Investigating the impacts of time-of-use electricity rates on lower-income and senior-headed households: A case study of Milton, Ontario (Canada).

by

Sarah Ivy Simmons

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I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Through the Smart Metering Initiative in the Canadian province of Ontario, all residential electricity customers will be converted from a tiered rate regime to a time-of-use (TOU) rate regime by the year 2010. Although TOU rates are designed to be cost-neutral for the average consumer, research suggests that TOU rates may affect consumers differently depending on their socioeconomic characteristics. In an effort to better understand the effects of TOU rates on lower-income and senior-headed households, a case-study in Milton was conducted between June and December of 2007. The overarching thesis question is: What are the behavioural responses to, and financial impacts of, TOU electricity rates on lower-income and senior-headed households?

Nine expert interviews were conducted with Ontario professionals working in government, environmental non-profit groups, citizen advocacy organizations and affordable housing associations in order to provide context for the study. Time-differentiated electricity consumption data were then collected from 199 households from two senior housing complexes and two affordable housing complexes in Milton, Ontario between June and December 2007. A questionnaire was also sent to each household to determine some socio-economic and structural characteristics of the households.

The electricity consumption data collected from the four sites suggest that the households would not benefit financially from TOU rates given electricity consumption behaviour during the period prior to the implementation of TOU rates in June 2007. Thus, they would have to change their behaviour in order to benefit financially from TOU rates. During this pre-TOU period, Site A, Site B and Site C would have paid more, on average, for their electricity under TOU rates than on tiered rates ($0.34, $0.61 and $0.15 per week, respectively). While Site D, on average, would have seen no change under TOU rates.

A conservation effect was detected by comparing the electricity consumption from billing periods in 2006 to corresponding billing periods in 2007 after the implementation of TOU rates. Site A saw a conservation effect during the first corresponding billing period (35%); while Site B saw a conservation effect for three corresponding billing periods (21%, 24% and 9%). Site C saw a conservation effect for the first five corresponding billing periods (ranging from 8% to 21%), while Site D saw a conservation effect for all corresponding billing periods (ranging from 10% to 34%). The presence of a conservation effect at Site D was unexpected, particularly because households at Site D are not responsible for paying their own electricity bills. Although a conservation effect was observed after the implementation of TOU rates, the extent to which it could be attributed to the implementation of TOU rates is unclear, and should be investigated further.

There was no considerable shift in the proportion of electricity consumed during each of the peak periods during the summer TOU period for Site A and Site D after the introduction of TOU rates. There

was, however, a slight reduction in the portion of electricity consumed during the summer TOU period for Site B and Site C (0.2% and 0.1% per week, respectively). Due to the change in the on-, mid- and off-peak schedule from the summer TOU period to the winter TOU period, the households consume more electricity during the off-peak periods in the winter than they do during the off-peak periods in the summer (even though their patterns of consumption do not change).

Similar to the pre-TOU period, during the summer post-TOU period, Site A and Site B, and Site C, on average, paid more for electricity (commodity) under TOU rates than they would have paid if they had continued on tiered rates ($0.38, $0.51 and $0.16 more per week, respectively), while Site D would have seen no change in their electricity costs. In contrast, during the winter post-TOU period several sites paid less for electricity on TOU rates than they would have if they had continued on tiered rates. Site B, Site C and Site D paid, on average, $0.78, $0.16 and $1.76 less per week, respectively. Although Site A paid more under on TOU rates during the winter post-TOU (on average $0.18 more per week), the cost was less than during the summer post-TOU period. The change in costs expressed here does not reflect any reduced costs that may have resulted from conservation. For example, if the households were shown to have a conservation effect, they might have lower electricity costs. Additionally, the changes in costs do not reflect any additional fees or charges that might be attributed to the smart meter installation and the Smart Metering Initiative (e.g., additional fees from Milton Hydro).

In conclusion, TOU rates appear to be ineffective at motivating these lower-income and senior-headed households in Milton, Ontario to shift electricity from on-peak periods to off-peak periods, however, a reduction in electricity usage may be attributed to TOU rates. Further research is required to confirm these effects. It is important to note that some of the lower-income and senior-headed households in this study appeared to see an increase in their electricity bill, particularly during the summer TOU period. Lower-income and senior-headed households are thought to be less able to shift electricity consumption, therefore it is important to develop mechanisms to identify households that are at risk of bill increases.

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As partners in this research, I would like to express my sincere appreciation to Milton Hydro Distribution Incorporated. In particular, I would like to thank Don Thorne, Mary-Jo Corkum, and Andrew Peers. The staff at Milton Hydro were enthusiastic about this research project and were instrumental in the development of this thesis. They helped me identify the study sites used in this research and shared with me data from these sites and were always quick to respond to my questions and concerns.

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Table of Contents

Appendices

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Background and research questions

Electricity is an integral part of modern life. It supplies power for essential services for regular daily activities, in Ontario and much of the world, including, lighting, heating, cooling, cooking, and laundry. Electricity is also a necessary component of the modern economy. It supplies power to manufacturing equipment, computers, tools, transportation and many other critical devices that allow economic development. There is no doubt that the supply of electricity greatly improves the quality of life for its users.

The drawback, however, is that electricity production can be costly and environmentally unsustainable. Presently in Ontario, the baseline supply of electricity is produced by nuclear and hydroelectric power (OPA, 2009). Renewable energy sources such as wind and solar, although under development, presently provide relatively little power to Ontario. During times of high demand, electricity is produced from more polluting and CO_2 emitting sources, such as natural gas and coal. Moreover, when electricity demand is exceptionally high, power is imported at an expensive rate from other jurisdictions such as Quebec and the USA. Power storage technologies, for example batteries or pumped storage, are not readily available either cheaply or effectively (OPA, 2009). Conservation and demand management during these times of high demand – on-peak periods – is therefore essential to improve the sustainability of electricity supply.

Through the Smart Metering Initiative, the Ontario Energy Board is introducing a Time-of-Use (TOU) electricity rate regime across Ontario by 2010 for residential customers and other small users. This will be a move away from the current two-tiered rate regime, which charges a lower rate for the first block of electricity consumed and a higher rate for all additional electricity consumed during the monthly billing period. Under a TOU rate regime, customers will be charged a higher rate for electricity consumed during on-peak periods and lower rates for electricity consumed during mid-, and off-peak periods. The intent of the TOU rate regime is to provide a financial incentive to customers to shift consumption away from on-peak periods, when electricity generation is expensive and more polluting, to off-peak periods, when electricity generation is cheaper and cleaner (Ontario Energy Board, 2008a). The TOU rate regime is designed to be revenue neutral compared to the tiered rate regime; meaning that for the average consumer, if they do not shift their usage, they should not see a change in their electricity bill (Faruqui and George, 2005).

TOU rates are touted as being a more economically efficient rate regime (Faruqui and George, 2005). When rates do not reflect the time that electricity is used, households that consume the majority of their power during off-peak periods are effectively subsidizing households that consume the majority of their power during expensive, on-peak periods. Therefore, households that contribute to electricity demand during on-peak periods raise the average price of electricity for all customers, which can put pressure on lower-income households. If on-peak demand is reduced, then the need to build additional generating facilities and transmission and distribution infrastructure would be reduced or deferred.

Although TOU rates may have the potential to remove this on-peak subsidy, the potential for a household to reduce their electricity bill will depend on the household's appliance use patterns and willingness to shift – notwithstanding the design of the rate structure to be revenue neutral. Moreover, Blocker (1985) suggests that TOU rates could cause higher electricity bills for lower-income households if they were disproportionate users of on-peak electricity or if they were unwilling or unable to shift electricity usage to off-peak periods. Echoing this concern, the Social Housing Services Corporation (SHSC) wrote a position paper on the effects of Ontario's Smart Metering Initiative (SHSC, 2007). The SHSC believes that tenants and property managers of social housing are at greater risk of electricity bill increases under the TOU rate regime because social housing is more likely to be electrically heated and less likely to have air conditioning. Therefore, tenants in social housing are believed to be at risk from TOU rates because they may be less able to shift electricity usage to off-peak periods (SHSC, 2007).

In addition to the impacts on lower-income households, senior-headed households are thought to be at risk of greater electricity bills increases under the TOU rate regime. Warriner (1981) suggests that seniors are at greater risk because they are more likely to live in older, inefficient homes and have fewer appliances. Additionally, they spend proportionately more time at home. This means that they may have less ability to shift the time of electricity consumption. Warriner (1981) notes that even though senior-headed households tend to have lower energy bills, they pay proportionately more of their income on electricity than other non-senior-headed households.

Through their US based research, Bhattacharya et al (2003) showed that although both rich and poor families increase their fuel expenditure during cold weather shocks, poor families reduce their food expenditures by roughly the same amount as the increase in fuel, while richer families increase their food expenditures. These findings demonstrate the vulnerability of lower-income families facing increases in energy costs. In other words, the risks of being affected by high electricity rates are greater for lower-income households. Tienda and Aborampah (1981, p. 269) express a similar concern by stating,

> Whereas the well-off can either spend a higher proportion of the family budget on energy or cut back on luxury consumption without necessarily altering comfort levels, the poor seldom have the same range of options. In effect, continued increases in the cost of energy can potentially reduce the real incomes of lower-income groups at a relatively higher rate than those of higher-income groups.

As the effects of TOU rates on lower-income and senior-headed households are uncertain, this thesis will attempt to answer the following research question: What are the behavioural responses to, and financial impacts of, TOU electricity rates on lower-income and senior-headed households? This leads to two sub-questions:

a) Do lower-income and senior-headed households respond to TOU electricity rates? More specifically, do they reduce electricity consumption or shift the time electricity is consumed?

b) In either the presence or absence of behavioural change, do lower-income and senior-headed households experience a change in the amount of their electricity bill upon the implementation of TOU rates?

1.2 Research contributions

The purpose of this research is to assess the impacts of TOU rates on lower-income and senior-headed households in Ontario. This study will be useful to current policymakers wishing to understand the broader impacts of the Ontario's Smart Meter Initiative. As well, this study will be of interest to non-profit organizations currently advocating for lower-income and senior-headed households by clarifying the issues related to the impacts of TOU rates. Further, this study is of interest to local electricity distribution companies, who might be concerned about the impacts of TOU rates on lower-income and senior-headed households, and who might be concerned about the ability of these households to pay their electricity bill.

The primary academic audience for this study is researchers in the field of environmental studies with an emphasis on sustainable energy, environmental policy and social equity. In particular, this study will be of interest to researchers who wish to understand the direct and indirect effects of electricity pricing policy on lower-income and senior-headed households. More broadly, this study will be of interest to academics who wish to understand how economic incentives affect resource consumption patterns.

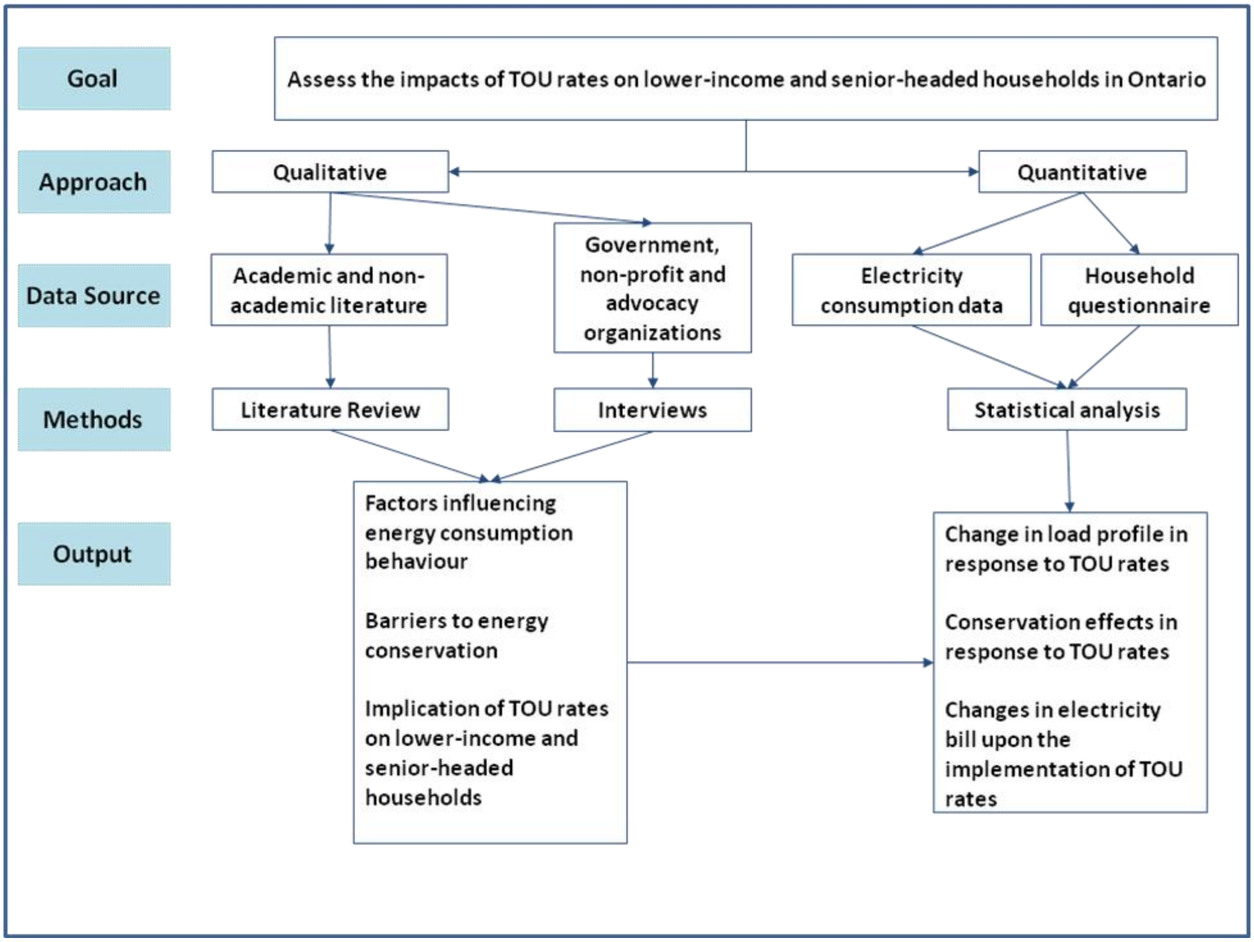

Figure 1. Thesis overview

As outlined in Figure 1, the research conducted in this thesis uses a mixed-methods approach, which combines qualitative and quantitative methodologies. A literature review of academic and non-academic literature, as well as interviews conducted with experts from government, environmental non-profit groups, affordable housing organizations and citizen advocacy organizations, are used to describe factors that influence energy conservation behaviour, barriers to energy conservation, and the possible implications of TOU rates on lower-income and senior-headed households. Subsequently, electricity consumption data and household questionnaires from lower-income and senior-headed households are used to determine if there is a shift in electricity usage in response to the implementation of TOU rates. The quantitative data are used to determine if TOU rates impact electricity conservation. Further, the quantitative data will help to determine if TOU rates have an impact on the electricity bill of lower-income and senior-headed households. The qualitative information is used to help explain the results of the quantitative analysis.

To clarify, as illustrated in Figure 1, qualitative data collected from the literature and interviews will help identify factors that influence energy consumption behaviour, barriers to energy conservation,

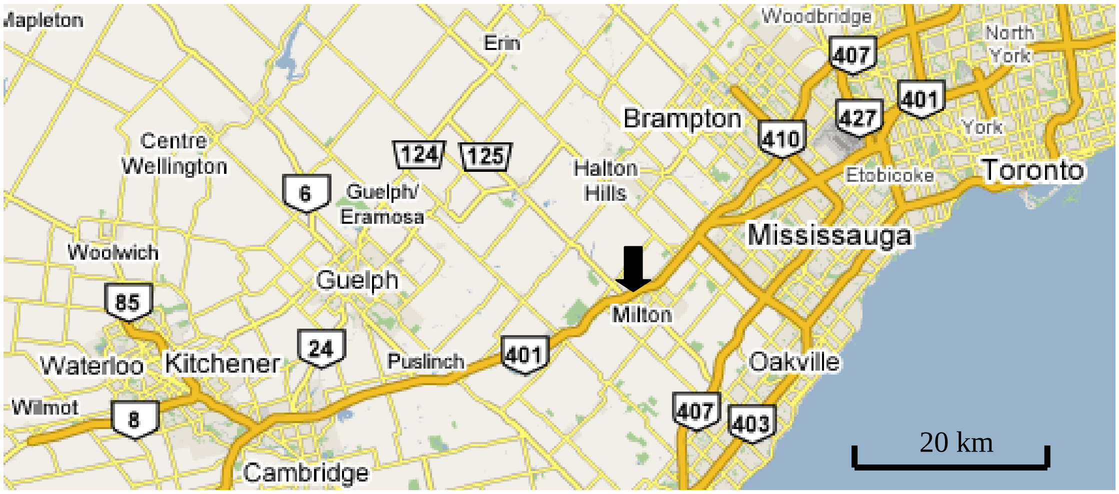

Figure 2. Location of study sites, Milton, Ontario
Source: Adapted from Google Maps.

and the implications of TOU rates for lower-income and senior-headed households. These qualitative data will be used to help explain the actual change in load profile, conservation effects and changes to the households electricity bill upon the implementation of TOU rates for a sample of lower-income and senior-headed households.

1.3 Study site

The study sites chosen for this research are found in the Town of Milton, Ontario. Milton has a population of 53,939 citizens (18,913 dwellings) as enumerated by the 2006 census and is located within Halton Region in south-western Ontario. The population of Milton grew by 71% between 2001 and 2006 (Statistics Canada, 2007), making it the fastest growing town region in Canada. A map showing the location of Milton relative to Toronto and Waterloo, Ontario is shown in Figure 2.

Selected demographic characteristics of Milton, Ontario and Ontario (as a whole) are shown in Table 1. As demonstrated in this table, some of the demographic characteristics of Milton differ from those of the broader Ontario population. For example, the median age of residents in Milton is less than the median age of Ontarians. Also, the median income of residents in Milton is greater than the median income of Ontario. Further, there are fewer low-income persons in Milton (as a percentage of total population) than there are in Ontario.

Regardless of the demographic differences between Ontario as a whole and Milton, locating the study sites in Milton is a reasonable choice. Milton Hydro Distribution Inc. is known as a leader amongst local distribution companies in Ontario and has led the province in terms of smart meter installations. Perhaps this is due to Milton’s rapid growth and new housing construction. The availability of data from smart metered homes is one of the main reasons that lower-income and senior-headed households from

Milton were selected for this study. Milton Hydro Distribution Inc. identified and retrofitted two seniors housing units and two affordable housing units and provided electricity consumption data from these units to be evaluated in this study.

Demographics	Milton, Ontario	Ontario
Population in 2006	53,939	12,160,282
Median Age of Population	34.4	39.0
Total private dwellings occupied by usual residents	18,465	4,555,025
Apartments, duplex - as a % of total occupied private dwellings	1.3%	3.4%
Number of rented dwellings	2,205 (12.9%)	1,312,290 (28.8%)
Median income in 2005 - All census families	$89,718	$69,156
Median monthly payments for rented dwellings	$980	$801
Percent in low income before tax - All persons	5.0%	14.7%

Table 1. Demographic characteristics of Milton and Ontario
Source: The 2006 Statistics Canada Census (Statistics Canada, 2007).

Milton Hydro Distribution Inc. and the University of Waterloo have a well established research partnership. With funding from the Ontario Centres for Excellence and leadership from Professor Ian Rowlands, Milton Hydro Distribution Inc. has contributed to a number of research initiatives involving TOU rates and electricity conservation. This partnership is another justification for the site selection.

1.4 Thesis overview

The remainder of this thesis is divided into four Chapters. In Chapter 2, the results of a literature review to determine the impacts of TOU rates on lower-income and senior-headed households are presented. The academic and non-academic literatures presented in this chapter provide an overview of energy conservation behaviour and the barriers to energy conservation. This chapter explores TOU rates in other jurisdictions.

In Chapter 3, the research design and methods are presented. This section provides justification for taking a mixed-methods and exploratory research approach. The interview process, including the interview design, the selection and recruitment of interview participants, and the interview analysis are described. In addition, the analysis of electricity consumption data is explained. The analysis of electricity consumption data is undertaken by addressing four key questions that flow from the overall research question:

1. Will the households *benefit naturally* – that is, in the absence of behavioural change – from the implementation of TOU rates?

2. Do the households conserve electricity upon the implementation of TOU rates?
3. Do the households shift the time when they consume electricity upon the implementation of TOU rates?
4. Do TOU rates change the costs of the household electricity bill?

In Chapter 4, the results of the research are presented. The interviews with relevant industry experts are summarized and the major themes that emerge are identified. The results of the analysis of electricity consumption data are also explored and compared to data that were collected through household questionnaires. In Chapter 5, the research findings are discussed. The major themes identified during the interviews are compared to the themes identified in the literature review. The implications of the results of the analysis of electricity consumption data are discussed and compared to the predictions of the industry experts. Finally, recommendations for future research and policy are made.

Chapter 2: Impacts of time-of-use rates on lower-income and senior headed households

2.1 Introduction

This thesis is based in a framework of sustainability. The term ‘sustainable’ has been defined in many ways since the concept was first widely popularized by the Brundtland Report (World Commission on Environment and Development, 1987). Here, the term sustainable development was defined as “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs” (p. 43). Alternatively, Robinson et al. (1990) defined sustainability as “the persistence over an apparently indefinite future of certain necessary and desired characteristics of the socio-political system and its natural environment” (p. 39). More recently, Gibson (2001) describes sustainability through seven essential principles, namely: Integrity, Sufficiency and Opportunity, Equity, Efficiency, Democracy and Civility, Precaution, and Immediate and Long-term Integration. Although the term can be defined in many ways, each definition emphasizes the need to preserve the adaptability, or resilience, of socio-ecological systems. There is also a strong emphasis on social equity and the maintenance of a safe and healthy natural environment. The concept of sustainability recognizes and embraces the web of relationships that link social systems to environmental systems. It is appropriate to base this thesis in a framework of sustainability because it recognizes the relationship between socio-economic characteristics and environmental behaviour. In other words, it recognizes that lower-income and senior-headed households might experience barriers with respect to energy conservation. This relationship is described in a position paper written by the Public Interest Advocacy Centre (2006, p. 1) when they state,

> Not only are conservation efforts essential as part of an overall strategy for meeting Canadian energy needs, but they are increasingly necessary for Canadian households to undertake to avoid economic burden.

As the price of electricity continues to increase, more attention has been given to concepts such as equitable pricing, production efficiency and the cost to obtain basic utility services (Reynolds and Christophersen, 1984, p. 89). The goal of this literature review is to discuss the behavioural responses to, and financial impacts of, TOU electricity rates on lower-income and senior-headed households. In particular, this literature review attempts to identify factors that influence the energy consumption and conservation behaviour in lower-income and senior-headed households. The remainder of this chapter is divided into two sections. Section 2.2 reviews energy conservation behaviour, including the attitude and economic models for conservation behaviour, types of conservation behaviour, energy-use demographics and barriers to energy conservation. Section 2.3 outlines common electricity pricing regimes found in North America, including lifeline and tiered rates, critical peak pricing, and TOU rates.

The information presented in this chapter on energy conservation behaviour and energy-use demographics provides a broad context for understanding the results of the electricity consumption analysis undertaken in Chapter 4.2. In other words, it helps explain why, or why not, there is a change in the electricity consumption behaviour as a result of the implementation of TOU rates.

2.2 Energy conservation behaviour

Energy conservation behaviour is a topic that is widely discussed in academic literature and is an important concept to explore in this thesis. Responding to TOU rates by shifting electricity consumption to off-peak periods, and reducing the amount of electricity used during on-peak periods, are examples of energy conservation behaviour. As described in the following section, factors that motivate energy conservation behaviour, and the types of conservation behaviour employed, can be affected by socio-economic status. Therefore, it can be expected that lower-income and senior-headed households may respond differently to TOU rates than more affluent and younger households. The literature presented in this section provides insight to why and how individuals respond, or do not respond, to TOU rates.

This section is divided into three sub-sections. The first describes how both attitude and economics can motivate energy conservation behaviour. The second describes how people can participate in energy conservation behaviour through an investment in efficiency and/or the curtailment of energy consuming behaviour, and how socio-economic characteristics of a household might affect the type of conservation behaviour that can be employed. The third describes how different demographic groups might display different energy conservation behaviour and experience different barriers to energy conservation.

2.2.1 Attitude and economic models

Two basic models are thought to explain energy conservation behaviour: the attitude model and the rational-economic model (Samuelson, 1990). The attitude model presumes that attitudes steer behaviour. As a result, in order to increase conservation behaviour in the public, favourable attitudes towards conservation must be created. Therefore, for example, to reduce electricity consumption during on-peak periods, individuals need to have a belief that reducing on-peak consumption is ‘a good thing to do’. The rational-economic model for conservation assumes that each consumer will take on conservation behaviours if the actions are beneficial to their own economic self-interest. Therefore, for example, an individual may respond to TOU rates if they believe that changing their electricity use patterns will result in savings on their electricity bill. It could be supposed that lower-income and senior-headed households may be inclined to shift or reduce electricity consumption to take advantage of TOU rates because of financial benefits. These two models are not necessarily mutually exclusive. For example, a person may be motivated to conserve electricity during on-peak periods, both because they believe it to be the 'right thing to do' and because they realize that their actions would save them money. Both models are discussed in the paragraphs below.

Kaiser, Wolfing, and Fuhrer (1999) discuss three attitude concepts that have been explored in ecological behaviour literature: attitudes towards the environment, attitudes towards environmental behaviour, and the new environment paradigm. Attitude towards the environment (e.g., air pollution) is commonly known as 'environmental concern'. Attitude towards environmental behaviour (e.g., reducing electricity usage) refers to a theory of reasoned action or planned behaviour. The new environment paradigm is a value-based approach that considers the "balance of nature, limits to growth, and humans over nature" (p. 2).

Stern (2000) discusses attitudinal factors, including values, beliefs and norms (VBN), which are theorized to affect behaviour. The VBN theory, developed by Stern and his colleagues, describes the relationship among these factors and how these factors influence pro-environmental behaviour (see Figure 3). Personal values, including biospheric, altruistic and egoistic values, influence personal beliefs, including ecological worldview, the awareness of adverse consequence (AC), and the ascription of responsibility to self (AR). In other words, personal values influence a person's belief in the state of the environment, their belief that the condition of the environment threatens others (AC), and their perceived ability to reduce the threat (AR). Egoistic values are thought to have a negative relationship with pro-environmental behaviour. Personal values and beliefs influence personal norms to take pro-environmental action, which ultimately impacts pro-environmental behaviour. To explain this theory in the context of this thesis, a person may believe that there is a need to eliminate the use of coal-fired power plants, and therefore they would be willing to reduce electricity consumption during on-peak periods. This person may have biospheric values, which would influence their belief that coal-fired plants should be shut down, which would increase their likeliness to reduce electricity consumption during on-peak periods.

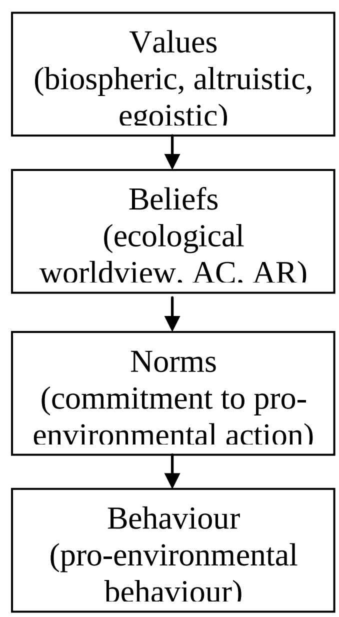

Figure 3. VBN Theory. Adapted from Stern (2000)

Differing from the attitude model, the economic model is based on economic theory that assumes that consumers have the best information to make informed choices. However, when it comes to energy, people tend to overestimate the amount of energy used by devices that are 'visible' to them and underestimate the amount of energy used by devices that are 'not-visible' to them (Stern, 1986). For example, Stern (1986) reports that consumers overestimated the amount of energy used by televisions and lighting and underestimated the amount of energy used by furnaces and water heaters. As a result, consumers tend to make poor choices when attempting to conserve. This suggests that if a person with the intention to shift electricity usage does not have the best information with respect to appliance loads, then they may be unable to successfully take advantage of TOU rates.

Compounding this problem, consumers frequently make decisions based on short-term costs and therefore they do not invest in energy efficiency as an economist might predict. The validity of the rational-economic model of energy conservation behaviour has been criticized because consumers frequently base decisions on incorrect or short-term information (Stern, 1986; Lutzenhiser, 1993; Samuelson, 1990). Lack of knowledge can cause people to make poor choices in behaviour and investments. Lutzenhiser (1993, p. 256) elaborates on this point,

> In economic analyses, prediction of the effects of changes in price on aggregated demand ultimately rests upon an image of individual consumers as knowledgeable actors who are concerned about costs.

Although this may be true in many cases, it should be noted that the success of TOU rates to motivate change in electricity usage patterns depends on the individual's awareness of the TOU rate schedule and their knowledge of the best ways to reduce electricity usage during peak periods.

Even though there are limitations to both models, they both provide context for this thesis. TOU rates are thought to be economically efficient and are thought to motivate changes in electricity consumption behaviour; therefore the economic model suggests that a consumer would take advantage of the new rate regime if they believed it was in their economic self-interest. On the other hand, some individuals may be motivated to change their behaviour, regardless of the rate regime, if they had strong pro-environmental values. Any financial savings resulting from changing electricity consumption behaviour would be a side benefit.

In this section, the topic of 'why' people might be motivated to partake in energy conservation behaviour has been explored. Next, the topic of the 'how' people might partake in energy conservation behaviour is explored by discussing the types of behaviour that they might employ.

2.2.2 Types of energy conservation behaviour

Two types of energy conservation behaviour are typically discussed in energy conservation literature: curtailment behaviour and adoption of energy-efficient technologies (Dillman and Dillman, 1983; Samuelson, 1990). Curtailment behaviour refers to change in routine energy consuming behaviour such as turning off the lights or manually adjusting the household thermostat. These actions do not require capital investment and might be a temporary response to higher energy prices. Adopting energy-efficient technology such as an energy efficient heating system, on the other hand, involves an upfront investment. Additionally, it means that consumers do not need to reduce their level of energy services to benefit from energy savings. Adopting new technologies is considered a 'one-shot' behaviour and usually has a higher potential for long-term energy savings (Stern and Gardner, 1981). Curtailment is thought of as a temporary change because it requires an individual to perform the behaviour repeatedly but does not require a capital investment. Curtailment could be permanent if a person remained committed to performing the behaviour over time.

A survey administered by Dillman and Dillman (1983) was used to measure the extent to which consumers made temporary changes (i.e., curtailment behaviour) or permanent changes (i.e., technology adoption) in response to higher energy costs. The results of the survey suggested that different types of conservation activities were undertaken by different groups of people. As predicted, curtailment behaviour was adopted by people who did not have the financial means to respond differently, while households with greater financial resources invested in new technology instead of adjusting their personal habits.

These results suggest that higher energy costs do not necessarily promote the adoption of permanent conservation, which questions the validity of promoting energy conservation by increasing energy prices (Dillman and Dillman, 1983). These findings are particularly critical for this thesis because it suggests that it is more likely for lower-income and senior-headed households to partake in curtailment behaviour rather than purchase energy saving technologies in order to reduce electricity usage during on-peak periods. It also suggests that lower-income and senior-headed households are likely to have fewer options to engage in energy conservation behaviour than more affluent and younger households.

