificial Neutral Networks. *Journal of Heat Transfer*. 132: pp. 122501-1 - 122501-9.

Prasad, B.K.R., Eskandari, H., Remmy, B. V.V. (2009). Prediction of compressive strength of SCC and HPC with high volume fly ash using ANN. *Construction and Building Materials*. 23: pp. 117-128.

Rebano-Edwards, S. (2007). Modelling perceptions of building quality - A neural network approach. *Journal of Building and Environment.* 42: pp. 2762-2777.

Roque, M, Straka, V., Fung, A. (2012). Survey of Household Energy Use in a Toronto Rental High-rise Multi-Unit Residential Building (MURB). *In Proceedings of the 2nd World Sustain. Forum, 1-30 November 2012*; Sciforum Electronic Conferences Series.

Sargent, D. J. (2001). Comparison of Artificial Neural Networks with Other Statistical Approachs: Results from Medical Data Sets. Conference on Prognostic Factors and Staging in Cancer Management: Contributions of Artificial Neural Networks and Other Statistical Methods. pp.1636-1642.

Scanada Consultants Limited. (1997). Study report on the energy audits of high-rise residential buildings.

Schipper, L., Ketoff, A., Meyers, S., 1982. International residential energy demand use data: analysis of historical and present day structure and dynamics. *Journal of Energy*. 7 (2): pp. 205–212.

Siero, F. W., Bakker, A. B., Dekker, G.B., van den Burg, M. T. C. (1996). Changing Organizational Energy Consumption Behaviour Through Comparative Feedback. *Journal of Environmental Psychology*. 16: pp. 235-246.

Sozen, A. (2009). Future projection of the energy dependency of Turkey using artificial neural network. *Journal of Energy Policy*. 37: pp. 4827-4833.

Staats, H.J., Wit, A.P., Midden, C.Y.H. (1996). Communicating the Greenhouse Effect to the Public: Evaluation of a Mass Media Campaign from a Social Dilemma Perspective. *Journal of Environmental Management*. 49: pp. 189-203.

Staats, H., Harland, P., Wilke, H.A.M. (2004). Environment and Behavior. 36 (3): pp. 341-367.

Statistics Canada. (1993). Survey of Household Energy Use, Microdata User's Guide, Ottawa.

Statistics Canada. (2003). Survey Methods and Practices. Catalogue no. 12-587-X.

Statistics Canada (2009). Spending Patterns in Canada 2009. Catalogue no. 62-202-X. Weblink: http://www5.statcan.gc.ca/access_acces/alternative_alternatif.action?teng=62-202-x2008000-eng.pdf&tfra=62-202-x2008000-fra.pdf&l=eng&loc=62-202-x2008000-eng.pdf

Steemers, K., Yun, G.Y. (2009). Household energy consumption: a study of the role of occupants. *Journal of Building Research and Information*. 37 (5-6): pp. 625-637.

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.

Stewart, K., Fry, K., & Alliance, T. E. (2006). A Low-Income Energy Efficiency Program: A report from the Toronto Environmental Alliance to the Ontario Power Authority. Toronto: Toronto Environmental Alliance (TEA).

Swan, L. G., Ugursal, V. I. (2009). Modeling of end-use energy consumption in the residential sector: A review of modeling techniques. *Renewable and Sustainable Energy Reviews*. 13: pp. 1819-1835.

Swan, L.G., Ugursal, V. I., Beausoleil-Morrison, I. (2011). Occupant related household energy consumption in Canada: Estimation using bottom-up neural-network technique. *Journal of Energy and Buildings*. 43: pp: 326-337.

Swan, L.G., Ugursal, V. I., Beausoleil-Morrison, I. (2013). Hybrid residential end-use energy and greenhouse gas emissions model - development and verification for Canada. *Journal of Building Performance Simulation.* 6 (1): pp. 1-23.

Toronto Environmental Alliance (TEA) (2008). Saving Energy - The 6-Step to Tenant Action. Weblink: http://www.torontoenvironment.org/

Warner, B., Misra, M. (1996). Understanding Neural Networks as Statistical Tools. *The American Statistician*. 50 (40): pp.284-293.

Williams, B. E. (2008). Overcoming Barriers to Energy Efficiency for Rental Housing. Massachusetts: Massassachusetts Institute of Technology; thesis.

Ugursal, V. I., Fung, A. S. (1996). Impact of appliance efficiency and fuel substitution on residential end-use energy consumption in Canada. *Journal of Energy and Buildings*. 24: pp. 137-146.

United Way Toronto. (2011). Vertical Poverty Retrieved November 12, 2011, from http://www.unitedwaytoronto.com/verticalpoverty/downloads/Report-PovertybyPostalCode2-VerticalPoverty-Final.pdf

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). *Journal of Thermal Biology.* 18(5/6): 533-540.

Yohanis, Y. G. (2012) Domestic Energy Use and Householders' energy behaviour. *Journal of Energy Policy*. 41: pp.654-665.

Yun, G., Steemers, K. (2011). Behaviour, physical and socio-economic factors in household cooling energy consumption. *Journal of Applied Energy*. 88: pp. 2191-2200.