The findings of Dillman and Dillman's (1983) survey are consistent with those discussed by Black, Stern and Elworth (1985), who reported that the adoption of energy efficient technology is motivated by economic factors (e.g., home ownership and monetary savings), while curtailment behaviour is more heavily motivated by personal norms. Black et al. (1985) also suggest that the establishment of personal norms is more effective than economic factors at maintaining curtailment behaviour. For example, if the only reason a person was motivated to conserve electricity during on-peak periods was to avoid high on-peak TOU rates, then they would not likely continue conserving electricity if TOU rates were no longer in place. Alternatively, if a person was motivated to conserve during on-peak periods by personal pro-environmental norms, then they may be more likely to continue to conserve even if TOU rates were no longer mandatory.

In this section, the topic of 'how' people may choose to partake in energy conservation behaviour was explored. Next, the barriers to partaking in energy conservation behaviour are explored.

2.2.3 Demographics and barriers to energy conservation

Although daily and weekly energy consumption patterns within a household can be relatively consistent, household patterns differ significantly between one household and another due to different demographic characteristics (Lutzenhiser, 1993). Several demographic characteristics have been identified within the literature as factors that influence energy conservation behaviour. These factors include income (Lutzenhiser, 1993; Herter, 2007; Tienda and Aborampah), family composition (Lutzenhiser, 1993; Samuelson, 1990), the age of the household occupants (Lutzenhiser, 1993; Warriner, 1981) owner-occupancy or tenancy (Tienda and Aborampah, 1981), and appliance characteristics (Lutzenhiser, 1993). These characteristics are discussed in the paragraphs below. A better understanding of energy use demographics and barriers to energy conservation behaviour is an essential component of this thesis. The information presented here helps to identify factors explored in the analysis. As well, this information might help explain the analytical results of this thesis.

Research conducted by Tienda and Aborampah (1981) illustrates how socio-economic characteristics influence a household's response to increased energy costs. They conducted random telephone surveys in four northern, non-metropolitan Wisconsin counties with a disproportionate number of lower-income households. A total of 297 random telephone surveys were conducted to gain insight on the impacts of rising electricity costs on lower-income families. The surveys collected information on lifestyle changes, retrofitting, comfort level, and fuel switching. The survey identified household characteristics such as type of dwelling, ownership, major appliances, family size, age of household head, and income. The results of the survey indicated renters and lower-income and senior-headed households were less likely to invest in household weatherization. Renters were thought to be less likely to invest because they consider the rental unit to be a temporary living space. More than half of the survey respondents stated that they were doing all that they could to conserve energy, or that they did not know what more they could do to conserve energy. Despite this, the researchers concluded that structural characteristics of the dwelling were more important than socio-economic factors in determining consumption levels and strategies to manage increasing energy costs.

Fixed income seniors have less ability than younger, wealthier people to cope with the rising cost of living, energy costs or otherwise, and those with lower incomes pay disproportionately more of their income on the cost of energy (Solano and Sparling, 1985). To cope with rising costs, the elderly may make lifestyle changes such as reducing their cost of living (i.e., reduced utilities, rent, transportation, and recreation), accepting fuel assistance, changing living arrangements (i.e., moving or taking boarders) or making health or nutritional sacrifices. Many seniors choose curtailment behaviour in response to rising energy prices. Thus, Solano and Sparling (1985) report that the implication of rising energy costs is declining standard of living, with the standard decreasing greatly for senior-headed households since they are more likely to have lower incomes. Senior-headed households living in colder climates are at greater risk of accidental hypothermia and senior-headed households living in hotter climates are at greater risks of suffering and dying from summer heat waves (Solano and Sparling, 1985). The findings from Solano and Sparling (1985) are important to this thesis because they demonstrate the vulnerability of senior-headed households to changes in electricity costs.

The elderly face a unique set of challenges when it comes to energy usage and conservation (Warriner, 1981). A large proportion of the elderly population have low or fixed incomes. Health requirements and already thrifty living makes it difficult for seniors to cut back on energy requirements. Moreover, seniors frequently live in older, inefficient housing and are more inclined to spend a greater proportion of their time at home. Some seniors choose to live in smaller residences because they are easier to get around in and require less maintenance. Additionally, senior-headed households tend to have fewer occupants per household (Warriner, 1981). Warriner's (1981) study provides significant rationale for including senior-headed households in this study, as they are shown to have much less control over their household and less ability to conserve electricity.

Samuelson (1990) identifies other important demographic factors that might influence the energy consumption behaviour of a household - bill payers, and family size and composition. If the person who is responsible for paying the energy bill is home during the day, then he or she may be more likely to adjust the household thermostat. Further, larger families with children may not be able to conserve as much energy as smaller families without children - this may be because households with children have less flexibility in their daily schedule. Samuelson's (1990) study shows that household characteristics can have a significant impact on the ability to conserve electricity. This is a key point for this study, as it is thought that lower-income and senior-headed households may have different abilities to shift or conserve electricity during on-peak periods.

Household demographic characteristics can lead to significant barriers to the ability to conserve electricity. Dresner and Ekins (2006) highlight some barriers that prevent investment in energy efficiency. First, energy efficiency is competing against other concerns within the household. Energy savings simply might not be the first priority for a family. Second, people might have insufficient or flawed information regarding energy efficient choices. Third, people might be suspicious of energy suppliers and their motives. These barriers can significantly impede the ability of some groups to learn about the best ways to conserve energy. Unfortunately, it can be predicted that lower-income and senior-headed households may be more significantly impacted by these barriers.

In a report by the Public Interest Advocacy Center (2006), the authors note that, for tenants, there is no financial motivation to conserve energy when utility expenses are included in the cost of the rent. On the other hand, there is no incentive for landlords to invest in energy conservation retrofits on their home if tenants pay for their own utility bill. In this way, the cost of electricity is passed down from the landlord to the tenants (PIAC, 2006). The tenant-landlord relationship is significant because it suggests that many lower-income and senior-headed households do not have control, or may not care to control, their electricity consumption.

So far, this chapter has demonstrated the differences between the attitudinal model and the economic model that could be used to encourage energy conservation. This chapter has also shown how different demographics might have different conservation responses and might experience different barriers to energy conservation. The main take-away messages here are:

- Positive attitude towards energy conservation can improve energy conservation behaviour;
- Economics can motivate changes in energy conservation behaviour provided that people make informed choices and have ability to make long-term investments;
- When faced with higher energy prices, lower-income households tend to curtail the amount of electricity they use (e.g., they reduce the use of electricity services), while higher-income households tend to invest in new energy efficient technologies; and
- Lower-income and senior-headed households have different electricity consumption and electricity conservation behaviour than wealthier or younger households, respectively.

In the next section of this chapter, different residential electricity rate regimes are explored. The characteristics of the different rate regimes are considered, including their ability to motivate conservation behaviour and their impacts on lower-income and senior-headed households.

2.3 Electricity rate regimes

Two broad categories of rates are discussed in this section. The first is tiered rates, including lifeline rates, which assign a price for electricity based on the amount of electricity consumed. The second is time-differentiated rates, which assign a price for electricity based on the time the electricity was consumed. As this section demonstrates, different rate structures have different advantages and disadvantages.

Bonbright, Danielsen, and Kamerschen (1988) identify three criteria that should be used when evaluating a rate regime: capital attraction, consumer rationing, and fairness to the rate payer. Capital attraction ensures that revenue requirements of the electrical utility are met through the rate design. Consumer rationing ensures that the rates are reflective of the marginal costs of the provision of the resource. Fairness to the rate-payer is achieved by distributing revenue requirements equitably by ensuring that one group of rate payers is not subsidizing another. These criteria are important to consider as different rate regimes are described.

2.3.1 Lifeline and tiered rates

Although the focus of this thesis is the TOU rate regime, it is beneficial to discuss tiered rate regimes. Tiered rates were the dominant rate regime in Ontario prior to the implementation of TOU rates through the Smart Metering Initiative. Under a tiered rate regime, customers pay different rates under different size tranches. For example, in Ontario in the summer of 2007, the first 600 kWh a household consumed was charged at a rate of 5.3 cents per kWh and all the electricity consumed above 600 kWh was charged 6.2 cents per kWh. The analysis performed in this thesis will compare the costs of the household electricity bill under the tiered rate structure and the TOU rate structure. Therefore, it is essential to understand the strengths and weaknesses of the tiered rate structure, as well as rationale for converting to a TOU rate structure.

Lifeline rates are a form of social energy policy (Reynolds and Christophersen, 1984). A lifeline rate regime uses an inverted-block structure, or inverted tiers, where the price of electricity increases as consumption increases. The first block is considered the lifeline amount for essential needs – heating, lighting, cooking, and food refrigeration – and varies by season and climate (Reynolds and Christophersen, 1984; Hennessy and Kean, 1989). In a lifeline rate structure, those who consume high amounts of electricity subsidize those who consume lower amounts of electricity, which encourages conservation (Hennessy and Kean, 1989). California was the first state in the US to adopt lifeline rates in 1975 (Reynolds and Christophersen, 1984). At this time, the lifeline amount, or the lowest costing tier, was set so that a family of four in a 1000 square foot home could afford enough electricity to meet their needs (Reynolds and Christophersen, 1984). The rates accounted for climate and seasonal variability, and minimal health requirements (Reynolds and Christophersen, 1984). In order to properly determine the lifeline amount, the jurisdiction must first answer the question of how much is an essential need (Hennessy and Kean, 1989). In 1978, lifeline rates in California were expanded to include air conditioning for those living in hot climates and life-support systems for the medically ill (Hennessy and Kean, 1989).

Hennessy and Kean (1989) suggest that lifeline rates are justified by two factors. The first is the assumption that a certain amount of energy is a basic human right. In other words, electricity is considered a necessity in modern society. The second assumption is that declining block rates promote wasteful and inefficient use of energy. Declining block rates, used in many jurisdictions prior to the 1970’s, charge a lower amount for each tier as consumption increased, which does not provide an economic incentive to conserve electricity. Legislation in California replaced declining block rates with increasing block rates in 1975.

Solano and Sparling (1985) propose that the establishment of lifeline rates is another way for governments to help reduce the costs of energy for seniors. The lifeline amount of energy can also be determined to be the minimum amount of energy required for maintaining a safe and healthy quality of life and enabling elderly households to purchase energy at a more affordable rate. This rate regime is also thought to influence energy conservation – amongst the elderly and other non-target groups – because users can take advantage of lower rates. On the other hand, Solano and Sparling (1985) state that lifeline rates have also been criticized because they might promote overconsumption; households might use more energy than they need because it is less expensive at lower tiers. Additionally, it is difficult to ensure that the savings of such a rate scheme would be passed down to those living in rental accommodations. Further, lifelines rates have many 'free-riders' – people who benefit from the rate who are not targeted by the rate design.

In the 1980's, many utilities in the US moved to the 'baseline' rates to clear up confusion over defining a "lifeline amount" (Hennessy and Keane, 1989). The new baseline amount was determined simply, without attempting to define an amount that is considered an essential need. Baseline rates are similar in structure to lifeline rates. Both regimes use inverted-block structures; the difference is how the tiers are calculated. The baseline amount is a fraction of the average household consumption. In 1982, the baseline amount was 50-60% of average residential consumption for most consumers, and 60-70% of residential consumption during the winter for those with electric heat. However, the baseline block was priced at 15-25% below the system rate and utilities were forced to raise second tier prices to recover revenue. In 1987, the utilities were given the flexibility to change the ratio between the two tiers but had to ensure that a program to assist low income users with large bills was in place.

Hennessy and Keane (1989) found that baseline rates reduced the electricity bill of both lower-income and non-lower-income households, especially those with electric heat. They address three major dilemmas created by baseline rates. First, revenue shortfall is made up for by higher prices from the second tier. Thus, residential consumers pay for the difference. However, the authors suggest that the burden of the baseline should be spread to industrial and commercial customers as well. Second, targeting criteria are not necessarily related to the load shape and do not recognize the difference in prices that occur at different times of day. Third, the benefits to lower-income households are not consistent and raise a question of fairness. The authors question the amount of savings a lower-income household would actually achieve under this rate structure and suggest that the savings would likely be minimal.

In summary, the rationale behind using an inverted-block rate structure is to ensure that people are able to meet their basic electricity needs affordably. This rate structure is founded on the principle that electricity is a basic necessity of modern life. As a consequence, inverted-block rates are thought to promote conservation. More affluent households might be motivated to conserve electricity to avoid paying higher rates for electricity consumption in higher tiers. Conversely, this rate design could promote overconsumption, as more affluent households may consider the cost of electricity at lower tiers inconsequential. If the lifeline or baseline amount is set too low, utilities may be forced to make up revenue requirements by increasing the rates in higher tiers. Further, this rate regime does not recognize the differences in the costs of electricity that occur at different times of day.

Applying the criteria developed by Bonbright et al (1988), electricity utilities can meet their revenue requirements under this rate regime, provided that they are able to make up the difference in the cost of electricity by higher tiers. Tiered rates do not ensure customer rationing, as the costs to provide electricity during different times of the day are not reflected in the rates. Although tiered rates were designed to ensure that a minimal amount of electricity is affordable to lower-income groups, they do not necessarily promote 'fairness' because consumers who use less electricity are subsidizing consumers who use more electricity.

The weakness in the tiered rate regime could support the transition to a rate structure, such as TOU rates, that differentiate prices based on the time that the electricity was consumed. However, as described in the next section of this chapter, TOU rates may have different impacts on lower-income and senior-headed households than more affluent and younger households.

2.3.2 Time differentiated rates

Two rate regimes are discussed in this section: TOU rates and Critical Peak Pricing (CPP). Similar to TOU rates, CPP charges higher rates for electricity consumed during on-peak periods and lower rates for electricity consumed during off-peak periods. However, CPP differs from TOU rates with the addition of a 'super-peak' price that provides additional incentive to consumers to shift electricity usage to off-peak periods during the hours that are expected to have the highest demand through the year. Usually under the CPP rate regime, customers are notified of super-peak periods a short time in advance. Lessons learned from key experiments on TOU and CPP rates are presented below, in sequential order. These studies provide significant background to this thesis, by describing the attributes of TOU rates, the ability of TOU rates to motivate a reduction in on-peak electricity consumption, as well as the impacts on different demographic segments of the population.

The first article to be reviewed in this section is from a study that was carried out in Wisconsin in the late 1970's. Warriner (1981) collected electricity consumption data from 82 seniors-only households (over the age of 65) that partook in the Wisconsin TOU experiment from 1976-1980. The participants were sent a mailed questionnaire to collect information on appliances, work schedule, family size, age and education. Additionally, electricity consumption data were collected from each household and were used to calculate the amount of electricity consumed per month in kWh and the monthly electricity bill.

Warriner's (1981) study indicates that, on average, under a TOU rate regime, households composed solely of seniors consumed one-third less energy than households that were not composed solely of seniors; however, they only paid 26% less than non-elderly households. Per capita, the seniors-only households use 39% less energy than the households that were not composed solely of seniors because there are fewer people living in seniors-only households. Additionally, seniors-only households spend approximately 2% more of their annual income on energy than households that were not composed solely of seniors. Additionally, 81% of the consumption in the seniors-only households was attributed to essential electricity services (such as lighting, heating, refrigeration, hot water and cooking), compared to 54% in households that were not composed solely of seniors. Further, even though the seniors-only households owned fewer appliances, the electricity used to power their appliances represented proportionately more of their electricity bill compared to households that were not composed solely of seniors (62% compared to 54%).

Warriner's (1981) study provides significant rationale for considering senior-headed households in this thesis. In this early study, senior-only households were shown to have different energy use characteristics than households that were not composed solely of seniors. Seniors-only households use less electricity, but paid proportionally more of their income on electricity (possibly because fewer people lived in the home), and more of their electricity consumption was used on essential services. Seniors-only households have fewer appliances, which mean they have less ability to shift electricity load to off-peak periods. This study was performed three decades ago, therefore it could be expected that the findings from this study might be out of date, particularly with respect to appliance ownership.

Using the same Wisconsin study, Heberlein, Linz and Ortiz (1982) focused on the acceptance of TOU rates and the change in behaviour in response to TOU rates. Using mail questionnaires, information was collected from 329 Wisconsin households who were on mandatory TOU rates for almost two years. The customers were on one of nine different price structures, varying peak times and ratios. The results of this survey showed that 52% of the respondents were satisfied with the TOU rate structure, while 17% were neutral and 30% dissatisfied (including 10% extremely dissatisfied). When asked about the fairness of the TOU structure, 61% stated that it was fairer than the pervious rates, 20% were neutral, and 18% said that it was less fair than the previous rates. However, 75% suggested that coping with the new rates was a reasonable request, and 25% said it was an unreasonable request. Overall, 38% of the respondents answered positively to each question and 64% indicated that they would stay on TOU after the experiment was over. Additionally, 62% said that all residents should be billed on TOU rates.

Overall, Heberlein et al (1982) found that the level of satisfaction was not related to age, education, or value of house. But, households with higher incomes were more satisfied than lower-income households, and larger households were less satisfied than smaller households. The level of satisfaction was not impacted by the length of the peak periods and the price ratio between the peaks. Of the respondents, 61% suggested that the savings gained by TOU were worthwhile, while 27% said that they tried to save but the effort did not pay off. Only 4% indicated that they made no effort to save money under the TOU rates. Additionally, 44% said that the savings were more than expected, 37% said the savings were less than expected, while 19% did not report any savings.

Heberlein et al (1982) found that more than one-third of the respondents did not know when the peak hours were. Eighty percent of respondents were somewhat or strongly committed to reducing electricity consumption during peak periods. Additionally, 18% used energy whenever, 48% would wait to use off-peak electricity if convenient, 12% changed their electricity consumption habits drastically to avoid on-peak electricity use. During focus groups that were conducted after the questionnaire, the researchers reported that the participants were disappointed with the amount of savings, saying that it was not worth the effort. As knowledge of actual savings increased, less shifting was expected.

This study by Heberlein et al (1982) provides interesting insight about the acceptance of TOU rates. In general, the majority of households were satisfied with the TOU rates and thought that TOU rates were fair. The level of satisfaction did not vary based on age, education, or house value, but did vary by income and size of households. Although the participants were generally satisfied with the results, many did not save as much money as expected, which they found disappointing. This could suggest that TOU rates do not provide a large enough economic incentive for conservation of electricity.

Additional research on TOU rates was conducted in the 1980's by Blocker (1985) which focused on reforming electricity rates to help make electricity more affordable for lower-income households; specifically, lifeline rates and TOU rates were compared. TOU rates were examined as an alternative rate structure that would reduce economic inefficiencies and energy waste typically found with lifeline rates without increasing the dependence of lower-income families on social welfare programs. The study included 852 owner-occupied, single-family households chosen randomly in Oklahoma. They were sent a questionnaire to learn about their energy use, energy conservation behaviour and demographic characteristics. Consumption data were provided by the local electricity utility. This study evaluated the relationship between household income, the number of people in the household, the age of household head, and number of persons in the home during the day against electricity consumption, appliance use patterns, and their willingness to shift appliance use to off-peak periods. The analysis used stepwise multiple regression to assess the effects of each variable.

Blocker (1985) found that income, the number of people at home, and the age of the household head attributed a quarter of the variation in the amount of electricity consumed. Larger households were more likely to use electricity during on-peak periods and senior-headed households were less likely to use electricity during on-peak periods. Income did not explain the variation in appliance use patterns;

therefore TOU rates would not likely benefit lower income households more than others. One-third of lower income households in the sample would benefit from TOU rates given their then current use patterns. Smaller households and senior-headed households were more likely to experience immediate benefits of TOU rates. About two-thirds of the lower-income households stated that they would be likely or somewhat-likely to change appliance use patterns to take advantage of lower off-peak prices. However, although there appeared to be a willingness to take advantage of TOU rates, overall results indicated that TOU rates would be less effective than lifeline rates at reducing the electricity bills of lower-income families. One-third of these lower-income households would benefit from TOU rates given their current electricity use patterns, the others would be required to make lifestyle changes, such as changing the household chore schedule, in order to benefit.

Blocker's (1985) study provides insight regarding the impacts of TOU rates on lower-income and senior-headed households. Most significantly, the findings of this study indicated that seniors were less likely to use electricity during on-peak periods and would likely experience immediate benefits to TOU rates. When compared with the findings of Warriner's (1981) study, however, the results of these two studies seem to suggest that although seniors may not be able to shift current use patterns, they may benefit naturally given their electricity consumption patterns prior to the implementation of TOU rates. When looking at lower-income families, Blocker's (1985) findings suggest that lower-income households were less likely to benefit naturally from TOU rates, and would have to shift appliance use patterns to take advantage of potential savings.

In the late 1980's, Mountain and Lawson (1995) conducted an experiment to examine some early evidence of responsiveness of Ontarian households to TOU rates across all months of the year. The experiment took place over the course of several years, from 1982 to 1988, and included 500 households from 28 municipalities and 11 regions in Ontario. The participants were assigned to several different TOU and non-TOU rate structures. The researchers collected electricity consumption data as well as household characteristics from a questionnaire. Monetary savings or losses were calculated using baseline consumption patterns. A shift to off-peak periods was determined by assessing if the overall average price decreased after the participants were started on TOU rates. The researchers concluded that, for the households participating in this study, on-peak reductions of electricity usage in the summer were somewhat higher than on-peak reductions of electricity usage in the winter. They recommended that TOU rates with narrow on-peak bands between 5pm-9pm would provide the most on-peak reduction during January's on-peak period which occurs from 5pm-7pm, and that TOU rates that focus on 7am-12pm period would reduce June's on-peak which occurs between 10am-12pm.

The contribution by Mountain and Lawson's (1995) research is significant for this thesis. The findings demonstrate that customers are responsive to time differentiated price structure. The findings also suggest that Ontario households are more able, or more willing, to shift electricity consumption during the summer periods compared to the winter period. The limited shift during the winter could be because of the use of electric heating.

Later in the 1990's Baladi, Herriges and Sweeney (1998) evaluated the participation decision and the change in residential load profiles upon the implementation of voluntary TOU rates using data from Midwest Power Systems of Iowa. The study evaluated 775 households over a two year period. The design of the experiment allowed them to determine if customers chose to participate in TOU rates based on their initial load patterns and to evaluate the change in load patterns once TOU rates were implemented. The researchers also evaluated whether or not the voluntary TOU participants were more responsive to TOU rates than the mandatory TOU participants. The study excluded low usage customers "because they would be unable to save money on the tariff given the additional metering charge associated with the tariff" (p. 228). Volunteer controls remained in standard flat rates for the first year of the program, and were then switched to TOU rates. During phase one of the study, volunteer controls and non-volunteers were subjected to standard flat rates. Although they expected volunteer controls to have lower on-peak demand than non-volunteers, they found that that they had very similar on-peak usage. They also expected that volunteers would have a higher baseline usage than non-volunteers; however, they found that non-volunteers had a slightly higher (but statistically insignificant) baseline usage during the summer months. Approximately 25% of volunteers stated that they use air conditioning only on the hottest days, compared to 14% of non-volunteers. Interestingly, they found that socio-demographic characteristics (e.g., appliance availability and existing electricity consumption patterns) did not influence the decision of the participants in this experiment.

In addition, Baladi et al (1998) evaluated whether or not households with high on-peak usage are more likely to volunteer for TOU rates if they can readily change their usage patterns. The researchers found that the responsiveness (i.e., shift in electricity consumption) to mandatory TOU rates in a study a decade earlier was similar to the responsiveness of their TOU volunteers. By evaluating elasticities, the authors found that socio-demographic characteristics – such as appliance ownership, home ownership, family composition, number of bedrooms and number of people living in the households - affected the ability of the consumer to respond to TOU rates. Notably, households with more appliances were more able to shift electricity consumption than households with fewer appliances

The research performed by Baladi et al (1998) contributes significant findings to the TOU rate literature. The research demonstrates that households that volunteered for TOU rates had similar on-peak electricity consumption to non-volunteers and that socio-demographics did not affect their willingness to sign up. Given that the findings suggested households with more appliances were more able to shift electricity consumption, it might be reasonable to predict that lower-income and senior-headed households, who do not own as many appliances, might have a limited ability to reduce electricity consumption during on-peak periods.

In 2003 and 2004, researchers collected data for California's State wide Pricing Pilot (SPP). This experiment was designed to estimate demand curves for electricity consumption by time-of-use for dynamic rates and price elasticities, to collect information on customer acceptance of dynamic rates, to associated technologies and information, to predict the impact of a full scale implementation of dynamic rates, and to provide information for a cost-benefit analysis of full scale implementation of dynamic rates (Faruqui and George, 2003; Faruqui and George, 2005). The sample size of this experiment was approximately 2000. This pilot project was novel for several reasons. First, it tested the dynamic rates against the current five-tiered inverted rate scheme. Second, it used integrated sample design across three service areas. Third, it used similar rates across three utilities. The SPP tested a TOU rate structure and two CPP rate structures (CPP-F, fixed peak period same as TOU, and CPP-V, variable-length for emergency days). The on-peak periods were from 2 pm – 7 pm during weekdays. The standard rate flat rate was $0.13/kWh. The TOU rate was $0.10/kWh during off-peak periods and $0.22/kWh during on-peak periods. The CPP rate was $0.64/kWh during on-peak periods of 12 summer days. For the average consumer, if they shifted 30% of their peak period load, they would save 10% on their electricity bill. If they did not shift any load, then their bill would only increase or decrease by 5%.

Using the consumption data, researchers estimated elasticities of demand, and using data collected from 2003 and 2004, determined the probability of on-peak electricity reduction as a result of the electricity rate. The researchers found that there was a 95% probability of a 12.1% - 14.1% reduction of on-peak electricity demand during critical days; however, results varied across climates. Households with air conditioning were more responsive than households without air conditioning. The rate system appeared to have no conservation effect, for on-peak reductions were met with off-peak increases. Faruqui and George (2005) state that evidence from this experiment supports Ontario's decision to implement the Smart Metering Initiative and a TOU electricity pricing regime.

The results from California's SPP give significant credibility to the implementation of TOU rates. The findings demonstrated that customers responded to the TOU price signal by reducing electricity consumption during on-peak periods. Consistent with previous studies (Baladi et al, 1998; Blocker, 1985; Warriner, 1981) the ability to respond to TOU rates was heavily dependent on appliance availability. Again, these findings seem to suggest that lower-income and senior-headed households who may not have access to as many appliances, may be limited in their ability reduce electricity consumption during on-peak periods.

In a more recent study, Herter (2007) attempted to determine whether or not CPP should be implemented state wide or just among targeted groups – high use customers with the highest potential for demand response - and to determine whether or not CPP should be mandatory or voluntary. The analysis also used data from 457 participants in California's State wide Pricing Pilot (2003-2004). The participants were divided into six groups: low use customers with high-, mid- and lower-incomes and high use customers with high-, mid- and lower-incomes. The analysis showed that high use customers reduced the amount of electricity consumed significantly more during critical peak periods than low use customers. However, low use customers saved significantly more in terms of percentage reduction on their energy bill than high use customers. Therefore, the author suggests, CPP should not be targeted only to high use customers.

The results of Herter's (2007) study indicate that a significant portion of the lower-income participants were high use consumers of energy, and that a significant portion of the high-income participants were low use consumers of electricity. Although these results seem counter-intuitive, it could have a simple explanation. For example, suppose a higher-income household had strong pro-environmental norms that influence its behaviour to conserve energy - it would be a high-income and low use household. Alternatively, suppose a lower-income household lived in a building that used inefficient appliances and electric heat – it would be a lower-income and high use household.

Herter's (2007) findings showed that low use consumers responded the same across all income levels. For high use consumers, the lower- and mid-income group's responses to TOU rates were not found to be different from those of high income consumers, which suggest that these groups may not be disadvantaged by CPP rates. Of the mid- and lower-income high use customers, 5% saw an increase of over 10% in their bill. High use customers respond more than low use customers. Low use customers saved on average more than high use customers (4.0% versus 1.7%).

Herter (2007) found that, on average, lower-income customers did not pay more under CPP rates. However, lower-income high use customers did not experience savings while the other five groups did show significant savings. This suggests that efficiency and education efforts should be targeted on lower-income high use customers. Therefore, since high use customers reduced their on-peak load more than low use customers and high use customers did not save more money than low use customers, the targeting of a CPP tariff to only high use customers was challenged. Since high-income customers did not benefit more than lower-income customers and the satisfaction levels amongst the groups were the same, the policy of mandatory implementation of this tariff could be supported, although the author cautions against applying these results in other jurisdictions.

The findings from Herter (2007) demonstrate the different impacts of, and responses to, TOU rates by different demographic groups. Specifically, the results showed that low use consumers respond the same to TOU rates across income levels, and that, on average, lower-income customers did not pay more under the CPP rate regime. Herter's (2007) analysis is consistent with the results of Faruqui and

George (2003) and Faruqui and George (2005), which demonstrate that customers are responsive to the TOU price signal. However, lower-income households seem to be at a disadvantage – particularly if they happen to be high use electricity consumers.

The Ontario Energy Board Smart Price Pilot was conducted in 2006 to evaluate customer impacts and reactions to TOU rates (IBM, 2007). The analysis considered 373 households in Ottawa, Ontario that were placed on three pricing groups: TOU rates, TOU rates with a critical peak period (CPP), and TOU rates with a critical peak rebate (CPR). Under the CPP rate structure, participants were charged 30 cents per kWh for electricity consumed during the critical peak period. Under the CPR rate structure, participants were refunded 30 cents for every kWh reduction below their baseline usage during the critical peak hours. Researchers evaluated the extent to which the various TOU rate structures caused a shift in the customers' electricity usage to off-peak periods, a change in the monthly electricity demand, as well as the customers' acceptance of the rate structure.

The results from the Ontario Energy Board Smart Price Pilot showed that there was 5.7% shift in load during the four critical peak days during the summer period for participants on TOU rates, although this reduction was not statistically significant at the 90% confidence level. For participants on CPP rates and CPR rates, the reduction was 25.4% and 17.5% respectively, which were both statistically significant. On average across the three rate structures, there was a 6.0% conservation effect observed. The participants paid an average of 3.0% less on their bills than they would have under tiered rates. Also, the majority of participants (78%) from all rate categories suggested that they would recommend TOU rates to their friends.

This study provides significant justification for the introduction of TOU rates in Ontario. The findings here are consistent with other studies that demonstrate that TOU rates are effective at reducing on-peak electricity consumption, while providing consumers with the opportunity to save money.

Other Ontario based studies on TOU rates are reported in a staff discussion paper from the Ontario Energy Board (Ontario Energy Board, 2008b). Several local distribution companies in Ontario that have conducted studies to evaluate the impacts of TOU rates on residential customers including Newmarket Hydro and Oakville Hydro.

Newmarket Hydro conducted a pilot using smart thermostats in combination with TOU rates and CPR rates (Ontario Energy Board, 2008b). Overall, the participants responded by reducing on- and mid-peak use by 0.4% and 0.3% respectively, while off-peak use increased by 0.7%. The results of the pilot also indicated that the smart thermostats increased the participant's ability to reduce electricity use during critical peak periods. TOU rates increased the commodity charge of electricity by approximately 2% compared to tiered rates. Further, households increased consumption by 1.1% under TOU rates compared to tiered rates. Knowledge about the rate structure was positively correlated with the demand shifting.

Oakville Hydro conducted a TOU rate pilot on residential customers living in sub-metered condominiums (Ontario Energy Board, 2008b). Changing from bulk metering to sub-metering caused an average reduction in electricity consumption by 20%. Reductions in on- and mid-peak demand were evident in all three buildings after TOU rates were introduced. Like the Newmarket Hydro pilot, this pilot also found that enabling technologies contributed to the household's ability to shift electricity use. Customers that consumed more electricity at tier one prices paid slightly more under TOU rates, while customers that consumed less electricity at tier one prices paid slightly less under TOU rates.

In summary, the findings from several studies indicate that time differentiated rate structures have the ability to motivate change in electricity consumption behaviour and incented people to shift electricity consumption to off-peak periods (Blocker, 1985; Mountain and Lawson, 1995; Faruqui and George, 2003; Faruqui and George, 2005; Herter, 2007; IBM, 2007). However, the findings from many case studies indicate that some lower-income and senior-headed households may not be able to respond as effectively to the TOU price signal (Warriner, 1981; Blocker, 1985; Herter, 2007). Primarily, this seems to be due to limited appliance ownership and an already frugal lifestyle (Warriner, 1981).

Applying the criteria to evaluate electricity rate regimes that were developed by Bonbright et al (1998), the TOU rate regime appears to satisfy the capital attraction and customer rationing criteria. Utilities are able to meet their revenue requirements through this rate design and the costs associated with the provision of electricity are more closely reflected in the TOU rate, as the costs to provide electricity during different times of day are reflected in the price. The rates also appear to achieve a level of fairness, as customers who use high amounts of on-peak electricity are not being subsidized by other customers who use high amounts of electricity during off-peak hours. That said, if lower-income and senior-headed households are not able to respond to the TOU price signal, then the fairness of this regime is questionable – especially if there is a risk of an increase in the cost of a household electricity bill in lower-income and senior-headed households.

In the next chapter, the research design and methods are explained. The methods outlined in this section use lessons learned from previous studies.

Chapter 3: Research design and methods

This chapter outlines the research methods and approaches used to answer the overall thesis question. As a reminder, the thesis question is: What are the behavioural responses to, and financial impacts of, TOU electricity rates on lower-income and senior-headed households? This leads to two sub-questions:

a) Do lower-income and senior-headed households respond to TOU electricity rates? More specifically, do they reduce electricity consumption or shift the time electricity is consumed?
b) In either the presence or absence of behavioural change, do lower-income and senior-headed households experience a change in the amount of their electricity bill upon the implementation of TOU rates?

As this chapter will describe, the research design follows a mixed-method approach by combining qualitative elite-level interviews, quantitative analysis of electricity consumption of 199 lower-income and senior-headed households and a household questionnaire sent out to the same lower-income and senior-headed households. Although the impacts of TOU rate have been studied by numerous researchers, the specific impacts on lower-income and senior-headed households are relatively understudied, as demonstrated by the literature review in Chapter 2. Therefore, the research methods are also reflective of exploratory research.

This chapter is divided into three sections. Section 3.1 presents the rationale for using a mixed-method approach and exploratory research is defined. Section 3.2 covers the methods associated with elite-level interviews, including recruitment, interview design and analysis. Section 3.3 describes the analysis of residential electricity consumption data, including site characteristics, questionnaire development, data collection and analysis.

3.1 Mixed-methods and exploratory research

Research combining quantitative and qualitative methodologies has become increasingly popular in academia (see for example Bryman, 2006; Pays and Atchisons, 2008; Steckler et al., 1992). Both quantitative and qualitative approaches to research have their own distinct attributes as shown in Table 2. Qualitative research methods are primarily used in the social sciences to evaluate social phenomena. The qualitative paradigm uses verbal and written data collected from participants with close proximity to the phenomenon of interest to develop insights regarding human behaviour and opinions. Qualitative research produces rich and sizeable data sets; however, the results can be subjective or unrepresentative. On the other hand, quantitative research methods are primarily used in the physical sciences to evaluate numerical data collected from experiments. The quantitative paradigm uses statistical analysis to determine the extent to which the variables of interest are related to each other. Quantitative research seeks to maximize objectivity; however, the results can seem “shallow and abstract” (Buchanan, 1992, p. 117). In combining the two dominant research paradigms, the weakness of each can be compensated for by the strengths of the other. Greene et al. (1989, p. 256) define mixed-method research designs

> as those that include at least one quantitative method (designed to collect numbers) and one qualitative method (designed to collect words), where neither type of method is inherently linked to any particular inquiry paradigm.

Quantitative	Qualitative
Deductive (Verification and outcome oriented) Objective measurements Reliable (Technology as instrument) Generalizable (Outsider’s perspective, population oriented)	Inductive (Discovery and process oriented) Subjective measurements Valid (Self as instrument) Ungeneralizable (Insider’s perspective, case oriented)

Table 2. Typical attributes of quantitative and qualitative research design
Source: Steckler et al, 1992, p. 2

The research conducted for this thesis uses a mixed-method design to determine the impacts of the TOU electricity rate structure on lower-income and senior headed households. The main components of the research design are:

a. **Elite –level Interviews (qualitative)** – conducted with leaders within organizations addressing energy policy and issues facing lower-income and senior-headed households in Ontario. The interviews provided relevant background information about how lower-income and senior-headed households might be impacted by energy conservation and demand management programs that are being implemented in Ontario.

b. **Analysis of Residential Electricity Consumption (quantitative)** – electricity consumption data collected from lower-income and senior-headed households were used to evaluate the change in the cost of electricity and consumption patterns (i.e., shifting or conserving) upon the implementation of TOU rates. The changes were evaluated with respect to the demographic and structural characteristics of the household (as collected through a household questionnaire).

When implementing a mixed-method approach, researchers should indicate the purpose for integrating the two approaches (Bryman, 2006; Creswell, 2003; Creswell et al., 2003; Greene et al., 1989). Greene et al. (1989) and Bryman (2006) identify five reasons to justify the integration of qualitative and quantitative research methods. The first is triangulation; researchers use different methods to converge or to corroborate results. The second is complementarity; researchers use different methods to elaborate or to clarify the results of one method with the results of another. The third is development; researchers use the results from one method to help inform the other method. The fourth is initiation; researchers attempt to uncover contradictions. The fifth is expansion; researchers use both methods to broaden the scope of the investigation. In this thesis, the purpose of integrating qualitative and quantitative research methods is complementarity. Since the problems facing lower-income and senior-headed households in energy conservation policy are diverse and complex (as demonstrated by the literature review in Chapter 2), using a mixed-methods approach helps to ensure that many aspects of this issue are addressed.

Steckler et al. (2006) identify four generalized models in which qualitative and quantitative methods can be combined. In the first model, qualitative results are used to develop quantitative measures. In the second model, qualitative results are used to help explain quantitative results. In the third model, quantitative results are used to help explain qualitative results. In the fourth model, qualitative and quantitative results are used in parallel (equally) to produce results. The research design of this thesis follows the fourth model. Both the elite-level interviews and the analysis of electricity consumption data contribute equally to answering the overall thesis question. The elite-level interviews will be used to identify possible social impacts associated with the implementation of TOU rates, while the analysis of electricity consumption data will offer insight into the change in electricity usage patterns and billing amounts as a result of the implementation of TOU rates.

It is important to identify whether qualitative and quantitative data are collected at the same time or successively and to indicate if either data set will be given priority (Bryman, 2006; Morgan, 1998; Morse, 1991). In this thesis, the qualitative and quantitative data were collected over an overlapping time period. The elite-level interviews were conducted in June and July of 2007 and the electricity consumption data were collected between June and December of 2007. Since the data were collected in this way, the elite-level interviews were not influenced by the results of the data analysis. Neither data set is given priority in this research, as each data set will contribute equally to answering the overall thesis question.

Further, it is important to specify whether the data are mono- or multi-stranded. In other words, do the data come from one source or from multiple data sources (Bryman, 2006; Tashakkori and Teddlie, 2003)? The data collected in this study are multi-stranded since the data come from different sources: expert interviews and lower-income and senior-headed households. Researchers should also specify during which stage of research are the two approaches combined (Bryman, 2006; Tashakkori and Teddlie, 2003). The two methods are combined during the data interpretation stage of this research. Qualitative and quantitative information for this thesis were collected and analyzed separately, but were linked together at the final and interpretive stages of this research to answer the overall thesis question.

In addition to using a mixed-methods approach, the research design presented in this thesis is typical of exploratory research. This thesis should be viewed as part of an emerging set of studies. The purpose of exploratory research is to gain insight into specific phenomena that are relatively unknown and are often the point of focus for inductive research (Palys and Atchison, 2008; p. 39, p. 41, p. 42). Although there has been a great deal of work on time-of-use rates, as demonstrated by the literature review in Chapter 2, there are very few recent and relevant studies on the impacts of time-of-use rates on lower-income and senior-headed households. The main goal of exploratory research is to produce inductively derived generalizations about a group or process, which can be used to establish grounded theory (Stebbins, 2001, p. 6). The process of exploratory research generally unfolds over the course of several studies which are linked together. As such, the weaknesses in sampling, validity and generalizability are corrected over time (Stebbins, 2001, p. 5). Many exploratory researchers favour a mixed-method approach (Stebbins, 2001, p. 12).

3.2 Elite-level interviews

Elite-level interviews (also known as expert interviews) are the primary qualitative approach undertaken for this thesis. Researchers use interviews for the purpose of discovering what individuals think or feel about an issue (Rubin and Rubin, 2005, p. 2). Elite-level interviews allow highly informed interviewees who have been known to participate in a certain situation to teach the researcher about what the problems, questions and situations are with respect to a given issue (Dexter, 1970, p. 5). Interviews with experts can provide researchers with an insider's account about the policy-making process (Dorussen, Lenz and Blavoukos, 2005). Qualitative interviews are particularly effective at describing social and political processes (Rubin and Rubin, 2005, p. 3).

During an interview with an expert, the researcher allows the participant to define the problem and to discuss what they regard as relevant (Dexter, 1970, p. 5). However, researchers must carefully assess the meaning and relevance of the interview based on the interviewee's frame of reference and social position by taking careful notes on the interviewee's personal biases and preconceptions (Dexter, 1970, p. 8). The strength of interviews is that they allow the participant to express multiple and complex points of view (Kvale, 1996, p. 7). Richards (1996, p. 200) states three advantages to conducting elite-level interviews:

1. "They can help in interpreting documents, or reports, particular if you gain access to the authors responsible for putting together a relevant document or report.
2. They can help in interpreting the personalities involved in the relevant decisions and help explain the outcome of events.

3. They can provide information not recorded elsewhere, or not yet available (if ever) for public release."

It is for the above mentioned reasons that elite-level interviews were selected as the primary qualitative research method for this study. The seven stages of an interview investigation are outlined by Kvale (1996, p, 88):

1. Thematizing – identifying the purpose of the interviews
2. Designing – planning the interview so that the intended information is obtained
3. Interviewing – conducting the interview using an interview guide and taking a reflective approach
4. Transcribing (or recording) – preparing the collected information for analysis
5. Analyzing – interpreting the information
6. Verifying – evaluating the generalizability, reliability, and validity of the interviews
7. Reporting – communicating the findings of the interviews

The rest of this section describes the first five stages outlined above. The sixth step will be reported in the discussion of results found in Chapter 5. The seventh step, reporting, is completed in preparing this thesis.

3.2.1 Interview purpose

Nine semi-structured elite-level interviews were conducted in June and July 2007 with Ontario professionals working in government, environmental non-profit, citizen advocacy, and affordable housing organizations that were known to work with lower-income and senior-headed households. The purpose of the elite-level interviews was to:

- Determine the factors that influence energy consumption behaviour in lower-income and senior-headed households;
- Illustrate how lower-income and senior-headed households participate in energy conservation and demand management programs;
- Predict the impact of the implementation of TOU rates on lower-income and senior-headed households;
- Explain how lower-income and senior-headed households are represented in energy conservation programs and policies in Ontario; and
- Justify the importance and relevance of this research topic.

3.2.2 Selection criteria and recruitment

Finding interview participants with relevant experience and knowledge on the topic of interest is crucial in order to produce credible results (Rubin and Rubin, 2005, p. 65). Credibility of the research is further enhanced by ensuring that interviews are held with individuals with varying perspectives (Rubin and Rubin, 2005, p. 67). For this research, interview candidates were selected from organizations based on one (or more) or the following criteria:

1. advocacy for lower-income households, seniors or tenant households;
2. focus on energy conservation in the residential sector; and
3. administration of energy conservation programs in Ontario.

The organizations were found using internet sources, relevant online publications, reports or conference proceedings. Recruitment of potential interview participants was done via telephone using a telephone interview script. In total, 25 potential interview participants were phoned during regular business hours. If a potential interview participant was not reached, a voice message was left and they were called back within a week. Some potential interview participants did not wish to participate, but instead referenced other colleagues within their organization. Some potential interview participants chose not to participate or were unavailable to participate in this study.

If the potential interview participant agreed to participate in the study, they were sent an information letter and consent form. The consent form asked for their permission to record the interview using audio equipment and for the use of anonymous quotes within research documents. This protocol was approved by the University of Waterloo's Office of Research Ethics, and documentation may be found in Appendix A. The organizations each participant represented were put into one of four categories: Government, Environmental Non-Profit, Citizen Advocacy and Affordable Housing.

3.2.3 Interview design

In this section, the rationale for the structure of the interviews, the types of questions, and the interview themes are discussed. The interviews were designed to be semi-structured, which is an approach that is commonly taken for elite-level interviews (Richards, 1996). Although specific questions were asked during each interview, care was given to ensure that the interview participants were able to express their opinions on the topic, even if the discourse was outside of the interview script.

Additionally, the interviews were scripted to only include open-ended questions. Palys and Atchison (2008, p. 171- 172) identify the strengths and weaknesses of open-end questions. Open-ended questions give the respondent an opportunity to respond to questions with a broad range of answers. Responses to open-ended questions more closely reflect the respondent's own concerns. In contrast, close-ended questions are more structured and restrict the range of responses by the respondent using

	Interview Themes	Theme Rationale	Questions
Theme 1	Brief description of the organization and the position/responsibilities of the participant within the organization.	Establishes credentials of the interview participant and justifies their participation in this study.	Q1 - What is your position and responsibilities within [name of organization]? Q2 - With respect to [name of organization], what services are provided to vulnerable[1] energy users?
Theme 2	The barriers to participation in the culture of energy conservation experienced by vulnerable households. The impacts/effects of current Ontario energy conservation programs and policies on vulnerable households in Ontario.	Identifies possible explanations for the energy consumption behaviour of lower-income and senior-headed households. Illustrates the extent to which lower-income and senior-headed households might be vulnerable to energy conservation policy.	Q4 - What do you expect are the major limitations or barriers in Ontario's current residential energy conservation programs, which might be experienced by vulnerable energy users? Q5 - What is your opinion about the effectiveness of Ontario's energy efficiency programs that are targeting social housing providers? Q6 - In your opinion, what criteria should be used for identifying appropriate candidates for participation in energy conservation programs targeting vulnerable households? Q9 - Is the situation in Ontario comparable to the situation in the northern US?
Theme 3	The expected effects of a time-of-use electricity rate structure on vulnerable households in Ontario.	Predicts the behavioural and financial impacts of time-of-use rates for electricity.	Q7 - How do you think the introduction of time-of-use rates will affect vulnerable households in Ontario? Do you think that these impacts will be different from the impacts experienced by the rest of Ontarians?
Theme 4	Important issues that should be considered when researching vulnerable energy consumers.	Identifies the participant's point-of-view on the topic and provides justification of the research topic.	Q3 - Why do you think it is important to advocate for vulnerable energy users? Q8 - In your opinion and experience, what are the most important features of energy conservation programs that target Ontario's vulnerable households? Q10 - In your experience, are vulnerable households concerned about energy efficiency and energy conservation?

[1] Please note: In the original proposal for this thesis, the term "vulnerable households" or "vulnerable energy users" was used to describe lower-income households (as defined by Statistics Canada's Lower-income Cut-Offs), households with one or more senior citizen or person with disabilities, single parent households or households that

Table 3. Interview themes, rationale and questions

researcher's pre-existing assumptions. Open-ended questions are the best way to discover a respondent's true opinion, particularly in exploratory research when the researcher may not be certain of possible responses. Open-ended questions, however, also have several noted weaknesses. The more open-ended the question, the more time is required and the better rapport required between interviewer and the respondent. Open-ended questions become very cumbersome with large samples. Analyzing and comparing the responses from different people is difficult because of the difference in context, responses and range of options.

Interview themes and the rationale are presented in Table 3. The themes and their rationale were designed to be consistent with the purpose of conducting interviews. Three interviews were conducted in-person at the participant's place of work, and six interviews were conducted via telephone. Handwritten notes were taken by the researcher, and seven interviews were recorded using an audio-tape. Two interviews were not audio-taped as a result of a technical malfunction of the recording equipment. Interviews lasted from about 30 minutes in length to about 90 minutes in length.

3.2.4 Interview analysis

Summaries of each interview were compiled into Contact Summary Sheets (see Figure 4) that were adapted from Miles and Huberman (1994, p. 51). The Contact Summary Sheets summarize the participant responses to each question. Participant responses were paraphrased. As Stebbins (2001, p. 45) explains, exact quotes from participants are not necessary in exploratory research as long as they are paraphrased to identify concepts. Each response was assigned a code to describe the aspect of the response. For example, if the participant mentioned that the ability to reduce electricity consumption was limited by the amount of money the household could invest, then the aspect would be 'upfront capital costs'. The Contact Summary Sheets were used for data reduction purposes. In other words, the Contact Summary Sheets were used to focus, simplify and transform the data into a manageable format for interpretation (Miles and Huberman, 1994, p, 10).

Contact Summary Sheet			
Organization:	Interview type: In person ☐ Telephone ☐	Interview Record: Notes ☐ Audio recording ☐	Interview Date:

are rented. The term "vulnerable households" was later replaced with "lower-income and senior headed households" after the completion of the interviews, because it was clearer terminology.

1. Question	Aspect
PARAPHRASED RESPONSE	CODE

Figure 4. Contact summary sheet template
Adapted from Miles and Huberman (1994, p. 10)

The second step in the analysis was to create a display to organize the complied interview content so that conclusions could be drawn. The displays were designed to be compact so that it was easier to determine relationships or inconsistencies in the responses (Miles and Huberman, 1994, p. 11). For this thesis, the interviews were summarized into a Conceptually Clustered Matrix (see Figure 5), which was adapted from Miles and Huberman (1994, p. 128). The matrix organized the coded responses related to each interview theme from each interview participant based on the type of organization they represented. This matrix allowed the comparison of how the cases (i.e., persons and settings) might be similar or different from each other in order to reveal explanatory concepts (Palys and Atchison, 2008, p. 310). Once clusters of individuals and variables of interest were isolated, the relationships among the concepts were examined.

Participant Category	Theme 1	Theme 2	Theme 3	Theme 4
Government				
Non-profit				
Citizen Advocacy				
Affordable Housing				

Figure 5. Conceptually clustered matrix template
Adapted from Miles and Huberman (1994, p. 11).

3.2.5 Limitations

There are several notable limitations when conducting interview with experts. First, elite-level interviews provide a subjective account of an event or issue, given that they are from only one person's point of view (Richards, 1996). Each interview is based on one person's experience within their own organization. Second, the sample of experts that were interviewed might not have opinions or points-of-views that are representative of their colleagues within their organizations or professions (Richards, 1996). Third, the interviews are based on the participant's memories of events, which can influence the reliability of the interview. It is possible that an expert might confuse what they have read or learned about an issue with what they have actually experienced (Richards, 1996). Fourth, the interviewer did not speak with persons that are from lower-income and senior-headed households (Rubin and Rubin, 2005, p. 65), therefore the perspectives might be biased.

To offset the limitations of qualitative elite-level interviews, an analysis of residential consumption was performed. This analysis is explained in the following section.

3.3 Analysis of residential electricity consumption

An analysis of residential electricity consumption was conducted to determine if lower-income and senior-headed households are responsive to the TOU price signal for electricity. The analysis was performed on electricity consumption data collected from 199 households in Milton, Ontario. The households that were studied came from four housing complexes: two affordable housing complexes and two seniors-only apartment complexes. The information collected from these groups included a demographic profile, physical and social household characteristics and hourly electricity consumption data. The dwellings chosen for this study were retrofitted with smart meters so that hourly interval data could be collected and analyzed. Further characteristics about the sample sites and the demographic and household characteristics are discussed in Section 3.3.1.

For this analysis, certain factors in the research design were not under the control of the researcher. Some of the aspects of the research design were determined based on requirements from the program partners and data availability. The lower-income and senior-headed households that were studied were not selected by the researcher. Instead, they were selected based on the Smart Meter retrofit schedule at Milton Hydro. Further, the dates when TOU rates were implemented in the households were based on policy which mandated that all households with Smart Meters are to be charged based on TOU rates. Despite these restrictions, every effort was made to ensure the reliability and validity of the results.

This section is divided into five sub-sections. First, the characteristics of the four housing complexes are described. Second, the methods for collecting individual household information are discussed. Third, the characteristics of the electricity consumption data are described. Fourth, calculations applied to the electricity consumption data and statistical analyses are described. Fifth, the limitations of this analysis are assessed.

3.3.1 Site characteristics

The characteristics of the four housing complexes are summarized in Table 4. Sites A and B represent senior-headed households. Both Site A and Site B offer rental units exclusively to seniors. Site A is the smallest housing complex used in this study and consists of only 13 households. Site C and Site D represent lower-income households. Both Site C and Site D are operated by non-profit affordable housing organizations. Site C solely consists of townhouse units, while Site D is a mixture of apartment and townhouse units. Site C is the largest complex used in this study, with 110 households. Site D is the only site where residents do not pay for their own electricity bill, and presumably, their electricity usage was included in their rent. All the households in this study were retrofitted with Smart Meters at the end of May 2007. The households were started on TOU rates at the end of June and early July 2007.

3.3.2 Household characteristics

Mail-out questionnaires were used to determine socioeconomic and structural information from each household. Mail-out questionnaires was chosen to collect the required information because they can cover large groups cheaply and maximize anonymity (Palys and Atchison, 2008, p. 156). The purpose of collecting socioeconomic and structural household information was so that the changes in electricity consumption patterns and individual responses to TOU rates could be evaluated based on the different housing characteristics. Information letters and feedback forms used for the questionnaire can be found in Appendix A.

Site A	Site B	Site C	Site D
• Senior-Headed	• Senior-Headed	• Lower-Income	• Lower-Income
• 12 Units • Individuals pay for own electricity bill • Seniors only • Retrofitted with smart meters May 25, 2007 • TOU rates started June 28, 2007	• 51 Units • Individuals pay for own electricity bill • Seniors only • Retrofitted with smart meters May 18 and May 22, 2007 • TOU rates started July 3, 2007	• 110 Units • Operated by a non-profit, affordable housing organization • Tenancy is restricted to families • Individuals pay for own electricity bill • 3 or 4 bedroom townhouses • Retrofitted with smart meters May 30 and May 31, 2007 • TOU rates started June 20, 2007	• 26 Units • Operated by a non-profit, affordable housing organization • Housing provider pays for electricity bill (included in rent) • 2 bedroom apartments and 3 or 4 bedroom townhouses • Retrofitted with smart meters May 25, 2007 • TOU rates started June 22, 2007

Table 4. Study site characteristics

Socioeconomic Characteristics	Structural Characteristics
Household income Number and age of persons in the household Number and age of persons at home during on-peak periods Age of household head Highest level of education achieved by someone in the household	Dwelling type (apartment/townhouse) Number of bedrooms Appliances, air conditioning and thermostat characteristics

Table 5. Household characteristics determined through questionnaire

The household characteristics that were determined through the household questionnaire are shown in Table 5. The rationale for selecting these characteristics comes from the literature review and is displayed in two tables found in Appendix B. A sample of the questionnaire is provided in Appendix C. A return, stamped envelope was provided with each questionnaire. The packages with the questionnaires were mailed to each household at the beginning of October 2007.

3.3.3 Electricity data characteristics

Each household was retrofitted with a Smart Meter during the second half of May 2007. The first meter reading on the TOU rate structure occurred between June 20, 2007 and July 3, 2007. Therefore, two to four weeks of time differentiated electricity consumption data were collected from the households while they were still being charged for electricity based on a two tiered, flat rate structure. Before the Smart Meters were installed, only non-interval electricity consumption data were available from each household during the billing period, which was approximately 30 days. Time-of-use electricity consumption data were collected from the beginning of June 2007 to the end of December 2007. Additional, non-interval electricity consumption data from June 2006 to December 2006 were also provided by Milton Hydro. The weeks that followed the installation of TOU meters were labelled 1 through 30. Week 1 started Sunday, June 3, 2007. The full week schedule can be found in Appendix D. The pre-TOU period is defined as the weeks before the households were started on TOU rates. The pre-TOU and post-TOU periods for each of the sites are shown in Table 6.

Site	First Smart Meter Read Date	Pre-TOU Period	Post-TOU Period
A	June 28, 2007	Weeks 1-3 June 3 – June 23, 2007	Weeks 4-30 June 24 – December 29, 2007
B	July 3, 2007	Weeks 1-4 June 3 – June 30, 2007	Weeks 5-30 July 1 - December 29, 2007
C	June 20, 2007	Weeks 1-2 June 3 – June 16, 2007	Weeks 3-30 June 17 - December 29, 2007
D	June 22, 2007	Weeks 1-2 June 3 – June 16, 2007	Weeks 3-30 June 17 - December 29, 2007

Table 6. First meter reading on TOU rates, and the pre- and post-TOU periods for each site

	Summer TOU rates		Winter TOU rates	
	May 1, 2007 – October 31, 2007		November 1, 2007 – April 30, 2008	
On Peak	$0.092/kWh	11am-5pm	$0.087/kWh	7am-11am 5pm-8pm
Mid Peak	$0.072/kWh	7am-11am	$0.070/kWh	11am-5pm

		5pm-10pm		8pm-10pm
Off Peak	$0.032/kWh	10pm-7am Weekends/holidays	$0.030/kWh	10pm-7am Weekends/holidays

Table 7. Time-of-use price schedule applicable in Milton, Ontario at the time of this study

Electricity consumption data from Milton Hydro were provided in hourly segments in Eastern Standard Time. When calculating the amount of electricity consumed, on-, mid- and off-peak, the hours were shifted appropriately to account for Daylight Savings Time between March and November. The rate schedules that were in place during the time of this study are shown in Table 7 and Table 8.

Summer Tiers		Winter Tiers	
May 1, 2007 – October 31, 2007		November 1, 2007 – April 30, 2008	
First 600 kWh Above 600 kWh	$0.053/kWh $0.062/kWh	First 1000 kWh Above 1000 kWh	$0.053/kWh $0.062/kWh

Table 8. Tiered price schedule applicable in Milton, Ontario at the time of this study

3.3.4 Calculations

The electricity consumption data collected from each household were manipulated in four ways to help determine the expected change in the electricity bill, conservation effect, and shift in electricity consumption in response to TOU rates. The four calculations are described below.

1. Will the households *benefit naturally* from the implementation of TOU rates? That is, are there any households that are expected to save money on their electricity bill given their electricity consumption patterns before the implementation of TOU rates? This calculation will use electricity consumption data collected after the installation of the smart meters and before the households were started on TOU rates (i.e., the pre-TOU period). This calculation will compare the cost of electricity under the tiered rate structure to what the cost of electricity would be under the TOU rate structure given the existing consumption patterns.

For each site, the unadjusted total kWh consumption was calculated, as well as the unadjusted electricity consumption that was used on-, mid-, and off-peak for the pre-TOU period. Since the first meter read date for the newly installed smart meters varied between sites, the length of the pre-TOU period varied between the sites.

Since tiered rates are associated with a monthly billing period and the billing periods are approximately one-month long, a calculation was performed to determine the expected electricity consumption for the billing period. The cost associated with tiered rates for the pre-TOU period was calculated using the following equation:

If $E < 600$, then $C_{Tier} = S \times \$0.053$

If $E > 600$, then $C_{Tier} = (S \times T_L/E \times \$0.053) + (S \times (E- T_L)/E \times \$0.062)$

Where,

E = kWh expected for month

Where, $E = S \times 30/D$

C_{Tier}= Tiered cost

S = Sum of unadjusted total kWh consumed over the pre-TOU period

D = Days in pre-TOU period

T_L = kWh in lower tier (i.e., 600 kWh during the summer)

The costs that would have been associated with TOU rates during the pre-TOU period were also calculated for the pre-TOU period using the following equation:

$C_{TOU} = (c_{on} \times \$0.092) + (c_{mid} \times \$0.072) + (c_{off}\ x\ \$0.032)$

Where,

C_{TOU} = TOU cost during the pre-TOU period

c_{on} = kWh consumed on-peak during the pre-TOU period

c_{mid} = kWh consumed mid-peak during the pre-TOU period

c_{off} = kWh consumed on-peak during the pre-TOU period

The difference between the tiered costs and the expected TOU costs ($C_{TOU} – C_{Tier}$) was calculated for each household. Positive differences indicate that the expected TOU costs would be greater than the actual tiered costs, and thus indicates that the household is not expected to 'benefit naturally' under the new TOU rate regime. Similarly, negative differences indicate that the expected TOU costs would be less than the actual tiered costs, and thus indicates that the household would be expected to 'benefit naturally' under the new TOU rate regime.

2. Do the households conserve electricity upon the implementation of TOU rates? This calculation will use electricity consumption data collected after the households were retrofitted with a smart meter and non-interval monthly electricity data from 2006. This calculation will compare the weather adjusted total electricity consumed during the 2006 billing period to weather adjusted total of electricity that was consumed during the 'corresponding 2007 billing period'.

The ‘corresponding 2007 billing period’ was simply determined as follows: if the 2006 billing period was 27/07/2006 to 28/08/2006, then the corresponding 2007 billing period was 27/07/2007 to 28/08/2007. Since the data collected are from the months of June to December, billing periods 7 to 12 are applicable. Appendix E shows the 2006 billing periods for the units at each site. Note that, if a participant moved during the course of the study, only the relevant data were utilized in this analysis. For example, if tenants change in July 2006, then only the months corresponding to August, September, October, November, and December were evaluated.

The amount of electricity consumed during each corresponding billing period was weather adjusted by an external expert from Hydro One Networks Incorporated using a proprietary econometric model. The weather adjusting removed variations in the data resulting from differences in weather (daily temperature, humidity, cloudiness) between the 2006 and 2007. Since the weather adjusting process for the 2007 interval data yielded a daily average of amount of electricity consumed in one hour, the weather adjusted total daily electricity consumption was calculated by:

$$WA_{Total} = WA_{Ave}/Raw_{Ave} \times Raw_{Total}$$

Where,

WA_{Total} = Weather Adjusted total daily consumption

WA_{Ave} = Weather Adjusted daily average amount of electricity consumed in one hour

Raw_{Ave} = Unadjusted daily average amount of electricity consumed in one hour

Raw_{Total} = Unadjusted total daily consumption

3. Do the households shift the time when they consume electricity upon the implementation of TOU rates? That is, do the households either shift electricity consumption to off-peak periods or reduce electricity consumption during mid-peak and on-peak periods? This calculation will use electricity consumption data collected after the households were retrofitted with a smart meter. The proportion of electricity consumed weekly during on-, mid- and off-peak will be plotted graphically over time to determine if the households changed electricity consumption patterns.

For this calculation, the weeks with holidays were removed because there would naturally be a greater proportion of electricity consumed during off-peak periods. The Weeks that were excluded are Week 5 (Canada Day), Week 10 (August Civic Holiday), Week 14 (Labour Day), Week 19 (Thanksgiving), and Week 30 (Christmas).

4. Do TOU rates change the costs of the household electricity bill? This calculation will use electricity consumption data collected after the households were started on TOU rates. This calculation will compare the cost of electricity under the TOU rate structure to what the cost of electricity would have been under the tiered rate structure. The calculations used for this question are the same as the calculations noted for Question 1, except the calculation was done on a weekly basis for during the post-TOU period. Therefore, to calculate the weekly costs associated with tiered rates the following calculation was used:

If $E < T_L$, then $C_{Tier} = S \times \$0.053$.

If $E > T_L$, then $C_{Tier} = (S \times T_L/E \times \$0.053) + (S \times (E - T_L)/E \times \$0.062)$

Where,

E = kWh expected for week

Where, $E = S \times 30/7$

C_{Tier}= Tiered cost

S = Sum of unadjusted total kWh consumed over the week

T_L = kWh in lower tier (i.e., 600 kWh during the summer, 1000 kWh during the winter)

Likewise, the costs associated with TOU rates were calculated:

$C_{TOU} = (c_{on} \times R_{on}) + (c_{mid} \times R_{mid}) + (c_{off} \text{ x } R_{off})$

Where,

C_{TOU} = TOU cost

c_{on} = kWh consumed on-peak during the week

c_{mid} = kWh consumed mid-peak during the week

c_{off} = kWh consumed off-peak during the week

R_{on} = On-peak rate (i.e., $0.092 during the summer, $0.087 during the winter)

R_{mid} = Mid-peak rate (i.e., $0.072 during the summer, $0.070 during the winter)

R_{off} = Off-peak rate (i.e., $0.032 during the summer, $0.030 during the winter)

The difference between the expected tiered costs and the TOU costs ($C_{TOU} – C_{Tier}$) was calculated for each household. Positive differences indicate that the household paid more under TOU rates than they would have paid under tiered rates. This calculation does not take into account any savings that may have resulted from a conservation effect associated with the implementation of TOU rates.

3.3.5 Limitations

The participants in this study do not own their own households and may not be representative of the situation experienced by lower-income and senior-headed households renting from private landlords or living in owner-occupied households. The occupants of the household were sent a letter in the mail on May 23, 2007 explaining TOU rates before they switched over to the new price structure. The letter may have influenced the behaviour of the occupants before the switch to TOU rates in preparation for the change. Only a short period of "pre-TOU" hourly electricity consumption data were available for each household. This period may not be representative of behaviour throughout the year. This analysis assumes that all changes in electricity consumption can be fully attributed to the implementation of TOU rates and does not account for other factors that may influence changes in electricity consumption patterns, for example, any changes or retrofits to the building, or changes as a result of a new living situation (e.g., an occupant going back to school or getting a new job). These questions were not asked through the household questionnaire. This analysis only evaluated impacts over a six month period. Further, this analysis only evaluated cost differences as a result of the commodity charge. Any additional distribution service charges that may have arisen as a result of the implementation of TOU rates were not considered in this analysis. As shown later in this thesis, there were some changes to the non-competitive electricity charges. These charges are shown in Table 20 on page 64.

Chapter 4: Qualitative and quantitative results

In this chapter the results of the research are presented. In Section 4.1, the interviews with relevant industry experts are summarized and the emerging themes are identified. In Section 4.2, the results of the analysis of electricity consumption data are described and evaluated in association with data that were collected through household questionnaires.

4.1 Results from elite-level interviews

In total, nine interviews were completed. Three interviews were completed with representatives from government agencies, two were completed with representatives from environmental non-profit organizations, two were completed with representatives from affordable housing agencies, and two were completed with representatives from citizen advocacy organizations. The interviews took place in June and July of 2007. As described in section 3.2.4, a contact summary sheet was created for each interview, recording the paraphrased responses to questions and the coded aspects of the response.

For example, if a participant said "this type of program requires a participant to invest money", then the coded aspect would be "upfront costs". Or, if a participant said "tenants don't own their own appliances", then the coded aspect would be "appliance ownership". Likewise, if a participant said "tenants don't have incentive to invest because they don't own the property", then the coded aspect would be "tenant/landlord relationship".

To summarize the contract summary sheets, a conceptually clustered matrix was created as described in section 3.2.4. The coded aspects were grouped together based on the "Theme of the question" and the participant category (i.e., government, non-profit, etc). The major results and findings are discussed below. In the summaries to follow, paraphrased responses are denoted by quotation marks which are then labelled:

G – Government

NP – Non-profit

CA – Citizen advocacy

AH – Affordable housing

4.1.1 Theme one

As a reminder (refer to Table 3), the first theme simply provides a brief description of the organizations that were involved in the study. Questions were asked to help establish the credibility of the interview participant. Participants were asked about their responsibilities within their organization, and the services that were provided to lower-income and senior-headed households. The results from this first theme are shown in Table 9.

Government	Non-profit	Citizen Advocacy	Affordable housing
Affordable housing program Analyst Building code Energy efficiency programs Indirect Low income programs Manager Partnership	Advocacy Affordable housing program Communication Coordination Energy efficiency programs Executive Director Indirect Information Policy analyst Policy direction Program development Reporting Representation Smart metering Training	Advocacy Consultation Information Lawyer Policy monitoring Representation Tenant advocacy	Communication Director Environment Indirect Information Research Sector development coordinator

Table 9. Theme one – conceptually clustered matrix

The participants in the government category represented people who work on government initiatives, including low-income programs, energy efficiency programs, and affordability programs. These government agencies often work in partnership with other organizations to promote energy conservation measures in lower-income households. Some of these participants only had an indirect relationship with lower-income and senior-headed households through their programs. The position these participants held within the organization was at the managerial or analyst level.

The participants from the non-profit category represented people who work for non-profit organizations that are responsible for administering programs for affordable housing or energy efficiency. These non-profit organizations play a key role in communications and reporting of issues related to lower-income and senior-headed households and energy efficiency, and coordinating of programming activities, and program development. Some of these participants only had an indirect relationship with lower-income and senior-headed households, however, their experiences seemed to be more direct than the participants from government agencies. The positions these participants held within their organization ranged from the analyst to the executive director level.

The participants from the citizen advocacy category represented people who advocate for the needs of lower-income and senior-headed households or tenants. These organizations provide either legal services to other non-profit organizations or consultancy services on issues related to lower-income and senior-headed households. The participants in this category actively monitor policy and regulation that could impact lower-income and senior-headed households. The positions these participants held within their organization were either legal services or consultancy services.

The participants from the affordable housing category represented people who work for organizations that represent affordable housing providers. These participants were responsible for researching information related to energy efficiency and other environmental issues in affordable housing. Generally speaking, these participants had an indirect relationship to lower-income and senior-headed households. The positions the participants held within their respective organizations were sector development coordinator and executive director.

4.1.2 Theme two

As a reminder (refer to Table 3), the second theme examines the barriers to participation in energy conservation. Questions were asked to help identify different types of energy conservation behaviours and the extent to which lower-income and senior-headed households might be impacted by energy conservation policy.

The full results from this second theme are shown in Table 10**.** A number of barriers were identified by representatives in most of the participant categories, including:

- Appliance ownership/discretionary electrical loads
- Awareness
- Disengagement
- Language barriers
- Tenant/landlord relationship
- Upfront capital costs

Lower-income and senior-headed households were thought to have limited appliance ownership. Limited appliance ownership means that lower-income and senior-headed households were expected to have limited discretionary electrical loads (e.g., loads that they could turn off). The consumption of electricity in this demographic is expected to be lower than more affluent households, and therefore they would be less able to participate in energy conservation programs that call for the replacement of energy inefficient appliances or the use of appliances during off-peak periods. Lower-income and senior-headed households may not have access to air-conditioning, laundry machines or dishwashers.

One participant noted “a lot of people don’t have air-conditioning and can’t afford it in the first place” (G). Similarly, another participant commented that in order to participate in some energy conservation initiatives, a participant would “need to have air-conditioning – truly vulnerable peoples don’t have these” (AH). Likewise, a participant noted that in the case of tenants, “the landlord owns the appliance" (CA) and they would therefore be unable to upgrade their appliances. The same participant noted that "vulnerable consumers do not have large load devices that can be turned off or moved" (CA).

Government	Non-profit	Citizen Advocacy	Affordable housing
Appliance ownership	Accessibility	Ability to pay bill	Appliance ownership
Awareness	Advocacy	Advocacy	Awareness
Building measures	Behavioural norms	Affordability	Broaden criteria
Capability and energy management	Broaden criteria	Appliance ownership	Building measures
Capacity building	Children	Appropriate marketing	Disengaged
Communication	Deep measures	Building measures	Existing programs
Depth of measures	Distributing savings	Buy-in	Few programs for low-income
Different regulation	Education	Children	Good results
Electricity service charges	Electricity service charges	Conservation programs	Incentives
Eligibility	Eligibility	Control	Include landlords
Existing programs	Emergency funds	Difficulty installing	Low-income home owners
Free-riders	Environment	Discretionary load	Need based
Incentives	Existing programs	Disengaged	Needs attention
Income threshold	Financial vulnerability	Energy poverty	Payback
Less experience in Ontario	Higher prices in the US	Environmental conscious	Property ownership
Limited experience	Home during day	Existing programs	Response is good
Limited participation	Inclusiveness	Financial impacts	Self identify
Limited tracking	Less experience in Ontario	Financial incentives	Short term
Low-income homeowners	Long term	Home during day	Subsidies
Marketing	Low priority	Indirect	Sufficient funding
Minimal savings	Low uptake	Language barriers	Sustainability
Need based	Need to prevent emergency	Less experience in Ontario	Upfront costs
Not substantial enough	Patchwork of programs	Poor infrastructure	Working poor
Only a pilot	piggy back on federal programs	Reduce Bills	
Political	Portion of income	Rent increase	
Prioritize	Rate affordability	Seniors health	
Seems comprehensive	Reduce Bills	Short term	
Seniors health	Rent increase	Smart meters	
Stop gap measures	Safety hazards	Social safety net	
Targeting	Seniors	Suspicion	
Tenant/Landlord relationship	Seniors health	Tenant advocacy	
Turn-key	Single moms	Tenant/Landlord relationship	
Upfront Cost	Social housing	Upfront costs	
Value added			

	Social marketing Sufficient funding Tenant/landlord relationship Turn-key Upfront costs		

Table 10. Theme two - conceptually clustered matrix

Related to this, another participant indicated that lower-income houses can feel disengaged from the conservation initiatives because “they felt like they were doing all that they can” (AH). This sentiment was echoed by another participant who stated that “often those people don't have a voice” (NP).

Making a similar point, one participant noted that lower-income and senior-headed households “are people that can least afford to pay rising energy costs and frequently live in the draftiest housing with out of date heating equipment” (NP).

The tenant-landlord relationship was frequently noted by participants when discussing barriers to conservation. If a tenant is not responsible for paying their own electricity bill, then they do not have a direct financial incentive to conserve electricity. On the other hand, if the tenant is responsible for their own electricity, the landlord does not have an incentive to invest in energy saving appliances or weatherization. One participant stated that a "landlord may not have any interest in replacing an appliance that's still working" and if they do the "landlord doesn't have to pass on the energy savings" (CA). Another participant said curtly that "landlords in Ontario have a nasty habit - every dime that they spend they want to pass a quarter of the costs to tenants" (CA).

Predictably, the most frequently mentioned barrier to energy conservation was upfront capital costs. Not having upfront capital limits the household's ability to invest in new appliances and to make other energy efficiency retrofits. One participant noted that, even with programs that provide free appliance disposal, "if you get rid of your old fridge, you defer cost of disposal, but not the cost of the new appliance" (CA). Another participant commented that "rebates assume that you have the money up front, if you're not in the position to borrow money then you are trapped" (G). Likewise, another participant stated that if a person is able to participate then "over the next ten years you'll save money, but to get into the program, you need to have upfront costs" (CA). This comment was echoed by another participant who stated that energy conservation programs "rely on the homeowner's ability to pay for audits, retrofits, and to finance - for the most part, this leaves low income earners in a tough situation" (AH). Likewise, another participant commented that limited upfront capital costs "affect all households - but are particularly strong for low income households where there is no money to invest in retrofits" (NP).

Another barrier to conservation described by the interview participants was awareness of programs and issues related to energy conservation. Generally speaking, the participants felt that often lower-income and senior-headed households did not have access to sufficient information that would allow them to reduce or to shift electricity usage. The participants noted that although the person may want to do the right thing, they may not know exactly what to do. For example, one participant highlighted the need to "inform individuals and affordable housing proponents that there are financial assistance programs out there for energy efficiency … communication and marketing is an important aspect" (G). Related to this are language barriers. Language barriers were noted by both participants from citizen advocacy organizations. Simply put, one participant stated: "vulnerable consumers tend to have a lot of language barriers" (CA), while the other stated "in terms of understand-ability, programs need to be put out in plain language, understandable by people whose first language isn't English" (CA).

The interview participants were asked to suggest criteria that could be used for identifying appropriate candidates for participation in energy conservation programs targeting lower-income and senior-headed households. Many stated that energy conservation initiatives should leverage social assistance programs (e.g., Ontario Works). One participant stated that using existing programs "eliminates costs, therefore you don't have to create another system to identify people" (CA). However, in contrast to this point-of-view, another participant suggested that by only using existing social assistance programs the ability to identify the working poor who could benefit from conservation initiatives is reduced and stated "there is a lot of working poor who are overlooked in favour of people already in other programs" (AH).

4.1.3 Theme three

The next theme that was evaluated dealt specifically with the implementation of TOU rates (refer to Table 3). Participants were asked to comment on the expected impacts of TOU rates on lower-income and senior-headed households. The full results from this third theme are shown in Table 11.

Government	Non-profit	Citizen Advocacy	Affordable housing
Appliance ownership Awareness Away during the day Children Cost of meters Empowerment Energy efficiency programs Home during day Minimal impact Minimal savings Seniors	Affordability Appliance ownership Building measures Children Control Discretionary load Electrical heated Home during day Impact unsure Minimal conservation Reduce peak demand Seniors health	Bill increase Children Discretionary Loads Disproportionate Fairness Home during day Overlapping demographics Risky Seniors Tenant/Landlord relationship Tenants concerned	Ability to respond Appliance ownership Bill increase Disproportionate Electrical heating Energy theft Home during day Inflexible Little GHG reductions Minimal savings Reduce need for new supply Shift workers Tenant/Landlord relationship Working poor

Table 11. Theme three – conceptually clustered matrix

The findings of the interviews suggest that there are mixed opinions amongst the interview participants about the financial implications of TOU rates on lower-income and senior-headed households. Some interview participants suggested that the impact would be very dramatic and very negative while others suggested that the impact would be very minimal, or that there would be positive impacts. Generally speaking, TOU rates are thought to empower those with the ability to control their electricity consumption, but penalize those who are at home during the day. For example, one participant noted that "the whole point is the price signal - it only works if the people that it affects have control over their spending decisions – if you are a tenant you don't" (NP).

Senior-headed households and lower-income families with children were expected to be at greatest risk of bill increases under TOU rates because they are likely to be at home during on-peak periods when the cost of electricity is the greatest or they may have temperature requirements for health reasons. For example, one participant said "TOU rates may end up penalizing people - retired people, or someone on social assistance with three kids at home" (G).

Lower-income households were thought to be less likely to have a "discretionary electrical load", which they would be able to move to off-peak periods. For example, a participant stated that "low income or fixed income seniors, may be at home for most of the day… what can they actually shift… how many vulnerable households have dishwashers?" (CA). Another participant said offhandedly "what's a low income person going to do... unplug their refrigerator?" (G).

In addition, the working poor are thought to have less flexibility in their schedule to take advantage of off-peak rates. One participant noted that TOU rates could "be more accessible to people who have more flexible time, likely those with higher incomes" (AH). Another participant said "if you're a mom with two kids, you're not going to be cooking at 10pm, and the kids will be doing their homework with the lights on" (NP).

One participant was concerned that over time TOU rates could disproportionately impact lower-income and senior-headed households. This participant stated that "if everyone who can move their load away from the highest cost area does, everyone else who is left is going to be paying the price… those are the people who can't move their load, and would more likely be vulnerable consumers" (CA). Echoing this concern, another participant stated that "the price for potential losers may be too much to pay" (CA).

Another participant was concerned that TOU rates would further exacerbate the tenant-landlord relationship and the split incentive for investment in energy conservation. This participant stated "it will be even less of an incentive for the landlord to do anything which is why we are really worried about it - if all the costs go directly to the tenants, where is the incentive for the landlord to then purchase an energy efficient fridge or upgrade insulation?" (NP).

Some interview participants thought that TOU rates are a good government initiative, however, they thought that TOU rates are not very likely to save lower-income and senior-headed households very much money. For example, one participant stated that TOU rates may be "good overall in terms of greenhouse gas reduction for the province… but for this population, it's going to be a big saver - if it doesn't save money, significant money to make a difference, they won't benefit" (G). On the other hand, another participant stated that "there are things you can do to reduce energy use that are a better investment than smart meters" (NP).

4.1.4 Theme four

As a reminder (refer to Table 3), the fourth theme was intended to explore other important issues that should be considered. This series of questions is to identify the participant's point-of-view on the topic and provide justification for this research topic.

Government	Non-profit	Citizen Advocacy	Affordable housing
Accessibility	Audit	Advocacy	Ability to participate
Affordability	Basic energy needs	Affordability	Accessibility
Appropriate language	Behavioural norms	Appropriate marketing	Affordability
Behavioural norms	Building measures	Awareness	Audits
Bill increase	CBSM	Behavioural norms	Awareness
Bill payment	Comfort	Buy-in	Behavioural norms
Building measures	Conservation culture	Children	Bill increases
Cold climate	Contractor availability	Conservation programs	Building measures
Comfort	Disengaged	Cooking	Buy-in
Control	Education	Cost allocation	Choices
Deep measures	Emergency assistance	Enthusiasm	Confusion
Demand savings	Environmental conscious	Environment	Deep measures
Education	Environmental policy	Environmental conscious	Education
Empowerment	Free-riders	Inclusiveness	Empowerment
Environmental conscious	Inclusiveness	Positive feedback	Greenhouse gas
Immediate problem	Legal clinic	Rate advocacy	Improving health
Incentives	Low-income homeowners	Rate fairness	Indirect
Limited choices	Positive feedback	Tenant advocacy	Less environmental consciousness
Long term	Poverty	Tenant/landlord relationship	Limited time
Major pressure	Program input	Upfront costs	Political
Need based	Rate assistance		Portion of income
Political	Shelter costs		Property ownership
Positive feedback	Social policy		Saving money
Rate advocacy	Sufficient funds		Shared interest
Reduce Bills	Turn-key		Strategies
Reduce consumption	Upfront costs		Subsidy
Severity of impact			Tenant/landlord relationship
Social marketing			Upfront costs
Upfront costs			Variable costs
			Varied concern

Table 12. Theme four – conceptually clustered matrix

The full results from this fourth theme are shown in Table 12**.** A number of factors were identified by many of the participant categories, including:

- Affordability, upfront costs, rate advocacy

- Basic energy needs
- Behavioural norms and environmental consciousness
- Buy-in, positive feedback and education
- Deep measures, building measures and long term measures

The most notable factors that emerged were affordability, upfront capital costs and rate advocacy. Lower-income and senior-headed households were thought to be "more likely to weigh immediate capital costs more heavily than they would the long term benefits… it doesn't matter if they are going to save some money over the course of two years if they can buy food today" (CA); therefore, they would be less likely to invest in energy saving measures. Another participant noted that "vulnerable people live in poorer housing conditions" and are "hostage to energy prices… energy competes with other necessities" (G). This sentiment was repeated by another participant, who stated that lower-income and senior-headed households need to make "choices between utilities and other things we take for granted" (AH).

Another participant noted that fixed and predictable costs are easier for lower-income and senior-headed households to manage and budget for. This participant called energy costs "variable costs" and stated that "it's the variable costs that will kill you over time - and energy is one of the biggest ones" (AH). In general, the participants seemed to feel that it was important for lower-income and senior-headed households to be able to meet their basic energy needs. For example, one participant stated that it was important to "ensure that everyone will be able to access their basic energy needs without going into crisis" (NP). Another participant stated that it was important to provide energy "at a fair and reasonable price to lower-income groups" (G).

Several interview participants noted that the best way to ensure on-going conservation within lower-income and senior-headed households was to ensure that the measures implemented within the households were deep measures that improved the dwelling more permanently. For example, one participant noted that it was important to "capture all the energy savings – the measures implemented should be based on what is actually going to achieve the most amount of savings" (NP). Another participant noted that "a program should to improve the dwellings once and for all… permanent changes and upgrades… to ensure that they are getting lower energy costs from now on" (G). It was also noted that these building measures may not be as easy to achieve: "It is easier to replace appliances and lighting… harder to do building upgrades" (AH).

Besides building factors, other factors that were noted that influence electricity consumption in lower-income and senior-headed households are behavioural norms and environmental consciousness. For example, some participants feel that lower-income households (especially tenants) might not be motivated to conserve because they believe that their neighbours do not conserve electricity. One participant suggested that lower-income households might think "why should I freeze in the dark when my neighbours are sitting with their windows open?" (NP). Other participants suggested that there is a varying degree of norms within the group - "some are responsive, some are energy hogs" (AH). Although lower-income and senior-headed households might be limited financially, they are "receiving the conservation messaging that is going on in the media and other places" (CA). However, a lower-income household is "not going to be a typical 'greeny'... if you can't pay your bill that's primary in your mind" (G). Participants suggest that financial concerns were greater than environmental concerns in this demographic group. For example, one participant stated: "I'm not saying that they aren't concerned with environmental issues like the rest of us - they are concerned, but being able to pay their bills is most important" (G).

In addressing energy conservation, the interview participants recognized that there was a need to encourage "buy-in" from the local community. For example, "if you get people enthused about it in the community, you identify the barriers and start addressing them" (CA). Another way to get buy-in from the local communities to give the community praise when they are engaging in behaviours that are positive: "Need to give great praise – reinforce positively, not finger-wagging" (NP).

Education was another factor identified. The households may not understand the best way to conserve electricity or the best way to find resources for help. One participant said simply "green stuff is confusing" (AH). Another participant suggested that people often do not consider electricity usage as an environmental issue and stated that we need to "need to link energy and the environment more clearly" (G).

Overall, the sentiment was that lower-income and senior-headed households should be considered when developing energy policy. This opinion was captured by one participant in particular who said "we should ensure that the most vulnerable are able to participate in our society and the culture of conservation - but they don't have the financial tools for involvement" (NP).

4.1.5 Summary of qualitative findings

The findings from these elite-level interviews provide important insights into the lives of lower-income and senior-headed households. Some of key findings from these interviews are summarized below:

- Appliance availability seems to be an important factor that would impact a household's ability to conserve electricity and could also impact their ability to move electricity use towards off-peak periods. Lower-income and senior-headed households are expected to have fewer appliances and fewer discretionary electrical loads;
- The tenant-landlord relationship influences the electricity conservation behaviour of renters and property owners. If the landlord pays for electricity, then the tenant has little

incentive to conserve electricity. If the tenant pays for electricity, then the landlord has less of an incentive to invest in energy efficiency;

- Predictably, upfront capital costs were identified as a major barrier to energy conservation. Lower-income and senior-headed households simply cannot afford to make investments that have long-term payback periods.

Interview participants had varying opinions on the potential impacts of TOU rates on lower-income and senior-headed households. The key findings - and contradictions - are summarized below:

1. TOU rates can be empowering because they give lower-income and senior-headed households control over their electricity bill. Some participants, primarily from government categories, felt that TOU rates would provide lower-income and senior-headed households with an opportunity to reduce their electricity bill. Households could participate simply by shifting the time when they consume electricity.

2. There will be minimal impacts and minimal savings. Some participants felt that even if lower-income and senior-headed households were able to shift or conserve electricity during on-peak periods, the savings that would be realized would be minimal. Further, they felt that lower-income and senior-headed households would not likely see a reduction in the amount of electricity consumed during on-peak periods.

3. Seniors will be the most impacted by TOU because they are home during the day. Senior-headed households were thought to be more affected by TOU rates than other demographics. For various reasons, they are more likely to be home during the day (e.g., retired or illness); therefore they may be unwilling or unable to shift or conserve electricity during on-peak periods.

4. Uncertainty about the potential impacts. Many interview participants were concerned about the potential for negative impacts, although they were uncertain to what extent negative impacts would be observed.

5. TOU rates pose a great financial risk to lower-income and senior-headed households. Some interview participants were convinced that there would be a real, negative financial impact on lower-income and senior-headed households as a result of the implementation of TOU rates.

6. Tenants are concerned that costs will be passed down to them. Some of the interview participants, particularly those working in citizen advocacy organizations, were concerned that the increase in costs that resulted from the implementation of TOU rates would be passed down to tenants.

7. TOU rates will result in little greenhouse gas savings. Primarily, some interview participants did not believe that TOU rates would motivate people to change their electricity consumption behaviour. In other words, TOU rates would not motivate people to shift or conserve electricity during on-peak periods.

8. TOU rates will reduce the need for new supply. Contrary to other opinions, some participants thought that TOU rates would have a positive impact on the electricity sector. They believed that TOU rates would effectively reduce the amount of electricity consumed during on-peak periods and would reduce the amount of supply needed during on-peak periods.

9. The working poor will be the most impacted because they have inflexible schedules. This demographic group were thought by many participants to have inflexible work schedules because they are more likely to not control the times of day that they are home.

These qualitative findings help set the context for the quantitative portion of this research. The impacts of TOU rates are generally unknown, even by experts working within the sector. The remainder of this chapter will focus on the quantitative aspects of this study.

4.2 Analysis of electricity consumption

As a reminder, a quantitative analysis of residential electricity consumption was conducted to determine if lower-income and senior-headed households are responsive to the TOU price signal for electricity. Electricity consumption data from four sites in Milton, Ontario – two seniors-only apartments and two affordable housing units – were used to answer four key questions:

1. Will the households *benefit naturally* – that is, in the absence of behavioural change – from the implementation of TOU rates?
2. Do the households conserve electricity upon the implementation of TOU rates?
3. Do the households shift the time when they consume electricity upon the implementation of TOU rates?
4. Do TOU rates change the costs of the household electricity bill?

Note that to answer these questions, average data from each of the four sites were use. It is, however, recognized that there is a risk in presenting average data, as there may be outliers within the data that are not recognized. For this reason, scatter plots of the data from the calculations performed are available in Appendix F. This appendix was developed to acknowledge that there are some outliers within the data.

To supplement this analysis, questionnaires were sent to all households involved in this study. The data collected from the questionnaires were used to determine which characteristics have the greatest influence on the ability of households to respond to TOU rates or their ability to benefit from TOU rates.

This section is divided in three sub-sections. First, the results of the questionnaires are summarized. Second, the results from the four key calculations are described in detail. Third, additional findings that compare the results from the questionnaires and the four key questions are presented.

4.2.1 Results from questionnaires

Out of 199 questionnaires mailed to participants, 42 were returned, giving an overall response rate of 21%. No questionnaire was returned indicating that there is ‘no such occupant’. A total of five questionnaires (38%) were returned from Site A, 24 questionnaires (48%) were returned from Site B, 13 questionnaires (12%) were returned from Site C, and no questionnaires (0%) were returned from Site D. The response rate from the seniors housing units was 46% (n=29) and the response rate from the affordable housing units was 9% (n=13).

Responses from the senior-headed households showed that the average year born was 1927, the oldest respondent was born in 1917 and the youngest respondent in 1941. The median year born was 1925. With one respondent giving no response, the questionnaires indicated that there were three people in their sixties, fourteen people in their seventies and twenty-one people over eighty (the total represent the number of people within all the households). Eighteen households had one person, and ten of the households had 2 people. There were 16 one-bedroom units and 13 two-bedroom units. Everyone that lived in the home was home during peak periods. The after tax income levels of the senior-headed household are shown in Figure 6.

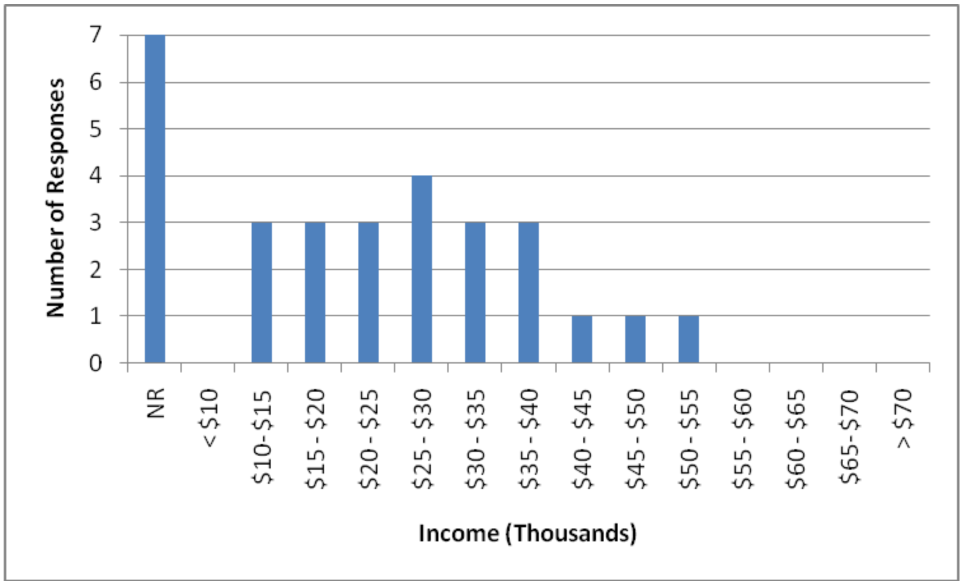

Figure 6. Results from questionnaire – after tax income level in the senior-headed households
NR – No response.

Education in the senior-headed households is shown in Figure 7. Three respondents filled out the questionnaire incorrectly by checking two categories. Instead of choosing the highest level of education achieved in the household, it appears the the participants indicated the education level of each member of the household. In these cases, the 'highest' category was taken. University was taken as 'higher' than techncial college. Appliances available in the senior-headed households are shown in Table 13**.**

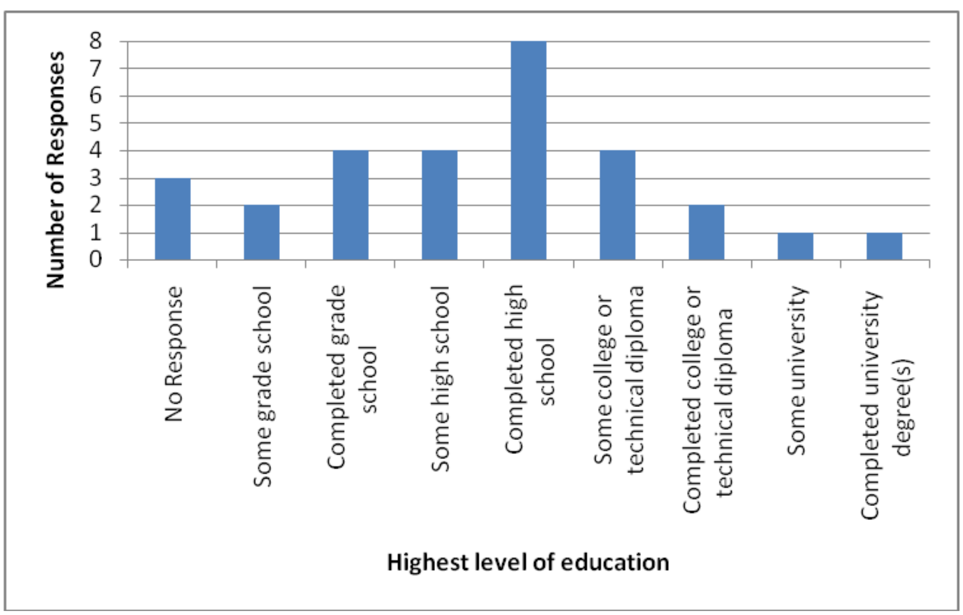

Figure 7. Results from questionnaire – education level in senior-headed households

Appliance	Number of responses	Percent of responses
Electric Stove	29	100%
Electric Dishwasher	13	45%
Electric Laundry Machine	25	86%
Electric Drying Machine	25	86%
Programmable Thermostat	21	72%
Freezer	11	38%
Central Air Conditioning	27	93%
Air Conditioning window unit	1	3%

Table 13. Results from questionnaire – appliance ownership in senior-headed households

Responses from the affordable housing units showed that the average year born was 1967, the oldest respondent was born in 1940 and the youngest respondent in 1982. The median year born was 1969. The remaining results from the other questions are shown in Table 14.

Characteristic	Result
Number of units with four bedrooms	3
Number of units with two bedrooms	10
Number of households with one person	1
Number of households with two people	5
Number of households with four people	6
Number of households with 5 people	1
Number of households with at least one child under ten	5
Number of households with at least one person between 11-20 years old	5
Number of households with at least one person between 21-30 years old	9
Number of households with at least one person between 21-30 years old	4
Number of households with at least one person between 31-40 years old	5
Number of households with at least one person between 41-50 years old	5
Number of households with at least one person over 80 years old	1
Number of households with at least one child under ten at home during on-peak periods	3
Number of households with at least one person between 11-20 years old at home during on-peak periods	7
Number of households with at least one person between 31-40 years old at home during on-peak periods	3
Number of households with at least one person between 41-50 years old at home during on-peak periods	2
Number of households with at least one person over 80 years old at home during on-peak periods	1

Table 14. Questionnaire results describing the affordable housing units

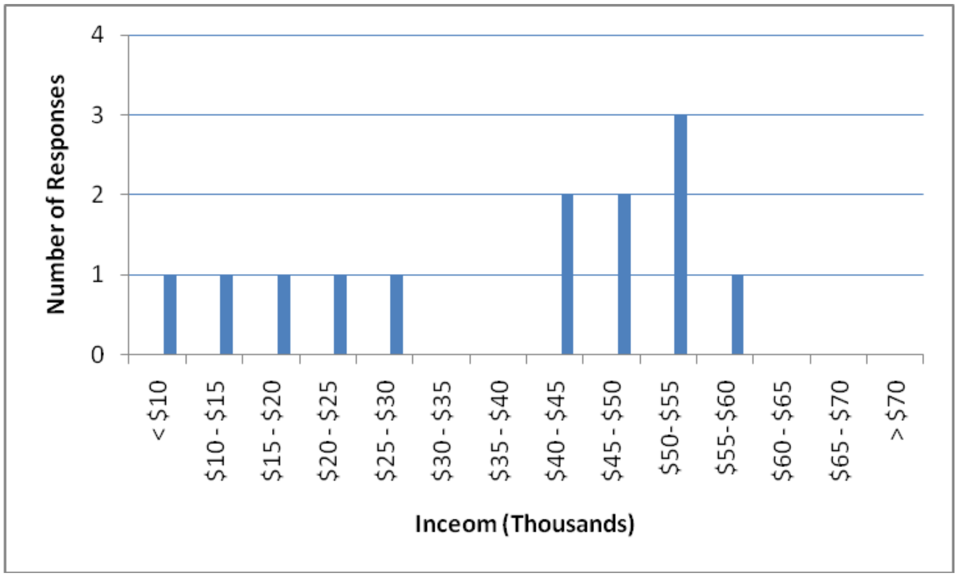

Figure 8. Results from questionnaire – income level in lower-income households

Income level of the respondents in the affordable housing units is shown in Figure 8. Education in the affordable housing units is shown in Figure 9. Two respondents filled out the questionnaire incorrectly by checking two categories. Instead of choosing the highest level of education achieved in the household, it appears the the participants indicated the education level of each member of the household. In these cases, the 'highest' category was taken. University was taken as 'higher' than techncial college.

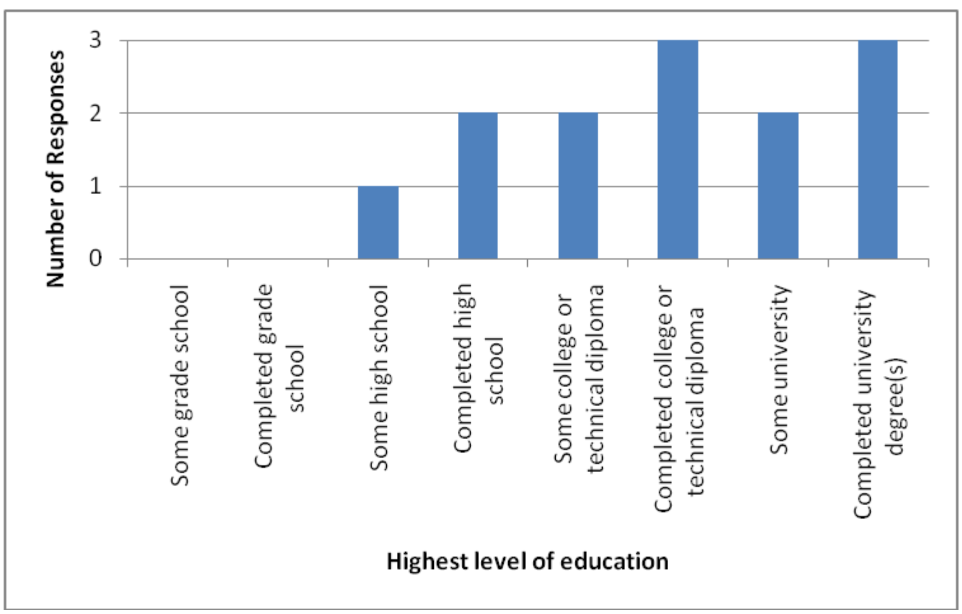

Figure 9. Results from questionnaire – education level in lower-income households

Appliance	Number of responses	Percent of responses
Electric Stove	12	92%
Electric Dishwasher	1	8%
Electric Laundry Machine	11	85%
Electric Drying Machine	11	85%
Programmable thermostat	6	46%
Freezer	7	54%
Central AC	0	0%
AC window unit	1	8%

Table 15. Results from questionnaire – appliance ownership in lower-income households

Appliances present in the affordable housing units are shown in Table 15. All of the comments from the questionnaires are shown in Table 16. These are responses from the proponents that were prompted at the end of the questionnaire by simply stating "Comments or Questions".

Group	Comments
Affordable	This new way sucks, we have cut our consumption by up to 20% but the monthly bill is $25 higher.
Affordable	Not sure if the thermostat is programmable, however it can be set to maintain a constant temp. in the house (not electronic)
Affordable	Since the smart meters were installed myself and a few of my neighbours have definitely become more aware of our usage. Personally, I am trying harder to use more at off-peak times. This is beneficial to me both financially and environmentally. However, I have not been through a winter with the new meters yet and I am quite concerned about this. I feel that I will not be able to run my furnace regularly and therefore, have to suffer in cold. With a special needs child in the house, this is simply not acceptable. On a positive note, my neighbours and I are sort of competing to have the lowest.
Affordable	We have a refrigerator with freezer
Affordable	from 3:15-5:00pm, 1/3 of a degree as well, I really wish I had known we were getting Smart Meters installed earlier. I had one installed several months AFTER signing up with Ontario Energy so I don't benefit from the Smart Meter :(
Affordable	I sincerely think that this is only another way of raising the already expensive price of electricity. Thanks a lot. Big company like Hydro ON Canada should work in ways to lower the price and not rising for your own greed.
Senior	I am seventy three years old just moved in my apartment from a house of forty-five years. So I don't know if this is a true questionnaire you want.
Senior	1 grandchild (perhaps home during peak hours?), small den (maybe additional?)
Senior	76 YEARS, I do take advantage of the off peak hours to do my dishes, washing and drying clothes especially - there are other things I do at the off peak hours since the smart meters have been installed
Senior	Why did we not do this years ago. We would not be in such a mess now. I'm not taking anything for granted at this age we know how to cut costs. A widow for 23 years. I get along very well - but I am from the old school. Wish you all the best in your studies.
Senior	I live in a 12 apartments building, but I live alone - I am a widow. I control my own thermostat for both heat and cooling.
Senior	Apartment unit

Table 16. Comments provided by participants through the household questionnaire
Note: comments were not edited for grammar.

The findings presented in this section will be used to evaluate the impacts of certain characteristics that influence a household's ability to respond to TOU rates and the ability to save money under the TOU rate structure. In the following sections, the findings from the quantitative analysis of the electricity consumption of the four sites are presented.

4.2.2 Natural benefits

As a reminder, the first calculation performed was intended to determine if lower-income or senior-headed households would 'benefit naturally' from the implementation of TOU rates. In other words, are the households expected to save money given their electricity consumption patterns before the implementation of TOU rates? To answer this question, an analysis was performed on the electricity consumption data from each household to compare the costs under the tiered rate regime to what the costs would be under the TOU rate regime. Refer to Section 3.3.4 for a detailed description of the calculation.

Descriptive statistics of the costs associated with the pre-TOU period are shown in Table 17 and Table 18. Site A and Site B have the lowest weekly average costs associated with tiered and TOU rates, while Site C and Site D have the highest weekly average costs associated with tiered and TOU rates. Notable from the descriptive statistics is that the range of costs (i.e., maximum minus the minimum) can vary greatly within each site.

		Average TOU costs		Average Tiered costs	
	Pre-TOU Period	**Period**	**Weekly Average**	**Period**	**Weekly Average**
Site A	3 weeks	$11.63	$3.88	$10.62	$3.54
Site B	4 weeks	$23.38	$5.85	$20.96	$5.24
Site C	2 weeks	$15.17	$7.59	$14.87	$7.43
Site D	2 weeks	$24.35	$12.18	$24.26	$12.13

Table 17. Average costs associated with TOU and tiered rates during the pre-TOU period

	Pre-TOU costs for rate regime	N	Minimum	Maximum	Mean	Std. Deviation
Site A	TOU	12	$6.23	$17.57	$11.63	$3.72
	Tier	12	$5.68	$15.85	$10.62	$3.38
Site B	TOU	51	$1.20	$51.38	$23.38	$12.76
	Tier	51	$1.25	$46.96	$20.96	$11.81
Site C	TOU	110	$1.33	$45.26	$15.17	$8.19
	Tier	110	$1.35	$44.56	$14.87	$8.48
Site D	TOU	26	$3.77	$42.97	$24.35	$9.72
	Tier	26	$3.30	$47.22	$24.26	$10.25

Table 18. Descriptive statistics of TOU and tiered rate costs during the pre-TOU period

A paired t-test (95% confidence) was performed to determine if there was a statistical difference between the expected TOU costs and the tiered costs. Results of this analysis are shown in Table 19 and discussed below. Recall that a 'positive difference' indicates that the expected costs of TOU rates are greater than the costs under tiered rate structure, and vice versa.

Cost TOU minus Cost Tier								
	Mean Difference	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**		**t**	**df**	**Sig. (2-tailed)**
				Lower	*Upper*			
Site A	$1.01	$0.57	$0.16	$0.65	$1.37	6.185	11	0.000
Site B	$2.42	$1.53	$0.21	$1.99	$2.85	11.319	50	0.000
Site C	$0.30	$0.96	$0.09	$0.12	$0.48	3.301	109	0.001
Site D	$0.09	$1.34	$0.26	-$0.45	$0.63	0.352	25	0.728

Table 19. Difference between expected costs of TOU rates and tiered rates during the pre-TOU period

For Site A, the mean cost associated with TOU rates was $11.63 and the mean cost associated with tier rates was $10.62 during the three week pre-TOU period. During the pre-TOU period, $C_{TOU} - C_{Tier}$ was positive for all households. The maximum difference was $2.31 and the minimum difference was $0.53. The average difference was $1.01 with a standard deviation of $0.57. The results of the paired t-test indicate that the differences between the expected TOU cost and the tiered costs are significant for this site. In other words, the expected costs associated with TOU rates are greater than the expected costs associated with tiered rates for this group consisting of senior-headed households.

For Site B, the mean cost associated with TOU rates was $23.38 and the mean cost associated with tiered rates was $20.96 during the four week pre-TOU period. During the pre-TOU period, $C_{TOU} - C_{Tier}$ ranged from positive to negative amongst the units at this site; however, only four units (8%) had a negative difference. The maximum difference was $6.07 and the minimum difference was -$0.05. The average difference was $2.42 with a standard deviation of $1.53. The results of the paired t-test indicate that the differences between the expected TOU cost and the tiered costs are significant for this site. In other words, the expected costs associated with TOU rates are greater than the expected costs associated with tiered rates for this group consisting of senior-headed households.

For Site C, the mean cost associated with TOU rates was $15.17 and the mean cost associated with tiered rates was $14.87 during the two week pre-TOU period. During the pre-TOU period, $C_{TOU} - C_{Tier}$ ranged from positive to negative, with 34 units (31%) having negative differences. The maximum difference was $2.14 and the minimum difference was -$3.12. The average difference was $0.30 with a standard deviation of $0.96. The results of the paired t-test indicate that the differences between the expected TOU cost and the tiered costs are significant for this site. In other words, the expected costs associated with TOU rates are greater than the expected costs associated with tiered rates for this group consisting of lower-income households.

For Site D, the mean cost associated with TOU rates was $24.35 and the mean cost associated with tiered rates was $24.26 during the two week pre-TOU period. During the pre-TOU period, $C_{TOU} - C_{Tier}$ ranged from positive to negative, with 9 units (34%) having negative differences. The maximum difference was $2.09 and the minimum difference was -$4.25. The average difference was $0.09 with a standard deviation of $1.34. The results of the paired t-test indicate that the differences between the expected TOU cost and the tiered costs are not significant for this site. In other words, the expected costs associated with TOU rates are not significantly different that the costs associated with tiered rates for this group consisting of lower-income households.

The findings imply that none of the four sites studied would benefit naturally from TOU rates - at least, not given their electricity consumption patterns in June 2007. Thus, these households would have to change their electricity consumption patterns in order to benefit from TOU rates. Given their pre-TOU usage patterns, Site A, Site B, and Site C would have had more expensive electricity bills if they had been charged under the TOU rate regime then they would have under the tiered rate regime. Over a three week period, on average, households in Site A would have paid $1.01 more under the TOU rates. Over a four week period, on average, households in Site B would have paid $2.42 more under TOU rates. Over a two week period, on average, households in Site C would have paid $0.30 more under TOU rates. At most, this works out to be a $0.61 difference per week (Site B).

	2006	2007
Delivery		
Customer Charge	$14.07 per month	$16.13 per month
Distribution	$ 0.0131 per kWh	$0.0133 per kWh
Transmission Network	$0.0056 per kWh	$0.0056 per kWh
Transmission Connection	$0.0045 per kWh	$0.0045 per kWh
Regulatory		
RPP Administration	$0.25 per month	$0.25 per month
Wholesale Market Service	$0.0062 per kWh	$0.0062 per kWh
Debt retirement Charge	$0.0070 per kWh	$0.0070 per kWh
Total variable costs	$0.0364 per kWh	$0.0366 per kWh
Total fixed charges	$14.32 per month	$16.38 per month

Table 20. Distribution service charges for Milton Hydro Distribution Inc.
Source: Milton Hydro Distribution Inc.

To put this into some context, $C_{TOU} - C_{Tier}$ is compared to the distribution service charges given the average electricity consumption of household at Site B. The average household at Site B consumed approximately 420 kWh during the billing period. Given the rate schedule for 2007 shown in Table 20, these households would have paid on average approximately $31.75 in distribution service charges[2]. Based on $0.61 per week, this works out to be $2.61 extra per month (30 days), which is approximately 8% of their distribution service charges.

The results of the paired t-test for Site D imply that the difference between the costs incurred under the two rate schemes is not significantly different; therefore the households in Site D cannot be said to benefit naturally from TOU rates, and would likewise need to change their electricity consumption pattern in order to benefit from TOU rates. Recall that households in Site D had the highest pre-TOU costs associated with both tiered and TOU rates.

4.2.3 Conservation effect

As a reminder, this second calculation was done to determine if the lower-income and senior-headed households conserved electricity upon the implementation of TOU rates. To complete this calculation, weather adjusted electricity consumption during the 2006 billing period was compared to weather adjusted electricity consumption during the 'corresponding 2007 billing period'. A paired t-test (95% confidence) was performed to determine if there was a statistical difference between the electricity consumption between each 2006 billing period and the corresponding 2007 billing period. Results of this analysis are discussed below.

As shown in Figure 10, households at Site A had mean electricity consumption during the 2006 billing periods that ranged from 235 kWh to 355 kWh. The mean consumption of these households during the 2007 billing periods ranged from 212 kWh to 280 kWh. The mean household electricity consumption during the 2006 billing periods was higher than the mean household electricity consumption during 2007 billing periods for all corresponding billing periods. However, the results of the paired t-test (shown in Table 21) indicate that the mean household electricity consumption level is not statistically different between 2006 and 2007 for all corresponding billing periods except for billing period #7 (at 95% confidence level). For billing period #7, 2006 consumption was greater than 2007 consumption, with a mean difference of 123 kWh – this is a 35% reduction.

[2] Given the following calculation: (420 kWh x $0.0366/kWh) + $16.38 = $31.75

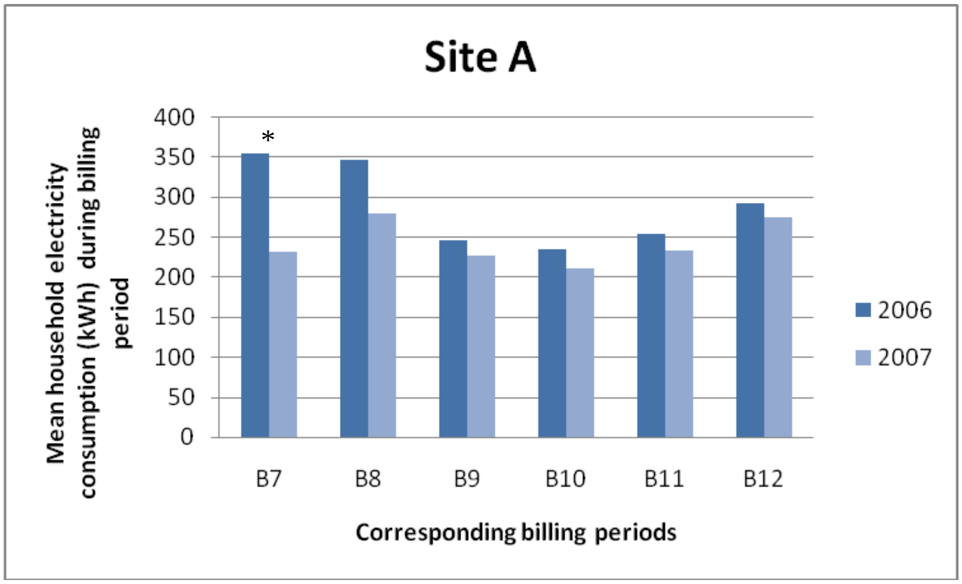

Figure 10. Conservation effect at Site A
* Significant difference between 2006 and 2007 corresponding billing periods at 95% confidence.

Site A (2006-2007)								
Billing period	Mean Diff. (kWh)	Std. Deviation (kWh)	Std. Error Mean (kWh)	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	*Upper*			
B7	123.03	131.23	37.88	39.65	206.41	3.248	11	0.008
B8	67.36	149.51	43.16	-27.63	162.35	1.561	11	0.147
B9	20.22	110.45	31.88	-49.96	90.40	0.634	11	0.539
B10	23.01	69.08	19.94	-20.88	66.90	1.154	11	0.273
B11	20.31	69.32	20.01	-23.73	64.36	1.015	11	0.332
B12	16.97	69.86	20.17	-27.42	61.36	0.841	11	0.418

Table 21. Difference in mean household electricity consumption between corresponding billing periods at Site A

As shown in Figure 11, households at Site B had mean electricity consumption during the 2006 billing periods that ranged from 277 kWh to 550 kWh. The mean consumption of each household during the 2007 billing periods ranged from 248 kWh to 434 kWh. The mean household electricity consumption during the 2006 billing periods was higher than the mean household electricity consumption during the 2007 billing period for all periods. The results of the paired t-test (shown in Table 22) indicate that the mean household electricity consumption is not statistically different between 2006 and 2007 for billing periods #10 and #11 (at 95% confidence level). However, the results indicate the difference is significant for billing periods #8, #9, and #12, implying the mean household electricity consumption for billing periods in 2006 are greater than in 2007. The average difference in electricity consumption for these billing periods was 115 kWh, 116 kWh and 29 kWh, respectively. Likewise, this represents a 21%, 24%, and 9% reduction, respectively.

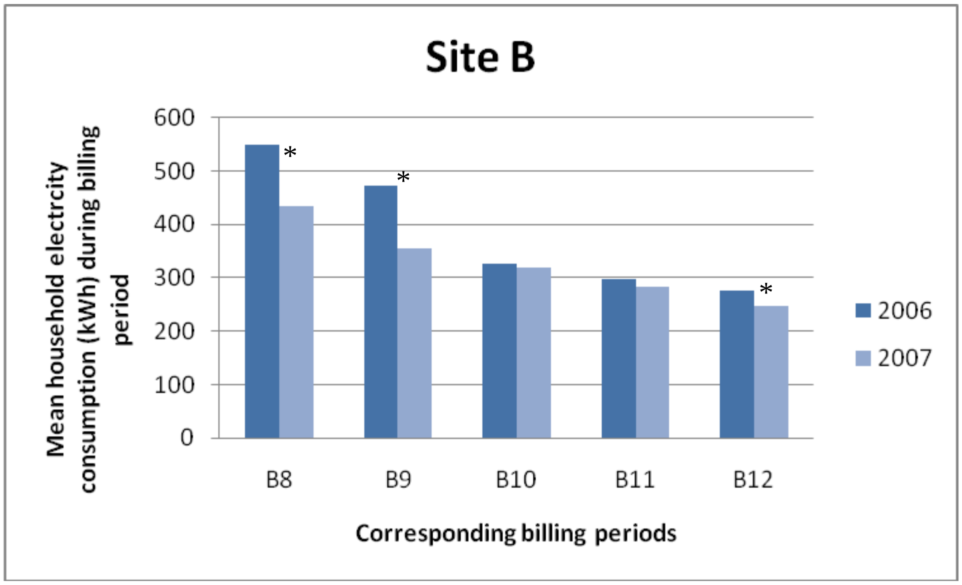

Figure 11. Conservation effect at Site B
* Significant difference between 2006 and 2007 corresponding billing periods at 95% confidence.

Site B (2006-2007)								
Billing Period	Mean Diff. (kWh)	Std. Deviation (kWh)	Std. Error Mean (kWh)	95% Confidence Interval of the Difference *Lower*	*Upper*	t	df	Sig. (2-tailed)
B8	115.17	209.26	29.30	56.32	174.03	3.930	50	0.000
B9	115.83	154.03	21.57	72.51	159.15	5.371	50	0.000
B10	6.03	141.04	19.75	-33.64	45.70	0.305	50	0.761
B11	15.26	109.00	15.26	-15.40	45.91	1.000	50	0.322
B12	29.14	82.41	11.54	5.96	52.32	2.525	50	0.015

Table 22. Difference in mean household electricity consumption between corresponding billing periods at Site B

As shown in Figure 12, households in Site C had a mean electricity consumption of the households during the 2006 billing periods that ranged from 551 kWh to 728 kWh. The mean consumption of each household during the 2007 billing periods ranged from 503 kWh to 575 kWh. The mean household electricity consumption during the 2006 billing periods was higher than the mean household electricity consumption during the 2007 billing period for all periods. The results of the paired t-test (shown in Table 23) indicate that the electricity consumption in the 2006 billing periods is statistically greater than the corresponding 2007 billing periods for all billing periods except #12 (at 95% confidence level). For billing periods #7, #8, #9, #10, and #11 the average differences in the mean household electricity consumption were 150 kWh, 152 kWh, 73 kWh, 48 kWh and 46 kWh, respectively. Likewise, this represents a 21%, 21%, 12%, 9%, and 8% reduction, respectively.

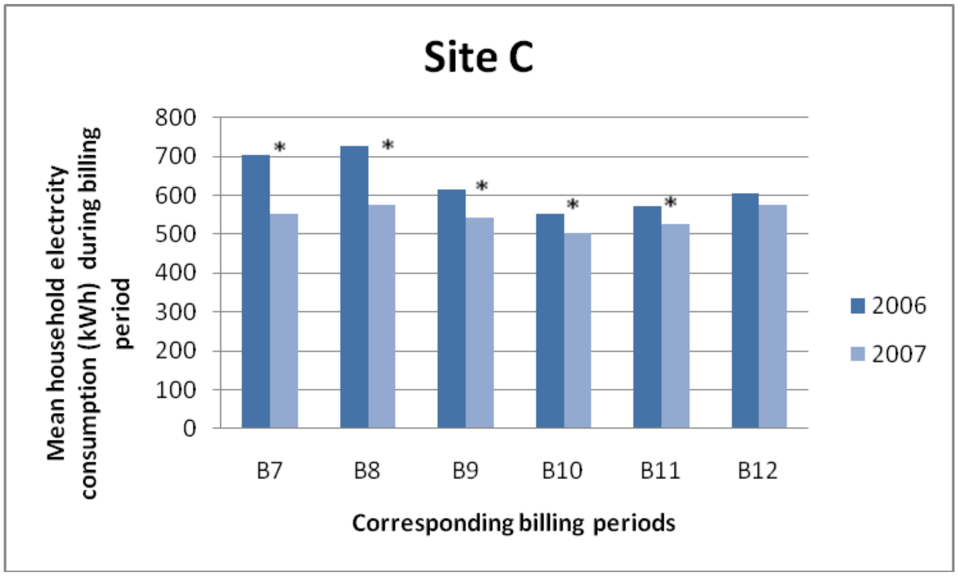

Figure 12. Conservation effect at Site C
Significant difference between 2006 and 2007 corresponding billing periods at 95% confidence.

Site C (2006-2007)								
Billing Period	Mean Diff. (kWh)	Std. Deviation (kWh)	Std. Error Mean (KWh)	95% Confidence Interval of the Difference *Lower*	*Upper*	t	df	Sig. (2-tailed)
B7	150.21	284.23	27.35	95.99	204.42	5.492	107	0.000
B8	152.63	248.00	23.65	105.76	199.50	6.455	109	0.000
B9	73.24	197.93	18.87	35.84	110.65	3.881	109	0.000
B10	48.04	193.00	18.49	11.39	84.68	2.599	108	0.011
B11	46.20	181.37	17.37	11.76	80.63	2.659	108	0.009
B12	31.36	176.71	17.16	-2.67	65.40	1.827	105	0.070

Table 23. Difference in mean household electricity consumption between corresponding billing periods at Site C

As shown in Figure 13, the households at Site D had mean electricity consumption during the 2006 billing periods that ranged from 1059 kWh to 1690 kWh. The mean consumption of each household during the 2007 billing periods ranged from 722 kWh to 1519 kWh. The mean household electricity consumption during the 2006 billing periods was higher than the mean household electricity consumption during the corresponding 2007 billing period for all periods. The results of the paired t-test (shown in Table 24) indicate that the electricity consumption is in the 2006 billing periods is statistically greater than the corresponding 2007 billing periods for all corresponding billing periods (at 95%

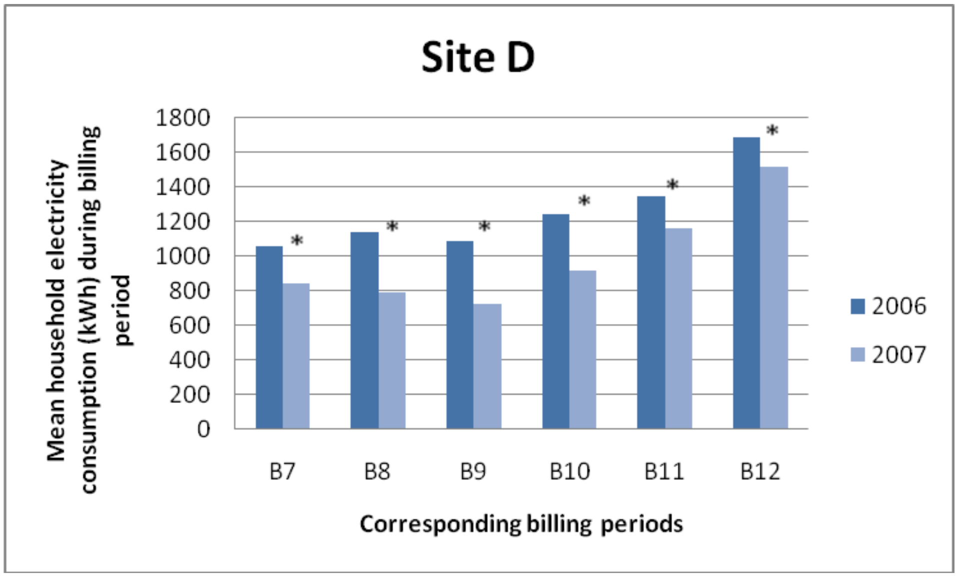

Figure 13. Conservation effect at Site D
* Significant difference between 2006 and 2007 corresponding billing periods at 95% confidence.

Site D Difference (2006-2007)								
				95% Confidence Interval of the Difference				
Billing Period	Mean Diff. (kWh)	Std. Deviation (kWh)	Std. Error Mean (kWh)	Lower	Upper	t	df	Sig. (2-tailed)
B7	215.74	369.57	72.48	66.47	365.02	2.98	25	.006
B8	349.00	414.38	81.27	181.63	516.37	4.29	25	.000
B9	367.85	415.61	81.51	199.99	535.72	4.51	25	.000
B10	323.38	344.46	67.55	184.26	462.51	4.79	25	.000
B11	190.89	242.76	47.61	92.83	288.94	4.01	25	.000
B12	170.79	372.52	73.06	20.32	321.25	2.34	25	.028

Table 24. Difference in mean household electricity consumption between corresponding billing periods at Site D

confidence level). The average difference was 216 kWh, 349 kWh, 368 kWh, 323 kWh, 191 kWh and 171 kWh, respectively. Likewise, this represents a 20%, 31%, 34%, 26%, 14%, and 10% reduction, respectively. This apparent conservation effect is unexpected, since participants at Site D are not responsible for their individual electricity bills.

The findings indicate that the different sites have different conservation responses that could be attributed to the implementation of TOU rates. For Site A, the first set of corresponding billing periods evaluated seem to indicate that there was a conservation response to the implementation of TOU rates, which is associated with the month of July. The subsequent billing periods for the rest of the year did not show any conservation effects. For Site B, a conservation effect was observed for three out of five corresponding billing periods. The billing periods when this effect is observed corresponds to the months of July, October, and November**.** For Site C, a conservation effect was observed for all corresponding billing periods except for the last billing period, which corresponds to the months of November and December. For Site D, there was a conservation effect for all corresponding billing periods. Site C and Site D, representing lower-income households, generally had greater electricity consumption than Site A and B, which are senior-headed households. Additionally, Site C and Site D typically had more people living in the household than Site A and Site B.

The 2006 and 2007 billing period data were investigated further to determine if there is a relationship between the amount of electricity consumed during the 2006 billing periods and the change between the 2006 and 2007 electricity consumption. Scatter plots were created for each site using data from the individual households. A negative value for the difference between 2006 consumption and 2007 consumption indicates that the household consumed less in 2007 than in 2006. The scatter plots are shown in the figures below. In general, the scatter plots show that households with higher electricity consumption in 2006 were able to conserve more in 2007**.**

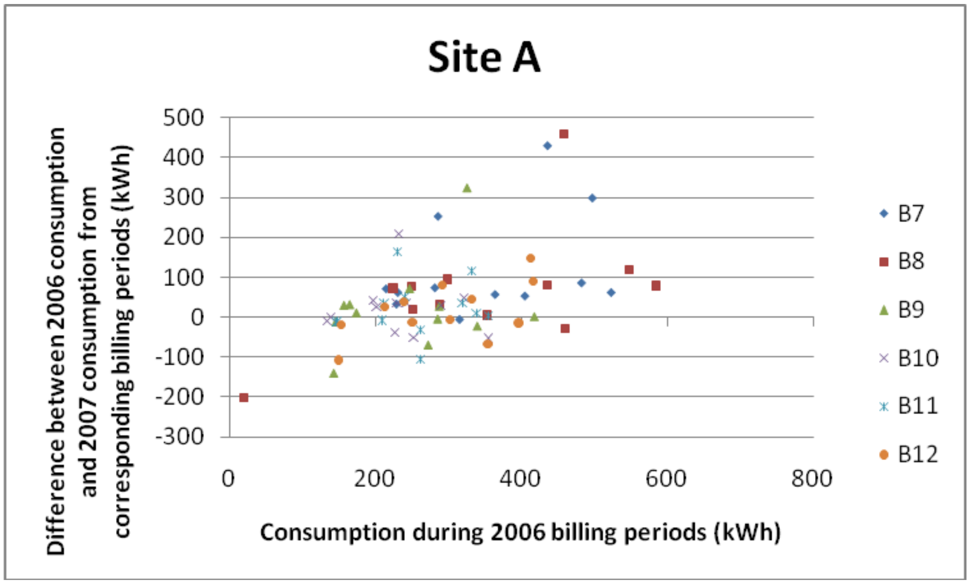

Figure 14. The difference between 2006 and 2007 electricity consumption from corresponding billing periods compared to the electricity consumption in 2006 for Site A.

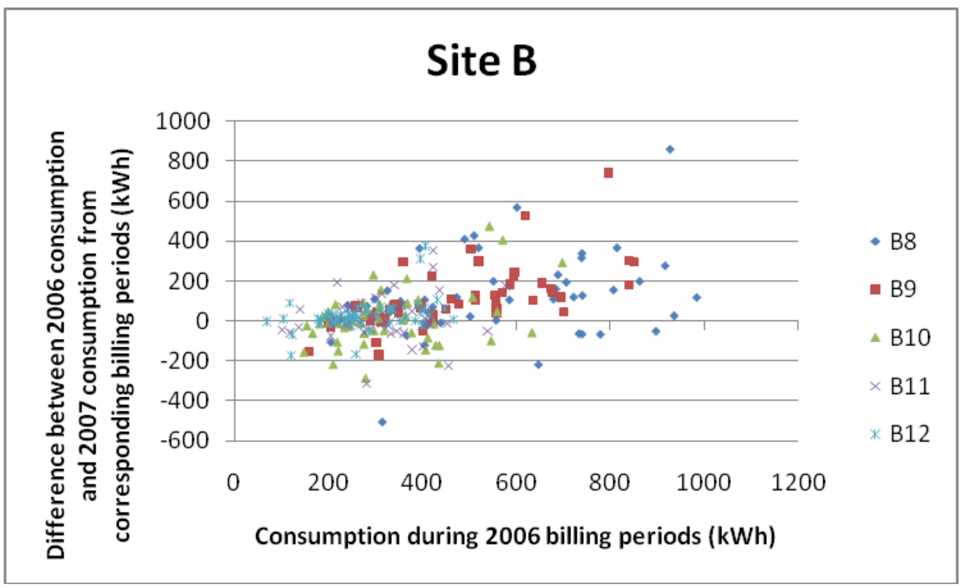

Figure 15. The difference between 2006 and 2007 electricity consumption from corresponding billing periods compared to the electricity consumption in 2006 for Site B.

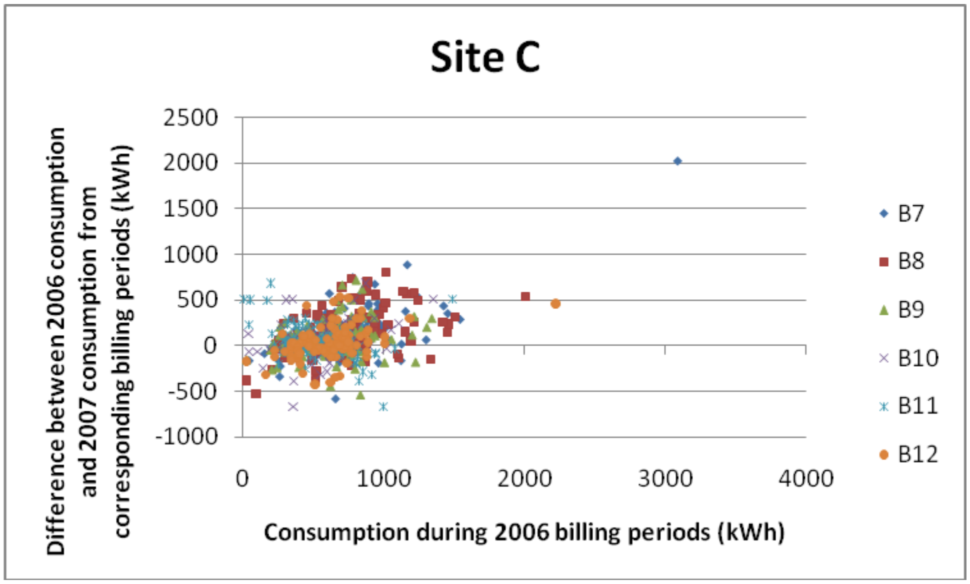

Figure 16. The difference between 2006 and 2007 electricity consumption from corresponding billing periods compared to the electricity consumption in 2006 for Site C.

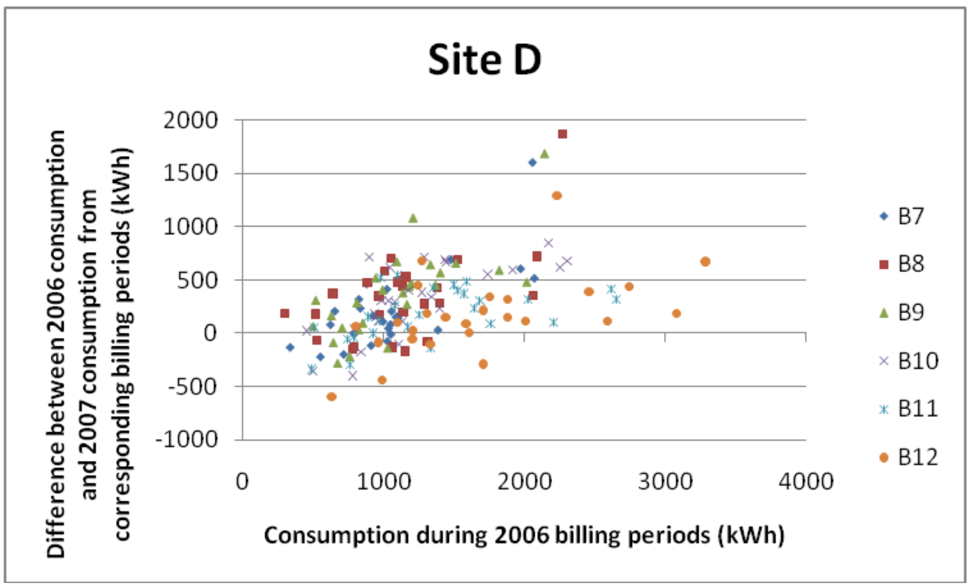

Figure 17. The difference between 2006 and 2007 electricity consumption from corresponding billing periods compared to the electricity consumption in 2006 for Site D.

4.2.4 Response to TOU price signal

As a reminder, this third calculation was performed to determine if households respond to TOU rates by either shifting electricity consumption to off-peak periods, or reducing consumption during on-peak and mid-peak periods. For each household, the percentage of electricity consumed during on-, mid-, and off-peak periods was calculated for each week of the study. For each site, an average of the household's weekly percentage of electricity consumed during the on-, mid-, and off-peak periods was calculated for each week of the study (excluding weeks with holidays). By evaluating the slope of the trend line, the percentage of electricity consumed during a given peak can be said to be increasing or decreasing over time (e.g., shifting). Positive slopes are taken as increasing over time, and negative slopes are taken to be decreasing overtime.

Mean percentage of electricity consumption during period (Week 1-30)				
	Site A	Site B	Site C	Site D
On Peak	23%	24%	20%	21%
Mid Peak	32%	29%	28%	29%
Off Peak	45%	47%	52%	50%

Table 25. Proportion of electricity consumed during peaks

Each of the sites had similar average percentage of electricity consumed during each period, as shown in Table 25. The mean household percentage of electricity consumed during on-peak periods ranged from 20-24% amongst the sites. Site B had the highest mean percentage of electricity consumed during on-peak periods. The mean percentage of electricity consumed during mid-peak periods ranged from 28-32% amongst the sites. Site A had the highest mean percentage of electricity consumed during mid-peak periods. The mean percentage of electricity consumed during off-peak periods ranged from 45-52% amongst the sites. Site C had the highest mean percentage of electricity consumed during off-peak periods.

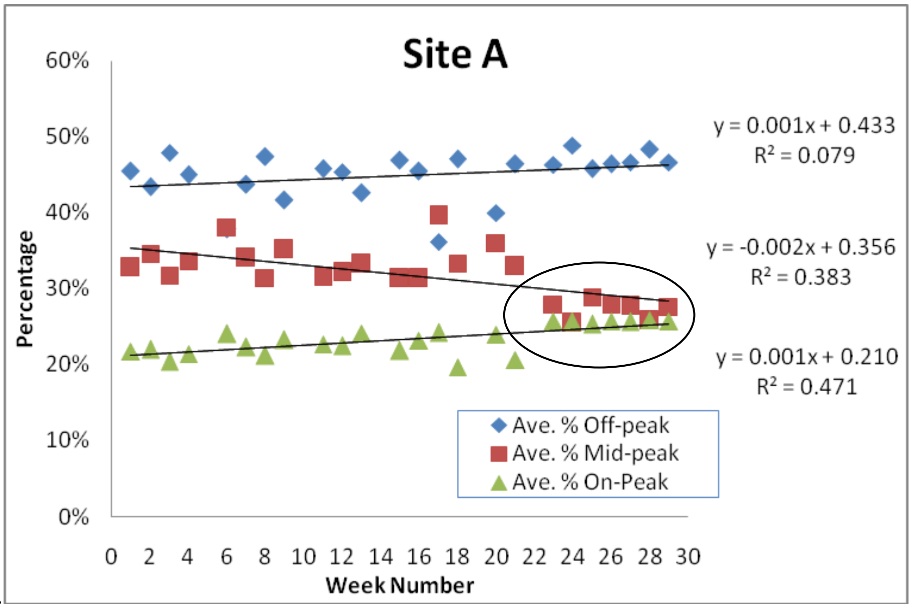

Figure 18. Response to TOU rates over time at Site A

Once completed however, the plots at each site showing the proportion of electricity consumed during each peak period over the course of the 30 week period indicated that there was a change in the percent of consumption for the peak periods after the TOU peak times switched from the summer peak schedule to the winter peak schedule (i.e. after Week 22). Recall that winter TOU peak periods are different than summer TOU peak periods. For example, Site A is shown in Figure 18 above.

It is unlikely that any of the households would abruptly change their electricity consumption behaviour as a result of the new rate schedule, and the shift in the proportion of electricity consumed during each peak is reflective of a change in the on-, mid-, off-peak calculations. As shown in Table 26, the study sites tended to have a slightly different proportion of electricity consumed during each peak between the summer and the winter TOU period. To determine if there was a change in the percentage of electricity consumed during the peaks, a regression analysis was conducted using data from Weeks 1 through Week 21 only.

	Site A	Site B	Site C	Site D
On				
Summer	22%	24%	19%	21%
Winter	26%	24%	22%	22%
Mid				
Summer	34%	31%	30%	31%
Winter	27%	25%	23%	24%
Off				
Summer	44%	45%	51%	48%
Winter	47%	50%	54%	54%

Table 26. Mean percentage of electricity consumption during peak

For Site A, when only considering Weeks 1-21, there is a negligible change in the percentage of electricity consumed over time during off-, mid- and on-peak (slope=-0.000, slope=0.000, and slope=0.000, respectively), as shown in Figure 19. Additionally, the results of the regression analysis using ANOVA indicate that all the changes are statistically insignificant (p=0.653, p=0.740, and p=0.598, respectively), as shown in Table 27, Table 28 and Table 29. These findings suggest that for these senior-headed households, there is no change in the proportion of electricity consumed during the peaks

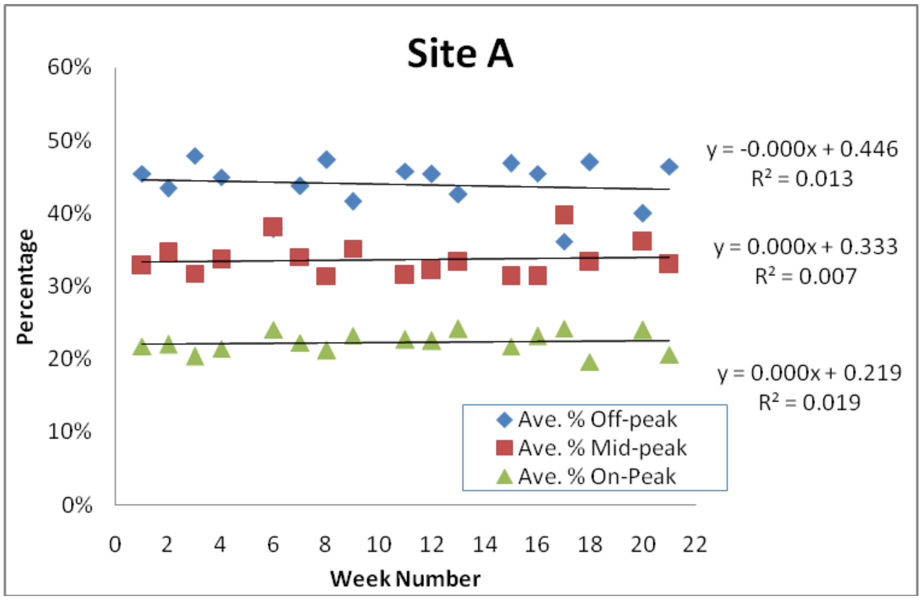

Figure 19. Response to TOU rates over time at Site A (Summer Only)

Site A - ANOVA Off-peak					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.000	1	.000	.210	.653
Residual	.018	15	.001		
Total	.018	16			

Table 27. Site A - Regression results for shift in off-peak period (Summer only)

Site A - ANOVA Mid-peak					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.000	1	.000	.114	.740
Residual	.009	15	.001		
Total	.009	16			

Table 28. Site A - Regression results for shift in mid-peak period (Summer only)

Site A - ANOVA On-peak					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.000	1	.000	.290	.598
Residual	.003	15	.000		
Total	.003	16			

Table 29. Site A - Regression results for shift in on-peak period (Summer only)

For Site B, when considering only Weeks 1-21, there is a general increase in the percentage of electricity consumed during the off-peak period (slope=0.002), a negligible decrease during mid-peak periods (slope=0.000), and a slight decrease in the during on-peak period (slope= 0.001), as shown in Figure 20. The results of the regression analysis using ANOVA indicate that the changes in the proportion of electricity consumed during off- and mid-peak periods are not statistically significant (p=0.052 and p=0.500 respectively), however, the change in the proportion of electricity consumed during on-peak periods is statistically significant (p=0.016), as shown in Table 30, Table 31 and Table 32. The slope of the trend line is equal to 0.002, which means that as each week passes the percentage of electricity consumed during the on-peak period decreases by about 0.2%. This amount would have only a small impact on the household's electricity bill for these lower-income households. These findings suggest that for these senior-headed houses, there is little to no change in the proportion of electricity consumed during the individual peaks.

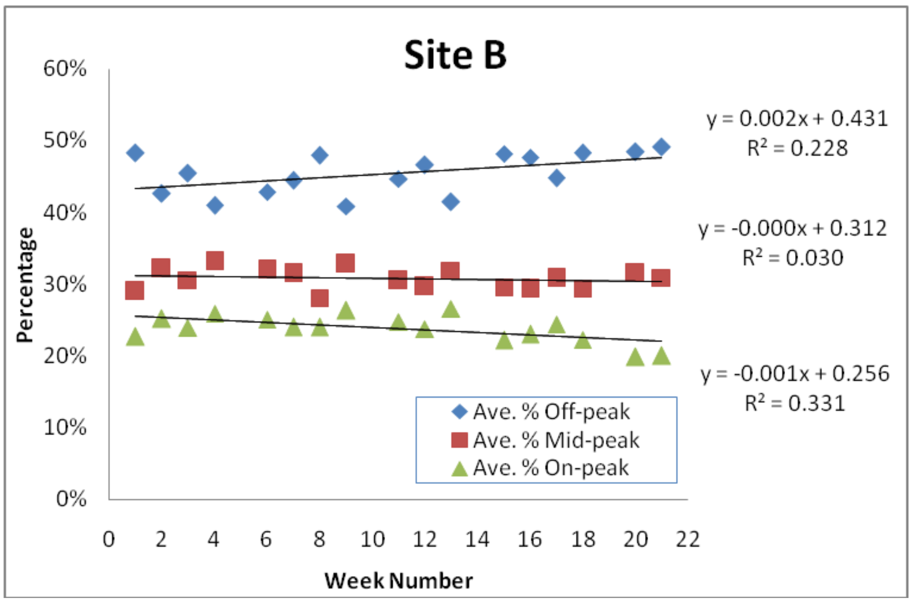

Figure 20. Response to TOU rates over time at Site B (Summer Only)

Site B – ANOVA *Off-peak*					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.003	1	.003	4.434	.052
Residual	.010	15	.001		
Total	.013	16			

Table 30. Site B - Regression results for shift in off-peak period (Summer only)

Site B – ANOVA *Mid-peak*					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.000	1	.000	.478	.500
Residual	.003	15	.000		
Total	.003	16			

Table 31. Site B - Regression results for shift in mid-peak period (Summer only)

Site B – ANOVA *On-peak*					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.002	1	.002	7.441	.016
Residual	.004	15	.000		
Total	.006	16			

Table 32. Site B - Regression results for shift in on-peak period (Summer only)

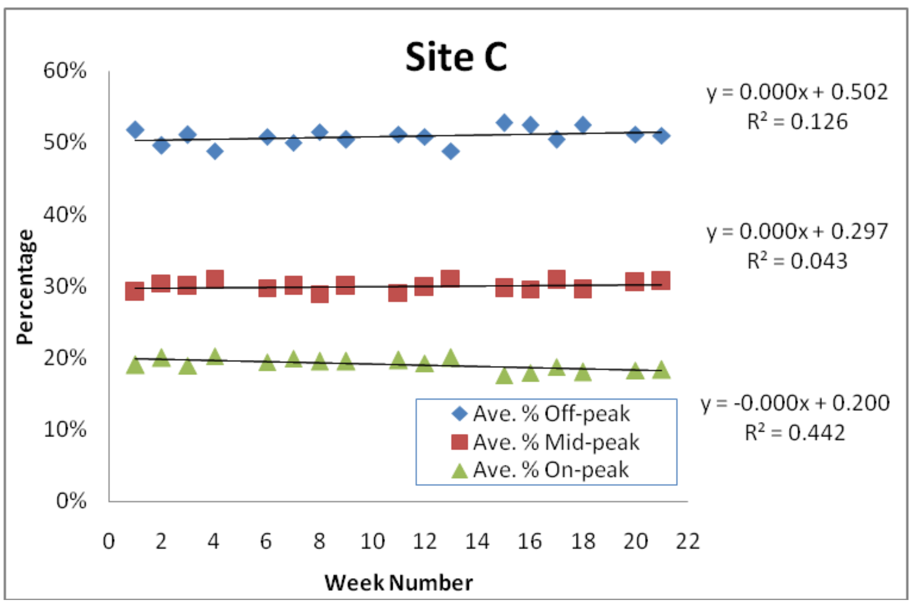

Figure 21. Response to TOU rates over time at Site C (Summer Only)

Site C – ANOVA *Off-peak*					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.000	1	.000	2.171	.161
Residual	.002	15	.000		
Total	.002	16			

Table 33. Site C - Regression results for shift in off-peak period (Summer only)

Site C – ANOVA *Mid-peak*					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.000	1	.000	.689	.420
Residual	.001	15	.000		
Total	.001	16			

Table 34. Site C - Regression results for shift in mid-peak period (Summer only)

Site C – ANOVA *On-peak*					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.000	1	.000	11.882	.004
Residual	.001	15	.000		
Total	.001	16			

Table 35. Site C - Regression results for shift in on-peak period (Summer only)

For Site C, when only considering Weeks 1-21, there is a negligible change in the percentage of electricity consumed over time during off-, mid- and on-peak (slope=0.000, slope=0.000, and slope=-0.000, respectively), as shown in Figure 21. The results of the regression analysis using ANOVA indicate that the change in the proportion of electricity consumed during off- and mid-peak periods are not statistically significant (p=0.161 and p=0.420, respectively); however, the change in the proportions of electricity consumed during on-peak periods is statistically significant (p=0.004), as shown in Table 33, Table 34 and Table 35. Taking a more precise look at the on-peak period, the change slope of the line is equal to -8.43×10^{-4}, which is roughly equal to -0.1%. Meaning, as each week passes the percentage of electricity consumed during the on-peak period decreases by less than 0.1%. This amount would have only a small impact on the household's electricity bill for these lower-income households.

For Site D, when only considering weeks 1-21, there is a negligible change in the percentage of electricity consumed over time during off-, mid- and on-peak (slope=0.000, slope=-0.000, and slope=0.000, respectively), as shown in Figure 22. Additionally, the results of the regression analysis using ANOVA indicate that all the changes are statistically insignificant (p=0.646, p=0.339, and p=0.837, respectively), as shown in Table 36, Table 37 and Table 38. These findings suggest that for these lower-income households, there is no change in the proportion of electricity consumed during the peaks.

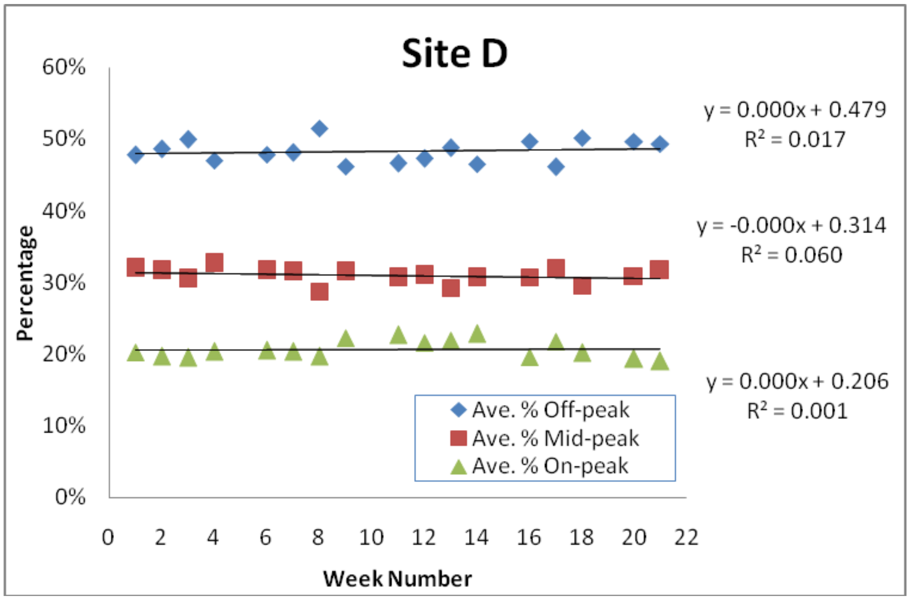

Figure 22. Response to TOU rates over time at Site D (Summer Only)

Site D – ANOVA ***Off-peak***					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.000	1	.000	.220	.646
Residual	.004	15	.000		
Total	.004	16			

Table 36. Site D - Regression results for shift in off-peak period (Summer only)

Site D – ANOVA ***Mid-peak***					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.000	1	.000	.975	.339
Residual	.002	15	.000		
Total	.002	16			

Table 37. Site D - Regression results for shift in mid-peak period (Summer only)

Site D – ANOVA ***On-peak***					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	.000	1	.000	.044	.837
Residual	.002	15	.000		
Total	.002	16			

Table 38. Site D - Regression results for shift in on-peak period (Summer only)

In summary, although there appears to be some shifts in electricity consumption behaviour over the course of the weeks following the implementation of TOU rates, the shifts are statistically insignificant, or almost negligible. Therefore, the results of the above analysis suggest that these lower-income and senior-headed households do not respond, during the course of the study period, to TOU rates by shifting the proportion of electricity consumed during on-, mid- and off-peak periods.

A similar analysis that isolated the winter post-TOU period was not performed. There are only six weeks during the post-TOU period, which corresponds to less than two billing periods. Therefore, it is assumed that the households would not receive sufficient feedback from their electricity bills and would not have enough time to adjust their behaviour if they thought it would be necessary. Furthermore, since the results of this analysis show that households do not respond to TOU rates by shifting electricity consumption during the summer, it is reasonable to assume that the households would not suddenly respond to the winter TOU rates.

4.2.5 Change in cost of electricity

The change in the cost in electricity was calculated in a method that was similar to how the 'natural benefits' was calculated; however the calculation was performed for weekly intervals. For each week following the implementation of TOU rates (e.g., the post-TOU period) the costs associated with TOU rates were calculated, C_{Tou}. Likewise, the costs that would be expected if the household remained on tiered rates was also calculated, C_{Tier}. The difference, C_{TOU}-C_{Tier}, was calculated for each household for each week following the implementation of TOU rates. A positive value represents an expected increase in the weekly amount spent on electricity that would not have occurred if the households remained on tiered rates. The average C_{TOU}-C_{Tier} for each week was calculated for each site, and plotted on the figures below. Since during Week 22 the households were switched from the Summer TOU schedule to the Winter TOU schedule, Week 22 is omitted from data calculations and the plots below. This analysis does not account for any changes in costs that may be caused by a conservation effect observed resulting from TOU rates.

A paired t-test (95% confidence) was performed to determine if there was a statistical difference between the cost of the electricity under the TOU rate scheme and what the household would have paid if they were charge tiered rates for each week following the implementation of TOU rates. Results of this analysis are discussed below.

For Site A, as shown in Figure 23 and Figure 24, the weekly costs associated with TOU rates are greater than the weekly costs associated with tiered rates for all weeks. The results of the paired t-test imply that the TOU costs are significantly greater than the tiered costs for all weeks, as shown in Table 39. This implies that the cost associated with TOU rates are greater than what the household would have paid had they remained on tiered rates. As demonstrated in Figure 23, the average weekly costs associated with TOU rates ranged from $2.68 to $4.83, and the average weekly costs associated with tiered rates ranged from $2.40 to $4.16. The weekly difference in the cost is modest; the greatest average difference was $0.67 in week 9.

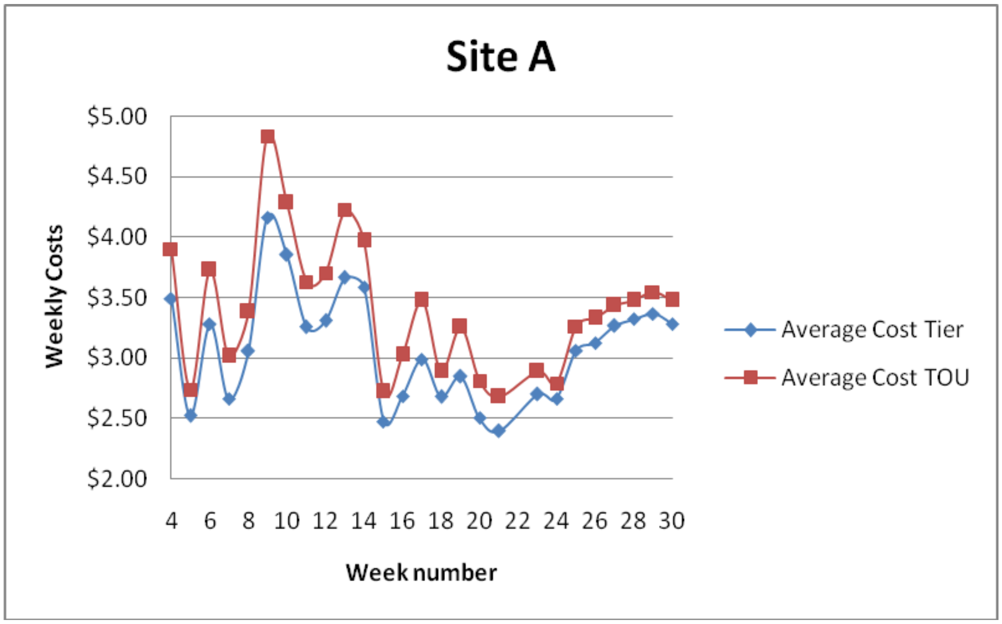

Figure 23. Weekly costs associated with TOU and tiered rates at Site A.

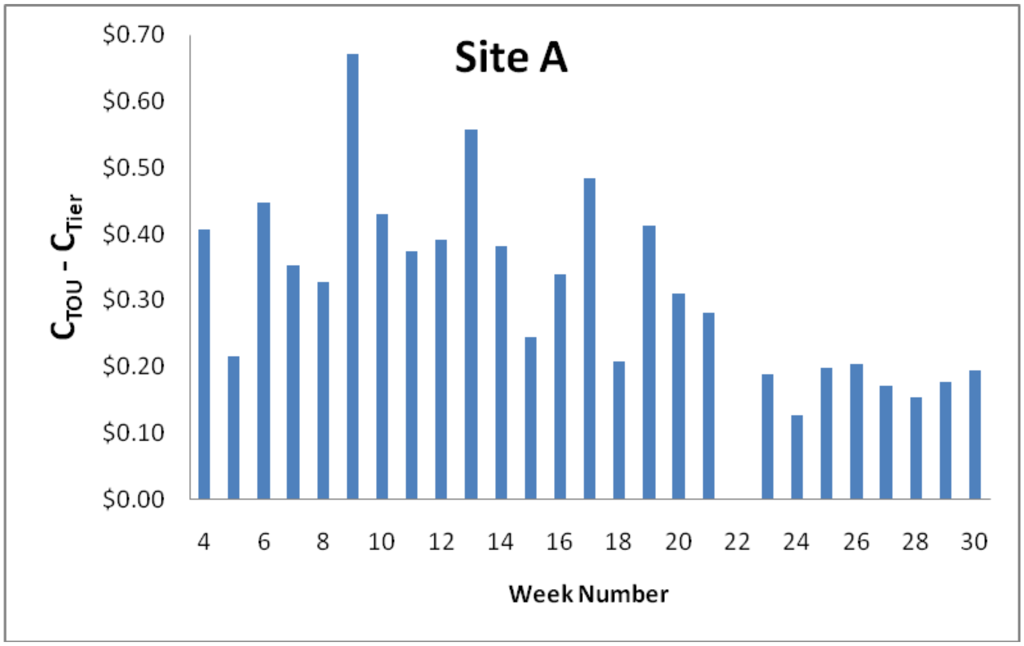

Figure 24. Difference in expected costs (TOU-TIER) at Site A.
Significance: $C_{TOU} - C_{Tier}$ are significant for all Weeks.

	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	*Upper*			
Week 4	$.40725	$.28805	$.08315	$.22423	$.59027	4.898	11	.000
Week 5	$.21621	$.20176	$.05824	$.08802	$.34440	3.712	11	.003
Week 6	$.44705	$.31809	$.09182	$.24494	$.64915	4.868	11	.000
Week 7	$.35275	$.26556	$.07666	$.18402	$.52148	4.601	11	.001
Week 8	$.32700	$.31772	$.09172	$.12513	$.52887	3.565	11	.004
Week 9	$.67031	$.60763	$.17541	$.28424	$1.05638	3.821	11	.003
Week 10	$.43052	$.44880	$.12956	$.14537	$.71568	3.323	11	.007
Week 11	$.37288	$.33067	$.09546	$.16278	$.58298	3.906	11	.002
Week 12	$.39074	$.31793	$.09178	$.18874	$.59274	4.257	11	.001
Week 13	$.55693	$.46695	$.13480	$.26024	$.85362	4.132	11	.002
Week 14	$.38118	$.30425	$.08783	$.18787	$.57449	4.340	11	.001
Week 15	$.24520	$.18047	$.05210	$.13054	$.35987	4.707	11	.001
Week 16	$.33990	$.27827	$.08033	$.16309	$.51670	4.231	11	.001
Week 17	$.48471	$.30336	$.08757	$.29197	$.67746	5.535	11	.000
Week 18	$.20830	$.11839	$.03418	$.13308	$.28352	6.095	11	.000
Week 19	$.41164	$.28063	$.08101	$.23333	$.58994	5.081	11	.000
Week 20	$.30998	$.12943	$.03736	$.22774	$.39221	8.296	11	.000
Week 21	$.28195	$.14290	$.04125	$.19116	$.37274	6.835	11	.000
Week 23	$.18829	$.21267	$.06139	$.05317	$.32341	3.067	11	.011
Week 24	$.12622	$.13949	$.04027	$.03760	$.21485	3.135	11	.009
Week 25	$.19889	$.21527	$.06214	$.06211	$.33566	3.201	11	.008
Week 26	$.20370	$.23163	$.06687	$.05653	$.35087	3.046	11	.011
Week 27	$.17111	$.20276	$.05853	$.04228	$.29994	2.923	11	.014
Week 28	$.15298	$.20170	$.05822	$.02483	$.28113	2.627	11	.024
Week 29	$.17716	$.18177	$.05247	$.06167	$.29266	3.376	11	.006
Week 30	$.19476	$.20490	$.05915	$.06457	$.32494	3.293	11	.007

Table 39. Site A - Difference between expected weekly costs (C_{TOU}-C_{Tier}) during the post-TOU period

For Site B, as shown in Figure 25 and Figure 26, the weekly costs associated with TOU rates are greater than the weekly costs associated with tiered rates for only the first weeks of the study. The results of the paired t-test imply that the TOU costs are not statistically different from the tiered costs for Week 5, Week 12, and Week 16 through Week 18, as shown in Table 40. The results imply that the TOU costs are significantly greater than the tiered cost for Week 6 through Week 11, and Week 13 and Week 14. The greatest average difference during these Weeks is $2.85 in Week 9. Conversely, for Week 15 and Week 19 through Week 30, the results imply that the TOU costs are significantly less than what the tier costs would have been. The greatest average difference during these weeks is modest, at -$0.83 in Week 25.

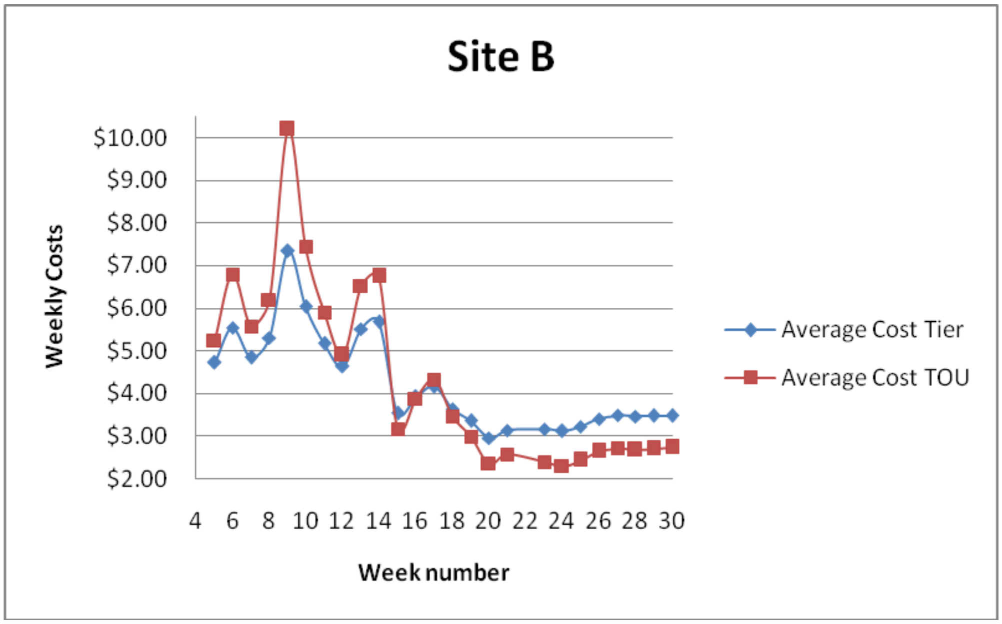

Figure 25 Weekly costs associated with TOU and Tiered rates at Site B

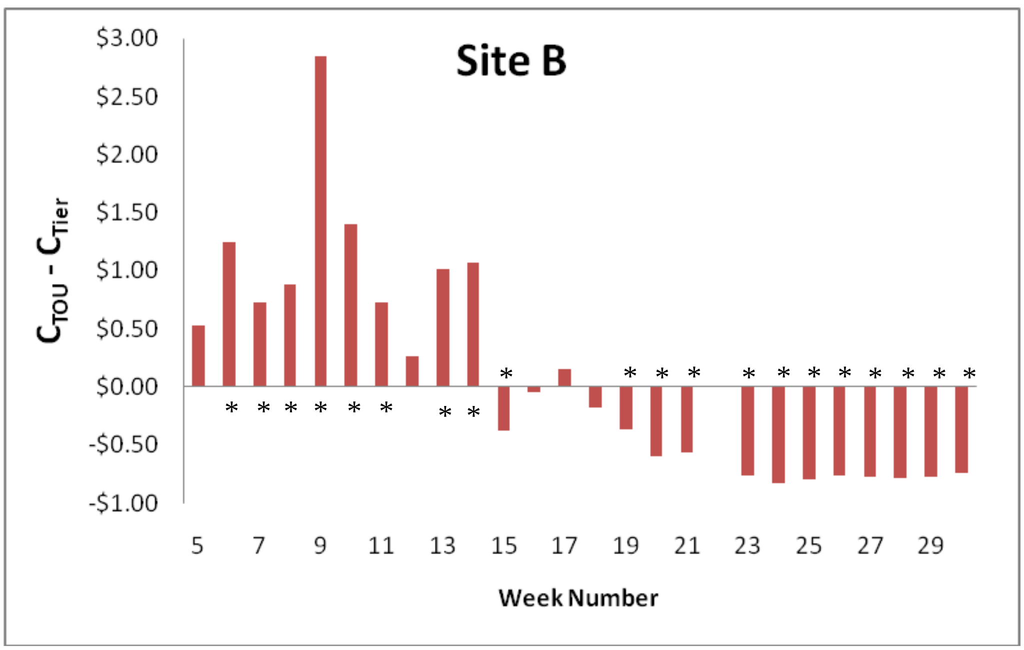

Figure 26. Difference in expected costs (TOU-TIER) at Site B.
* $C_{TOU} - C_{Tier}$ is significant.

	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	*Upper*			
Week 5	$.52650	$1.87353	$.26235	-$.00043	$1.05344	2.007	50	.050
Week 6	$1.24912	$2.79611	$.39153	$.46270	$2.03554	3.190	50	.002
Week 7	$.72652	$1.98987	$.27864	$.16686	$1.28618	2.607	50	.012
Week 8	$.88548	$1.97465	$.27651	$.33010	$1.44086	3.202	50	.002
Week 9	$2.84909	$3.83066	$.53640	$1.77170	$3.92648	5.312	50	.000
Week 10	$1.40368	$2.43639	$.34116	$.71843	$2.08892	4.114	50	.000
Week 11	$.72700	$1.85594	$.25988	$.20501	$1.24899	2.797	50	.007
Week 12	$.26368	$1.71018	$.23947	-$.21731	$.74468	1.101	50	.276
Week 13	$1.01102	$2.20508	$.30877	$.39083	$1.63121	3.274	50	.002
Week 14	$1.06953	$2.32535	$.32561	$.41551	$1.72354	3.285	50	.002
Week 15	-$.37245	$.94798	$.13274	-$.63908	-$.10583	-2.806	50	.007
Week 16	-$.04116	$1.22880	$.17207	-$.38677	$.30445	-.239	50	.812
Week 17	$.15737	$1.46515	$.20516	-$.25471	$.56945	.767	50	.447
Week 18	-$.17569	$1.29008	$.18065	-$.53853	$.18715	-.973	50	.335
Week 19	-$.36419	$.71841	$.10060	-$.56624	-$.16213	-3.620	50	.001
Week 20	-$.59943	$.51015	$.07144	-$.74291	-$.45594	-8.391	50	.000
Week 21	-$.57019	$.53896	$.07547	-$.72178	-$.41861	-7.555	50	.000
Week 23	-$.76712	$.22685	$.03177	-$.83092	-$.70332	-24.150	50	.000
Week 24	-$.83237	$.22667	$.03174	-$.89612	-$.76862	-26.225	50	.000
Week 25	-$.79641	$.24475	$.03427	-$.86525	-$.72757	-23.238	50	.000
Week 26	-$.76136	$.27601	$.03865	-$.83898	-$.68373	-19.699	50	.000
Week 27	-$.77331	$.22969	$.03216	-$.83792	-$.70871	-24.043	50	.000
Week 28	-$.78144	$.26047	$.03647	-$.85470	-$.70818	-21.425	50	.000
Week 29	-$.77151	$.28438	$.03982	-$.85149	-$.69152	-19.374	50	.000
Week 30	-$.73770	$.36661	$.05134	-$.84081	-$.63459	-14.370	50	.000

Table 40. Site B - Difference between expected weekly costs (C_{TOU}-C_{Tier}) during the post-TOU period

For Site C, as shown in Figure 27 and Figure 28, the Weekly costs associate with TOU rates are greater than the weekly costs associated with tiered rates for only the first weeks of the study. The results of the paired t-test imply that the TOU costs are not statistically different from the tiered cost for Week 3, Week 6, and Week 8 through Week 10, and Week 15, as shown in Table 41. The results imply that the TOU costs are significantly greater than the tiered cost for Week 4, Week 5, Week 7, Week 11 through Week 14, and Week 16 through Week 21. The greatest average difference during these Weeks is $0.30 in Week 14. Conversely, for Week 23 through Week 30, the results imply that the TOU costs are significantly less than what the tier costs would have been. The greatest average difference during these weeks is modest, at -$0.32 in Week 28.

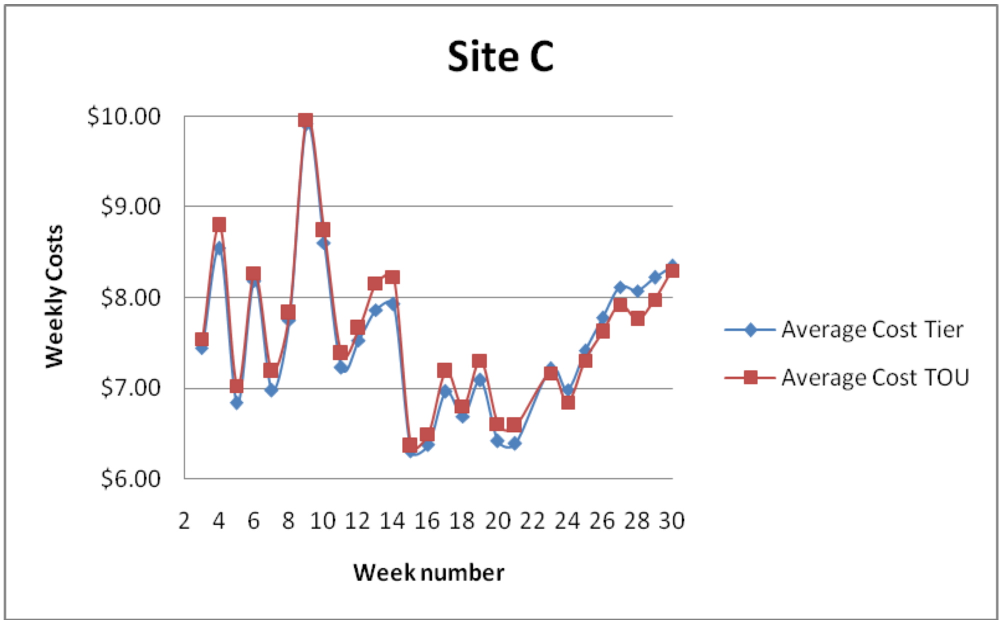

Figure 27. Weekly costs associated with TOU and Tiered rates at Site C.

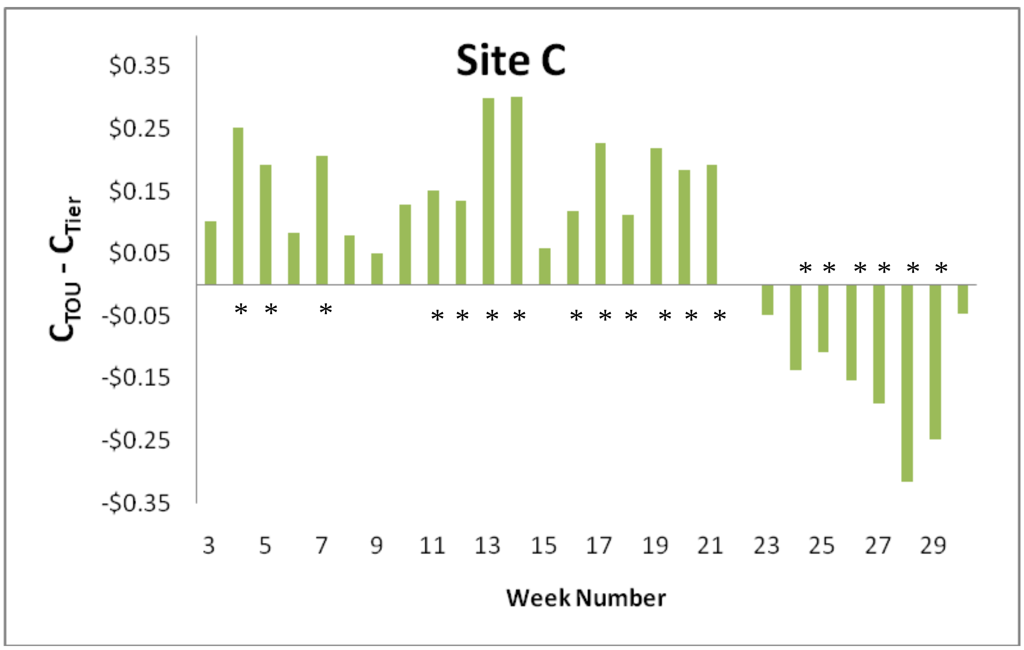

Figure 28. Difference in expected costs (TOU-TIER) at Site C.

* $C_{TOU} – C_{Tier}$ is significant.

	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	*Upper*			
Week 3	$.10076	$.55403	$.05283	-$.00393	$.20546	1.907	109	.059
Week 4	$.25189	$.62736	$.05982	$.13334	$.37045	4.211	109	.000
Week 5	$.19245	$.53460	$.05097	$.09143	$.29348	3.776	109	.000
Week 6	$.08407	$.51519	$.04912	-$.01329	$.18142	1.711	109	.090
Week 7	$.20630	$.53926	$.05142	$.10439	$.30820	4.012	109	.000
Week 8	$.07891	$.54927	$.05237	-$.02489	$.18271	1.507	109	.135
Week 9	$.04950	$.72727	$.06934	-$.08794	$.18693	.714	109	.477
Week 10	$.12837	$.73107	$.06970	-$.00978	$.26652	1.842	109	.068
Week 11	$.15186	$.53992	$.05148	$.04983	$.25389	2.950	109	.004
Week 12	$.13365	$.51292	$.04891	$.03672	$.23058	2.733	109	.007
Week 13	$.29873	$.53622	$.05113	$.19740	$.40006	5.843	109	.000
Week 14	$.30031	$.49564	$.04726	$.20665	$.39398	6.355	109	.000
Week 15	$.05909	$.38417	$.03663	-$.01350	$.13169	1.613	109	.110
Week 16	$.11746	$.41551	$.03962	$.03894	$.19598	2.965	109	.004
Week 17	$.22763	$.46279	$.04412	$.14018	$.31509	5.159	109	.000
Week 18	$.11102	$.46387	$.04423	$.02337	$.19868	2.510	109	.014
Week 19	$.21849	$.48632	$.04637	$.12659	$.31039	4.712	109	.000
Week 20	$.18350	$.45700	$.04357	$.09714	$.26986	4.211	109	.000
Week 21	$.19295	$.43980	$.04193	$.10984	$.27606	4.601	109	.000
Week 23	-$.04840	$.40975	$.03907	-$.12583	$.02904	-1.239	109	.218
Week 24	-$.13692	$.42746	$.04076	-$.21770	-$.05615	-3.360	109	.001
Week 25	-$.10763	$.55413	$.05283	-$.21235	-$.00291	-2.037	109	.044
Week 26	-$.15443	$.55657	$.05307	-$.25960	-$.04925	-2.910	109	.004
Week 27	-$.19149	$.51399	$.04901	-$.28862	-$.09436	-3.907	109	.000
Week 28	-$.31536	$.60264	$.05746	-$.42924	-$.20148	-5.488	109	.000
Week 29	-$.24889	$.52296	$.04986	-$.34772	-$.15007	-4.992	109	.000
Week 30	-$.04566	$.48726	$.04646	-$.13774	$.04642	-.983	109	.328

Table 41. Site C - Difference between expected weekly costs (C_{TOU}-C_{Tier}) during the post-TOU period

For Site D, as shown in Figure 29 and Figure 30, the weekly costs associated with TOU rates are greater than the weekly costs associated with tiered rates for only the first weeks of the study. The results of the paired t-test imply that the TOU costs are not statistically different from the tiered cost for Week 3 through Week 10, Week 12, Week 13 and Week 15 through Week 21, as shown in Table 42. The results imply that the TOU costs are significantly greater that the than the tiered cost for Week 11 and Week 14. The average difference for these Weeks is $0.36 and $0.42, respectively. Conversely, for Week 23 through Week 30, the results imply that the TOU costs are significantly less than what the tier costs would have been. The greatest average difference during these weeks is -$3.27 in Week 28.

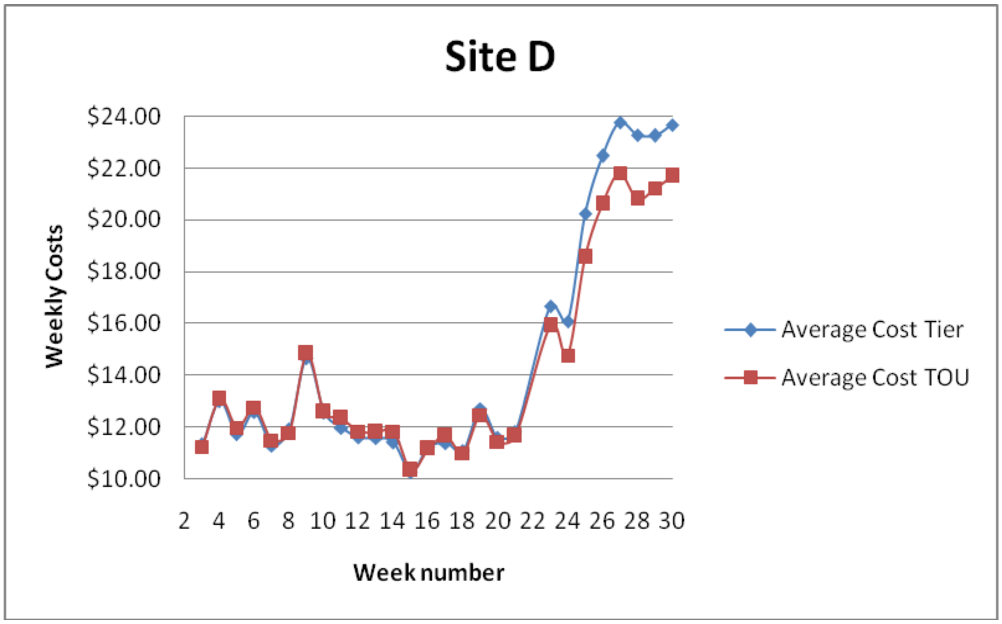

Figure 29. Weekly costs associated with TOU and Tiered rates at Site D.

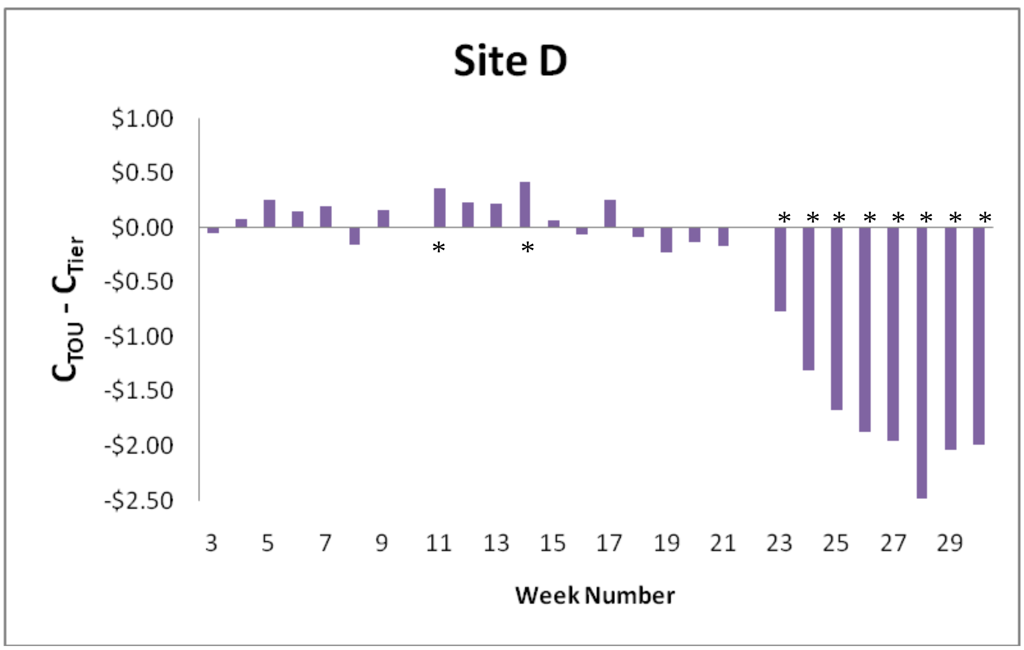

Figure 30. Difference in expected costs (TOU-TIER) at Site D.
* $C_{TOU} - C_{Tier}$ is significant.

	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	Upper			
Week 3	-$.05418	$.69891	$.13707	-$.33648	$.22811	-.395	25	.696
Week 4	$.07549	$.86062	$.16878	-$.27212	$.42310	.447	25	.659
Week 5	$.25420	$.72287	$.14177	-$.03777	$.54617	1.793	25	.085
Week 6	$.15484	$.75331	$.14774	-$.14943	$.45910	1.048	25	.305
Week 7	$.20043	$.66316	$.13006	-$.06742	$.46829	1.541	25	.136
Week 8	-$.15705	$.66892	$.13119	-$.42723	$.11314	-1.197	25	.242
Week 9	$.15583	$.78478	$.15391	-$.16115	$.47281	1.013	25	.321
Week 10	$.01382	$1.09422	$.21459	-$.42814	$.45579	.064	25	.949
Week 11	$.35882	$.57973	$.11370	$.12466	$.59298	3.156	25	.004
Week 12	$.23114	$.82012	$.16084	-$.10012	$.56240	1.437	25	.163
Week 13	$.22115	$.85901	$.16846	-$.12581	$.56811	1.313	25	.201
Week 14	$.41569	$.78482	$.15392	$.09870	$.73269	2.701	25	.012
Week 15	$.07255	$.69416	$.13614	-$.20783	$.35293	.533	25	.599
Week 16	-$.06442	$.67443	$.13227	-$.33683	$.20799	-.487	25	.630
Week 17	$.25896	$.77189	$.15138	-$.05281	$.57074	1.711	25	.100
Week 18	-$.08148	$.71323	$.13988	-$.36956	$.20660	-.583	25	.565
Week 19	-$.22902	$.90924	$.17832	-$.59627	$.13823	-1.284	25	.211
Week 20	-$.13191	$.86010	$.16868	-$.47931	$.21549	-.782	25	.442
Week 21	-$.16500	$.70157	$.13759	-$.44837	$.11837	-1.199	25	.242
Week 23	-$.76313	$1.40045	$.27465	-$1.32878	-$.19748	-2.779	25	.010
Week 24	-$1.31250	$1.74119	$.34148	-$2.01578	-$.60922	-3.844	25	.001
Week 25	-$1.67108	$1.64389	$.32239	-$2.33506	-$1.00710	-5.183	25	.000
Week 26	-$1.87125	$1.91194	$.37496	-$2.64350	-$1.09900	-4.991	25	.000
Week 27	-$1.95241	$1.85021	$.36286	-$2.69972	-$1.20509	-5.381	25	.000
Week 28	-$2.48483	$2.04573	$.40120	-$3.31112	-$1.65854	-6.193	25	.000
Week 29	-$2.03834	$1.71069	$.33549	-$2.72931	-$1.34738	-6.076	25	.000
Week 30	-$1.99463	$1.46732	$.28776	-$2.58729	-$1.40197	-6.931	25	.000

Table 42. Site D - Difference between expected weekly costs (C_{TOU}-C_{Tier}) during the post-TOU period

All sites showed general decrease over time in C_{TOU}-C_{Tier}. Meaning, as time when on, the costs associated with TOU rates generally became more favourable than the costs that would have been associated with tiered rates.

For Site A, C_{TOU}-C_{Tier} was positive for all weeks during the post-TOU period. This indicates that for these senior-headed households the costs associated with TOU rates were higher than what they would have been if the households had remained on tiered rates. However, the cost differences between the two rate structures are modest, and decreased over time. Site B, Site C and Site D, had a positive C_{TOU}-C_{Tier} value in the early weeks (i.e., summer TOU period) but then decreased over time to a negative value in the later weeks (i.e., the winter TOU period).

For Site B, the costs associated with TOU rates were significantly higher than what they would have been if the households remained on tiered rates for 12 out of 17 weeks during the summer period. Conversely, the costs associate with TOU rates were significantly lower than what they would have been if the households had remained on tiered rates for the winter period.

For Site C, the costs associated with TOU rates are significantly higher than what they would have been if the households remained on tiered rates for 13 out of 19 weeks during the summer period. Conversely, the costs associated with TOU rates were lower than what they would have been if the households had remained on tiered rates for six out of the eight weeks studied during the winter period.

For Site D, the costs associated with TOU rates were not significantly higher than what they would have been if the households remained on tiered rates for 17 out of 19 weeks during the summer period. For the other two weeks, TOU costs were slightly higher than the tiered costs would have been. Conversely, the costs associated with TOU rates were significantly lower for all weeks studied during the winter period.

Any additional costs and benefits that were realized by TOU rates were very modest across all sites. For example, the maximum average weekly savings under the TOU rate structure was $2.48 at Site D, which had the highest weekly electricity costs. The maximum average weekly loss under the TOU rate structure was $2.85 at Site B, which had moderate weekly electricity costs. With a few exceptions, C_{TOU}-C_{Tier} for each week was within the ± $1.00 range. One notable exception is Site D, which saw savings of about $2 per week once the households were started on the winter TOU rates.

These findings are slightly counter intuitive. Savings appear to be greater during the winter TOU period. One might have expected that savings would have been less during the winter because the tiered rates are designed to account for more consumption at a lower tier price (i.e., the lower tier increases from 600 kWh to 1000 kWh). However, as noted in the previous calculations, households appear to have a greater proportion of electricity consumed during off-peak periods during the winter period than the summer.

To investigate this further, a supplementary analysis was performed to determine if there were differences between summer costs and winter costs at each study site. For all households, the average weekly costs associated with TOU rates in the summer and winter, and the average weekly costs associated with tiered rates in the summer and winter were calculated. The average costs for each study site, as well as the percent difference between the two costs, are shown in Table 43.

Next, the average weekly C_{TOU}-C_{Tier} during the summer and the average weekly C_{TOU}-C_{Tier} during winter were calculated for each household. A paired t-test (95% confidence) was performed to determine if the average weekly C_{TOU}-C_{Tier} during the summer was different than the average weekly C_{TOU}-C_{Tier} during winter (shown in Table 44). The results indicate that the difference between the costs associated with TOU rates and tiered rates are significantly greater in the summer than the winter for all sites. TOU rates are shown to have a more positive financial impact in the summer – keeping in mind that Site A saw a cost increase under TOU rates.

Average Weekly Cost during post-TOU period						
	Summer			*Winter*		
	TOU	*Tier*	*Percent Difference*	*TOU*	*Tier*	*Percent Difference*
Site A	$3.46	$3.08	11%	$3.27	$3.10	5%
Site B	$5.19	$4.68	10%	$2.57	$3.35	-30%
Site C	$7.58	$7.42	2%	$7.61	$7.77	-2%
Site D	$11.95	$11.87	1%	$19.42	$21.18	-9%

Table 43. Weekly average costs during post-TOU period and percent difference

Summer($C_{TOU} – C_{Tier}$) minus Winter($C_{TOU} – C_{Tier}$)								
	Mean	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**		**t**	**df**	**Sig. (2-tailed)**
				Lower	*Upper*			
Site A	$0.20	$0.26	$0.08	$0.04	$0.37	2.696	11	.021
Site B	$1.29	$1.39	$0.19	$0.90	$1.68	6.637	50	.000
Site C	$0.32	$0.45	$0.04	$0.23	$0.40	7.393	109	.000
Site D	$1.84	$1.46	$0.29	$1.25	$2.43	6.439	25	.000

Table 44. Summer differences minus winter differences in electricity costs

As shown in Table 45, for Site A, the average weekly costs associated with TOU rates in the summer are significantly greater than the average weekly costs associated with tiered rates in the summer (p=0.000). Further, the average weekly costs associated with TOU rates in the winter are significantly greater than the average weekly costs associated with tiered rates in the winter (p=0.005). This is consistent with the results shown in Figure 24, which shows that the average weekly costs associated with TOU rates are significantly greater than the costs associated with tiered rates for all weeks during the post-TOU period. Further analysis reveals that the average weekly costs associated with TOU rates in the summer are not significantly different than the average weekly costs associated with TOU rates in the winter (p=0.664), and that the average weekly costs associated with tiered rates in the summer are not significantly different than the average weekly costs associated with tiered rates in the winter (p=0.956).

Site A								
				95% Confidence Interval of the Difference				
	Mean	**Std. Deviation**	**Std. Error Mean**	*Lower*	*Upper*	**T**	**df**	**Sig. (2-tailed)**
Summer C_{TOU} – Summer C_{Tier}	$.38	$.23	$.07	$.23	$.53	5.629	11	.000
Winter C_{TOU} – Winter C_{Tier}	$.18	$.18	$.05	$.06	$.29	3.457	11	.005
Summer C_{TOU} – Winter C_{TOU}	$.18	$1.42	$.41	-$.72	$1.09	.447	11	.664
Summer C_{Tier} – Winter C_{Tier}	-$.02	$1.18	$.34	-$.77	$.73	-.057	11	.956

Table 45. Site A – cost differences between winter and summer rate regimes.

As shown in Table 46, for Site B, the average weekly costs associated with TOU rates in the summer are significantly greater than the average weekly costs associated with tiered rates in the summer (p=0.012). Further, the average weekly costs associated with TOU rates in the winter are significantly less than the average weekly costs associated with tiered rates in the winter (p=0.000). This is consistent with the results shown in Figure 26, which show that the average weekly costs associated with TOU rates are significantly greater than the costs associated with tiered rates for most weeks in during the summer during the post-TOU period. Additionally, Figure 26 shows that the average weekly costs associated with TOU are less than the average weekly costs associated with tiered rates for all weeks during the winter during the post-TOU period. Further analysis reveals that the average weekly costs associated with TOU rates in the summer are significantly greater than the average weekly costs associated with TOU rates in the winter (p=0.000), and that the average weekly costs associated with tiered rates in the summer are significantly greater than the average weekly costs associated with tiered rates in the winter (p=0.000).

Site B								
				95% Confidence Interval of the Difference				
	Mean	**Std. Deviation**	**Std. Error Mean**	*Lower*	*Upper*	**T**	**df**	**Sig. (2-tailed)**
Summer C_{TOU} – Summer C_{Tier}	$.51	$1.42	$.20	$.12	$.91	2.593	50	.012
Winter C_{TOU} – Winter C_{Tier}	-$.78	$.23	$.03	-$.84	-$.71	-24.395	50	.000
Summer C_{TOU} – Winter C_{TOU}	$2.62	$2.87	$.40	$1.81	$3.43	6.508	50	.000
Summer C_{Tier} – Winter C_{Tier}	$1.33	$1.65	$.23	$.86	$1.79	5.750	50	.000

Table 46. Site B - cost differences between winter and summer rate regimes.

As shown in Table 47, for Site C, the average weekly costs associated with TOU rates in the summer are significantly greater than the average weekly costs associated with tiered rates in the summer (p=0.000). Further, the average weekly costs associated with TOU rates in the winter are significantly less than the average weekly costs associated with tiered rates in the winter (p=0.000). This is consistent with the results shown in Figure 27, which shows that the average weekly costs associated with TOU rates are significantly greater than the costs associated with tiered rates for most weeks in the summer during the post-TOU period. Additionally, Figure 28 shows that the average weekly costs associated with TOU are less than the average weekly costs associated with tiered rates for most of the winter weeks during the post-TOU period. Further analysis reveals that the average weekly costs associated with TOU rates in the summer are not significantly different than the average weekly costs associated with TOU rates in the winter (p=0.924), and that the average weekly costs associated with tiered rates in the summer are not significantly different than the average weekly costs associated with tiered rates in the winter (p=0.266).

Site C								
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	Df	Sig. (2-tailed)
				Lower	*Upper*			
Summer C_{TOU} – Summer C_{Tier}	$.16	$.35	$.03	$.10	$.23	4.906	109	.000
Winter C_{TOU} – Winter C_{Tier}	-$.16	$.41	$.04	-$.23	-$.08	-4.033	109	.000
Summer C_{TOU} – Winter C_{TOU}	-$.03	$2.98	$.28	-$.59	$.54	-.095	109	.924
Summer C_{Tier} – Winter C_{Tier}	-$.35	$3.24	$.31	-$.96	$.27	-1.118	109	.266

Table 47. Site C - cost differences between winter and summer rate regimes.

As shown in Table 48, for Site D, the average weekly costs associated with TOU rates in the summer are not significantly different than the average weekly costs associated with tiered rates in the summer (p=0.389). Further, the average weekly costs associated with TOU rates in the winter are significantly less than the average weekly costs associated with tiered rates in the winter (p=0.000). This is consistent with the results shown in Figure 30, which shows that the average weekly costs associated with TOU rates are not significantly different than the costs associated with tiered rates for most of the summer weeks during the post-TOU period. Additionally, Figure 30 shows that the average weekly costs associated with TOU are less than the average weekly costs associated with tiered rates for all weeks during the winter during the post-TOU period. Further analysis reveals that the average weekly costs associated with TOU rates in the summer are significantly less than the average weekly costs associated with TOU rates in the winter (p=0.000), and that the average weekly costs associated with tiered rates in the summer are significantly less than the average weekly costs associated with tiered rates in the winter (p=0.266).

Site D								
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
				Lower	*Upper*			
Summer C_{TOU} – Summer C_{Tier}	$.08	$.47	$.09	-$.11	$.27	.876	25	.389
Winter C_{TOU} – Winter C_{Tier}	-$1.76	$1.62	$.32	-$2.41	-$1.11	-5.560	25	.000
Summer C_{TOU} – Winter C_{TOU}	-$7.47	$5.81	$1.14	-$9.82	-$5.12	-6.554	25	.000
Summer C_{Tier} – Winter C_{Tier}	-$9.31	$7.07	$1.39	-$12.17	-$6.45	-6.712	25	.000

Table 48. Site D - cost differences between winter and summer rate regimes.

For further analysis related to this fourth question, an additional regression analysis using ANOVA was performed to determine if there is a change in this cost difference ($C_{TOU} – C_{Tier}$) over time. As shown in Table 49, only Site B saw a statistically significant change in $C_{TOU} – C_{Tier}$ during the summer post-TOU period. This change means the difference between the TOU costs and the tiered costs decreased over time. The change is consistent with the trend demonstrated in Figure 26, which shows $C_{TOU} – C_{Tier}$ moving from positive to negative over the summer post-TOU period. Also, this finding is consistent with the findings from the previous section, which shows that households from Site B have a slight decrease (0.2% per week) in the percentage of electricity consumed during the on-peak period.

	Summer post-TOU period (Weeks 1-21)			Winter post-TOU period (Weeks 23-30)		
	Average $C_{TOU} – C_{Tier}$	*Slope*	*Sig. for slope*	*Average $C_{TOU} – C_{Tier}$*	*Slope*	*Sig. for slope*
Site A	$0.38	-.005	.406	$0.18	.002	.734
Site B	$0.51	-.123	.002*	$0.78	.006	.139
Site C	$0.16	.002	.455	- $0.16	- .014	.363
Site D	$0.08	-.011	.165	- $1.76	- .176	.012*

Table 49. Summer and winter change in costs during the post-TOU period
*Significant difference at 95 % confidence.

Also shown in Table 49, is that only Site D had a statistically significant change in $C_{TOU} – C_{Tier}$ during the winter post-TOU period. This change means the difference between the TOU costs and the tiered costs decreased over time. The change is consistent with the trend demonstrated in Figure 30, which shows $C_{TOU} – C_{Tier}$ generally decreasing over the winter post-TOU period. Interestingly, this seems to suggest that there is some change in behaviour upon the implementation of TOU rates during the winter post-TOU period. However, residents at Site D do not pay for their own electricity bill, so it is difficult to attribute this change to the implementation of TOU rates.

4.2.6 Summary of quantitative findings

1. Do the households benefit naturally from TOU rates?

No, these findings suggest that the households would not benefit naturally from the implementation of TOU rates, at least not during the summertime period. That is, they would have to change their electricity consumption behaviour in order to benefit financially from TOU rates, given their electricity consumption behaviour during the pre-TOU period. It is important to note that the pre-TOU period was very short for these sites. Therefore, this result should be interpreted with caution. The pre-TOU period may not be reflective of the electricity consumption behaviour that may be exhibited by these households during other times of the year.

2. Do the households conserve electricity upon the implementation of TOU rates?

A conservation effect was primarily observed at the two sites representing lower-income households. For Site C, the conservation effect was observed for all corresponding billing periods except for the billing periods that corresponded to the winter months of November and December. During this last billing period of the year, there was no significant difference between the amounts of electricity consumed during the two corresponding billing periods. For Site D, a conservation effect was observed for all corresponding billing periods.

For Site B, representing senior-headed households, a conservation effect was observed for three out of five corresponding billing periods, which is close to the response observed from the two sites representing lower-income households. Site B consumed less electricity than Site C and Site D.

A limited conservation effect was observed at the Site A, which represented senior-headed households. Here, the conservation effect was only observed for the corresponding billing periods that were associated with the month of July. Site A consumed less electricity than all of the other sites in this study.

It appeared that the largest conservation effect was observed during the first billing period in which TOU rates were implemented. Perhaps this was a ‘cautious response’ to TOU rates from the individuals within the study sites. In other words, perhaps the households made a greater effort to conserve in during the first billing period on TOU rates because they were unsure about the impacts of TOU rates.

Worthy of note as well, is the conservation response from Site D. Recall from Table 4, which showed that households within Site D do not pay for their own electricity bills. Therefore, the response from this group is unexpected. Unfortunately, this result cannot be further explained. It is unclear whether there were different factors influencing the behaviour at this site. For example, the households could have been fitted with energy efficient appliances that were not known to this researcher.

3. *Do the households shift the time when they consume electricity upon the implementation of TOU rates?*

The findings from this study suggest that, on average, the households within the sites show little or no shift in their electricity use patterns in response to the TOU price signal. That is, these households do not appear to shift electricity consumption away from on-peak periods as a result of the implementation of TOU rates. Site A and Site D show no shift in electricity consumption between the peak periods. Site B and Site C show a slight reduction in the proportion of electricity consumed during the on-peak period in the summer TOU period, however this reduction was minimal (i.e., less than 1%), and was not met with a significant increase in another peak period.

4. *Do TOU rates change the costs of the household electricity bill?*

Yes, the cost of electricity changed after the implementation of TOU rates. Site A (senior-headed households) spent more money on electricity under TOU than they would have under the tiered rate structure during both the summer and the winter post-TOU periods.

For all other sites, they appear to spend less money under the TOU rate structure than they would have under the tiered rate structure during the winter TOU period. Site B and Site C showed similar findings; both showed that the costs associated with TOU rates during the summer were greater than the costs that would have been under the tiered rate structure. However, during the winter post-TOU periods, both sites saw significant savings. It is not expected that these households changed their response (e.g., by shifting), therefore it can be concluded that the existing electricity consumption behaviour within the households is more favourable for the winter TOU rate schedule.

For Site D, the costs associated with TOU rates were not significantly different than what they would have been under tiered rates during the summer post-TOU period. However, during the winter, similar to latter two sites, households at Site D had less electricity costs under the TOU rate regime than they would have if they had remained on tiered rates.

4.2.7 *Further analysis to reflect household characteristics*

The following paragraphs compare the analytical results to the household characteristics that were found in the questionnaires. Since only 21% of the questionnaires were returned, mostly from senior-headed households, the findings presented below are only descriptive, and not statistically valid. Therefore, the results should be interpreted with caution. Note that due to low questionnaire response rate, the data from the questionnaires are aggregated.

4.2.7.1 *Household characteristics and expected natural benefits*

During the pre-TOU period, C_{TOU}-C_{Tier} was calculated for all households. A positive value indicated that, given the current electricity consumption patterns, the household would be expected to pay more under the TOU rate regime than the tiered rate regime. Although the results indicated that the study sites would not benefit naturally from the implementation of TOU rates, individual household costs and benefits varied within each site. To investigate these findings further, the frequency of 'positive' values was compared to household characteristics. Recall that a positive result means that the costs associated with TOU rates would be higher than the costs associated with tiered rates. The results are shown in Table 50 below.

Household Characteristic	n	$C_{TOU} < C_{Tier}$ during the pre-TOU period
Some grade school to some high school	11	9%
Completed high school to completed technical school	15	7%
Some university to completed university degree(s)	12	42%
Households with only one person	19	5%
Households with more than one person	21	29%
No Children	36	14 %
With Children	4	50%
Households with seniors	29	7%
Households without seniors	11	45%
Households with one person home during on-peak period	24	12%
Households with more than one person home during on-peak period	16	25%
Households without children home during on-peak period	37	33%
Households with children home during on-peak period	3	16%
Households with incomes less than $25,000	9	100%
Households with incomes between $25,000-$49,999	21	24%
Households with incomes greater than $50,000	4	50%
Households with 3 or less appliances	6	100%
Households with 4 or 5 appliances	19	21%
Households with 6 or 7 appliances	16	19%

Households with 1 bedroom	16	6%
Households with 2 bedrooms	13	8%
Households with 3 bedrooms	6	33%
Households with 4 bedrooms	3	67%

Table 50. Proportion of households that are expected to benefit naturally

These additional findings tentatively suggest that:

- Households with higher levels of education are more likely to benefit naturally from TOU rates than those with lower levels of education;
- Households with more than one person in the home are more likely to benefit naturally from TOU rates than those with only one person in the home;
- Households with children are more likely to benefit naturally from TOU rates than those without children;
- Households without seniors are more likely to benefit naturally from of TOU rates than those with seniors;
- Households with more than one person home during the on-peak period are more likely to benefit naturally from TOU rates than those with only one person at home during on-peak periods;
- Households without children at home during the on-peak period are more likely to benefit from TOU rates than those with children at home;
- Households with higher incomes are more likely to benefit naturally from TOU rates than those with lower incomes;
- Households with more appliances are more likely to benefit naturally from TOU rates than those with fewer appliances;
- Households with more bedrooms are more likely to benefit naturally from TOU rates than those with fewer bedrooms.

4.2.7.2 Household characteristics and observed conservation effects

Although the results showed that the sites had a conservation effect for several corresponding billing periods, this effect varied at individual households within with the sites. To investigate these findings further, the consumption of electricity during the 2006 study period (all billing periods) was compared to the consumption of electricity during the 2007 study period. If the 2006 electricity consumption was less than the 2007 electricity consumption, then a conservation effect was observed.

The frequency of households where a conservation effect was observed was compared to household characteristics. The results are shown in Table 52 below.

Household characteristic	n	Conservation effect observed
Some grade school to some high school	11	91%
Completed high school to completed technical school	15	60%
Some university to completed university degree(s)	12	83%
Households with only one person	19	79%
Households with more than one person	21	76%
No Children	36	78%
With Children	4	75%
Households with seniors	29	79%
Households without seniors	11	73%
Households with one person home during on-peak period	24	75%
Households with more than one person home during on-peak period	16	81%
Households without children home during on-peak period	37	76%
Households with children home during on-peak period	3	100%
Households with incomes less than $25,000	9	78%
Households with incomes between $25,000-$49,999	21	71%
Households with incomes greater than $50,000	4	74%
Households with 3 or less appliances	6	100%
Households with 4 or 5 appliances	19	68%
Households with 6 or 7 appliances	16	81%
Households with 1 bedroom	16	75%
Households with 2 bedrooms	13	84%
Households with 3 bedrooms	6	67%
Households with 4 bedrooms	3	100%

Table 51. Proportion of households with conservation effect observed

These additional findings tentatively suggest that:

- There does not seem to be a clear relationship between education and the presence of a conservation effect as a result of TOU rates;
- Differences in the number of people living at home does not appear to affect the likeliness to have a conservation effect as a result of TOU rates;
- Having children at home does not appear to affect the likeliness to have a conservation effect as a result of TOU rates;

- Having seniors at home does not appear to affect the likeliness to have a conservation effect as a result of TOU;
- Households with more than one person at home during the on-peak periods does not appear to affect the likeliness to have a conservation effect as a result of TOU rates;
- Households without children at home during on-peak periods are less likely to have a conservation effect as a result of TOU rates;
- Differences in income do not appear to affect the likeliness to have a conservation effect as a result of TOU rates;
- Households with few appliances are more likely to have a conservation effect as a result of TOU rates; however, households with 4-5 appliances are less likely to have a conservation effect than households with 6-7 appliances;
- Households with many bedrooms are more likely to have a conservation effect as a result of TOU rates.

4.2.7.3 Household characteristics and the response to TOU price signal

Although the results showed that the sites did not have a significant response to TOU rates, the responses at individual households varied within the sites. To investigate these findings further, the overall shift of electricity was determined by evaluating the slope of the line, positive slopes indicating shift toward the peak, and negative slope indicating shift away from the peak. The frequency of households with a positive slope was compared to the household characteristics. The results are shown in Table 52 below.

Household characteristic	n	On-peak Increase	Mid-peak Increase	Off-peak Increase
Some grade school to some high school	11	55%	0%	82%
Completed high school to completed technical school	15	73%	7%	70%
Some university to completed university degree(s)	12	75%	0%	75%
Households with only one person	19	0%	0%	84%
Households with more than one person	21	5%	5%	76%
No Children	36	67%	0%	81%
With Children	4	75%	25%	75%
Households with seniors	29	82%	0%	83%
Households without seniors	11	62%	9%	73%
Households with one person home during on-peak period	24	58%	0%	88%
Households with more than one person home	16	81%	6%	69%

during on-peak period				
Households without children home during on-peak period	37	68%	0%	81%
Households with children home during on-peak period	3	67%	33%	67%
Households with incomes less than $25,000	9	44%	11%	78%
Households with incomes between $25,000-$49,999	21	76%	0%	81%
Households with incomes greater than $50,000	4	100%	0%	75%
Households with 3 or less appliances	6	83%	0%	83%
Households with 4 or 5 appliances	19	36%	0%	32%
Households with 6 or 7 appliances	16	62%	6%	68%
Households with 1 bedroom	16	56%	0%	81%
Households with 2 bedrooms	13	62%	0%	84%
Households with 3 bedrooms	6	89%	11%	78%
Households with 4 bedrooms	3	67%	0%	67%

Table 52. Proportion of households with increases in peak consumption

These additional findings tentatively suggest that:

- Households with higher education levels are more likely to increase the proportion of electricity consumed during on-peak periods and are less likely to increase the proportion of electricity consumed during off-peak periods;
- Having more than one person in the home does not appear to change the likeliness of a shift in electricity consumption;
- Households with children are more likely to see an increase in the proportion of electricity consumed during the mid-peak period;
- Households with seniors are more likely to increase in the proportion of electricity consumed during the on-peak periods, and they are more likely to increase the proportion of electricity consumed during off-peak periods;
- Households with more than one person home during the on-peak period are more likely to increase the proportion of electricity consumed during the on-peak period than households with only one person at home during the on-peak period, and they are less likely to reduce the proportion of electricity consumed during off-peak periods;
- Households with children home during on-peak periods are more likely to increase the proportion of electricity consumed during mid-peak periods, and are less likely to increase the proportion of electricity consumed during off-peak periods;

- Households with higher incomes are more likely to increase the proportion of electricity consumed during on-peak periods.
- There does not seem to be a clear relationship between appliance ownership and the proportion of electricity consumed during on-peak periods.

4.2.7.4 Household characteristics and the change in cost of electricity

Although the results indicated that some sites were expected to save money during the winter TOU period, while others were expected to spend more on tiered rates, the change in the cost of electricity of individual households varied within the sites. To explore this change further, the frequency of an increase in costs (i.e., $C_{TOU}>C_{Tier}$) during both the summer and winter post-TOU periods was compared to several household characteristics. The results are shown in Table 53 below.

Household characteristic	n	$C_{TOU}>C_{Tier}$ during the summer post-TOU period	$C_{TOU}>C_{Tier}$ during the winter post-TOU period
Some grade school to some high school	11	55%	18%
Completed high school to completed technical school	15	80%	20%
Some university to completed university degree(s)	12	58%	17%
Households with only one person	19	63%	26%
Households with more than one person	21	66%	10%
No Children	36	64%	17%
With Children	4	75%	25%
Households with seniors	29	74%	21%
Households without seniors	11	46%	9%
Households with one person home during on-peak period	24	58%	25%
Households with more than one person home during on-peak period	16	75%	6%
Households without children home during on-peak period	37	65%	19%
Households with children home during on-peak period	3	67%	0%
Households with incomes less than $25,000	9	67%	22%
Households with incomes between $25,000-	21	71%	14%

$49,999			
Households with incomes greater than $50,000	4	50%	25%
Households with 3 or less appliances	6	100%	83%
Households with 4 or 5 appliances	19	63%	11%
Households with 6 or 7 appliances	16	56%	0%
Households with 1 bedroom	16	69%	13%
Households with 2 bedrooms	13	77%	23%
Households with 3 bedrooms	6	56%	22%
Households with 4 bedrooms	3	33%	0%

Table 53. Proportion of households with higher costs associated with TOU rates

These additional findings tentatively suggest that:

- Households with a higher level of education and households with a lower level of education are less likely than households with a moderate level of education to have an increase in their electricity bill during the summer post-TOU period;
- Households with more than one person are less likely than households with only one person to have an increase in their electricity bill during the winter post-TOU period;
- Households without children are less likely than households with children to have an increase in their electricity bill during the summer post-TOU period;
- Households without seniors are less likely than households with seniors to have an increase in their electricity bill during the summer post-TOU period and the winter post-TOU period;
- Households with only one person at home during the on-peak period are less likely than households with more than one person at home during the on-peak period to have an increase in their electricity bill during the summer post-TOU period and the winter post-TOU period;
- Households with children at home during the on-peak period are less likely than households without children at home during the on-peak period to have an increase in their electricity bill during the winter post-TOU period;
- Households with higher incomes are less likely than households with lower incomes to have an increase in their electricity bill during the summer post-TOU period;
- Households with fewer appliances are less likely than households with more appliances to have an increase in their electricity bill during the summer post-TOU period and the winter post-TOU period;
- Households with fewer bedrooms are less likely than households with more appliances to have an increase in their electricity bill during the summer post-TOU period.

4.2.7.8 Summary of further analysis

The expanded analysis provides more insight to the research findings, even though the results should be interpreted with caution. There are a number of interesting findings that should be noted.

Within the sample sites, households with seniors appear to be:

1. Less likely to benefit naturally from TOU rates compared to households without seniors;
2. More likely to increase the proportion of on-peak electricity consumption compared to households without seniors;
3. More likely to have an increase in their electricity bill in the post-TOU period compared to households without seniors.

Within the sample sites, households with the lowest incomes (e.g., the lowest incomes within the study site) appear to be:

1. Less likely to benefit naturally from TOU rates compared to households with modestly higher incomes;
2. Less likely to increase the proportion of on-peak electricity consumption compared to households with modestly higher incomes,
3. More likely to increase the proportion of electricity consumed during mid-peak periods compared to households with modestly higher incomes;
4. More likely to have an increase in their electricity bill in the post-TOU period compared to households with modestly higher incomes (about the same as those with median incomes).

Within the sample sites, households with the highest education levels appear to be:

1. More likely to benefit naturally from TOU rates compared to those with lower education levels;
2. More likely to increase the proportion of on-peak electricity consumption compared to those with lower education levels;

Within the sample sites, households with children appear to be:

1. More likely to benefit naturally from TOU rates compared to households without children;
2. More likely to increase the proportion of on-peak electricity compared to households without children;

3. More likely to have an increase in their electricity bill in the post-TOU period compared to households without children.

Throughout this chapter, there have been several significant and interesting findings that in some ways support the academic literature to date. However, there are several instances where the findings from this study are counter to the expectations as set out in the existing literature. In the next chapter, the findings from this study are compared to the academic literature on the impacts of TOU rates on lower-income and senior-headed households.

Chapter 5: Discussion and Conclusions

Presented in Table 54 is a summary of the major findings from the analysis of electricity consumption data collected from the four study sites, representing lower-income and senior-headed households in Milton, Ontario. On average, none of the households within the study sites benefited naturally given their pre-TOU period electricity consumption behaviour which occurred during July 2007. Site A, Site B and Site C would have had higher costs under the TOU rate regime than under the tiered rate regime. The differences in costs between the two rate regimes ranged from $0.15 per week to $0.61 per week. For Site D, there was no difference between the costs associated with tiered rates and what the costs would have been under TOU rates.

All sites were shown to have some conservation effect after the implementation of TOU rates. For Site A, a conservation effect was observed for the first corresponding billing period (35%), however, no conservation effect was observed for any subsequent billing periods during the study period. For Site B, a conservation effect was observed for three out of five corresponding billing periods during the study period (21%, 24%, and 9%, respectively). For Site C, a conservation effect was observed for five out of six corresponding billing periods during the study period (21%, 21%, 12%, 9% and 8%, respectively). For Site D, a conservation effect was observed for all corresponding billing periods during the study period (20%, 31%, 34%, 26%, 14%, and 10%, respectively). All sites showed a conservation effect during the first corresponding billing period and the conservation effect, if observed, appeared to be greater in the summer than in the winter. A possible reason for this trend may be that the people within the households made a greater effort to reduce electricity usage immediately after TOU rates were implemented because they were unsure, or concerned, about the impacts to their electricity bill. However, the reason for this apparent trend remains unknown.

Despite any observed conservation effect, the study sites showed either no response to, or only a slight response to, TOU rates by changing the proportion of electricity consumed during the on-, mid-, and off-peak periods. This result is based on the assumption that the households did not change their electricity consumption behaviour prior to June 2007 when they would have received an information package about the new TOU rate regime. When considering only the summer post-TOU period, Site B and Site C demonstrated a slight reduction in the proportion of electricity consumed during the on-peak period (0.2% per week and 0.1% per week, respectively). This reduction, however, would not have a significant impact on the household electricity bill. Due to differences in the summer and winter TOU peak schedules (e.g., the time of each peak period), the sites consume a greater proportion of their electricity during the off-peak period during the winter compared to the summer.

	Site A	Site B	Site C	Site D
1	C_{TOU} are greater than C_{Tier} during the pre-TOU period. *Mean $C_{TOU} - C_{Tier}$ = \$0.34 per week*	C_{TOU} are greater than C_{Tier} during the pre-TOU period. *Mean $C_{TOU} - C_{Tier}$ = \$0.61 per week*	C_{TOU} are greater than C_{Tier} during the pre-TOU period. *Mean $C_{TOU} - C_{Tier}$ = \$0.15 per week*	C_{TOU} are not different from C_{Tier} during the pre-TOU period.
2	A conservation effect was observed for the first corresponding billing period (B7), but not for any other billing period. *Mean change = 35% for B7*	A conservation effect was observed for the first, second and fifth corresponding billing periods (B8, B9, B12), but not for the other billing periods (B10, B11). *Mean change = 21%, 24% and 9% for B8, B9 and B12, respectively.*	A conservation effect was observed for the first five corresponding billing periods (B7 to B11), but not for B12. *Mean change = 21%, 21%, 12%, 9% and 8% for B7 to B11, respectively.*	A conservation effect was observed for all corresponding billing periods (B7 to B12). *Mean change = 20%, 31%, 34%, 26%, 14%, and 10% for B7 to B12, respectively*
3	There was no change in the proportion of electricity used during any of the on-, mid- or off-peak periods.	There was no change in the proportion of electricity used during the mid- or off-peak periods. During the summer TOU period, there was a reduction in the proportion of electricity consumed during the on-peak period. *Mean reduction in proportion consumed on-peak = 0.2% per week*	There was no change in the proportion of electricity used during the mid- or off-peak periods. During the summer TOU period, there was a reduction in the proportion of electricity consumed during the on-peak period. *Mean reduction in proportion consumed on-peak = 0.1% per week*	There was no change in the proportion of electricity used during any of the on-, mid- or off-peak periods.
4	C_{TOU} are greater than C_{Tier} during the post-TOU period. This difference is greater during the summer post-TOU period than the winter post-TOU period. *Mean $C_{TOU} - C_{Tier}$ = \$0.38 per week (summer rates)* *Mean $C_{TOU} - C_{Tier}$ = \$0.18 per week (winter rates)*	During the summer post-TOU period C_{TOU} are greater than C_{Tier}. During the winter post-TOU period C_{TOU} are less than C_{Tier}. *Mean $C_{TOU} - C_{Tier}$ = \$0.51 per week (summer rates)* *Mean $C_{TOU} - C_{Tier}$ = -\$0.78 per week (winter rates)*	During the summer post-TOU period C_{TOU} are greater than C_{Tier}. During the winter post-TOU period C_{TOU} are less than C_{Tier}. *Mean $C_{TOU} - C_{Tier}$ = \$0.16 per week (summer rates)* *Mean $C_{TOU} - C_{Tier}$ = -\$0.16 per week (winter rates)*	During the summer post-TOU period C_{TOU} are not different from C_{Tier}. During the winter post-TOU period C_{TOU} are less than C_{Tier}. *Mean $C_{TOU} - C_{Tier}$ = -\$1.76 per week (winter rates)*

Table 54. Summary of major findings from all study sites

During the summer post-TOU period, the observed changes in the electricity costs are consistent with the changes observed during the pre-TOU period. For Site A, Site B and Site C, the costs associated with TOU rates were greater than the costs associated with tiered rates. The average difference in costs between the two rate regimes ranged for these sites from $0.16 per week to $0.51 per week. For Site D, there was no difference between the costs associated with TOU rates and the costs associated with tiered rates during the summer post-TOU rates.

The change in the electricity costs differed between the summer and the winter post-TOU period. For Site A, although the costs associated with TOU rates remained greater than what the costs would have been under tiered rates, the difference between these two rate regimes was less during the winter post-TOU period. For the other three sites, the costs associated with TOU rates were less than what the costs would have been under tiered rates. The average difference in costs between the two rate regimes for these sites ranged from $0.16 per week to $1.76 per week. Note that the change in the costs of electricity does not reflect any savings that may be attributed to a conservation effect.

The observed conservation effect was an unexpected result, particularly for Site D. Recall that households at Site D are not responsible for paying their electricity bill directly; instead the bill is paid for by their affordable housing provider. It is unclear whether the conservation effect can be attributed to the implementation of TOU rates, or if there were other factors that influenced the change. Since there was little to no shift in the proportion of electricity consumed during the peaks, the reduction in energy usage must have occurred proportionately within each peak. This leads one to believe that structural changes to the households may have occurred. However, facts to support this belief are unknown to the researcher.

The remainder of this chapter is divided into five sections. This chapter will demonstrate how the findings from this study support the present academic literature and will show how the findings contradict the literature. In the first section, the findings from the elite-level interviews are compared to the academic literature. Second, the findings from the analysis of the electricity consumption patterns and costs from lower-income and senior-headed households are compared to the academic literature. Third, the findings from the analysis of electricity consumption patterns and costs from lower-income and senior-headed households are compared to the elite-level interviews that were conducted for this study. The forth section of this chapter provides a final summary of the conclusions of this thesis. Finally, fifth section of this chapter gives recommendation for policy analysts and academics.

5.1 Comparison of elite-level interviews and the literature

There was a 'mixed-opinion' discovered in the interviews surrounding the financial and behavioural impacts of TOU rates. Some interview participants thought that TOU rates would provide an opportunity for lower-income and senior-headed households to save money. This perception is similar to the rational-economic model, which assumes that people will undertake energy conservation behaviours if the actions are financially beneficial. Presumably, this group of interview participants believed that the lower-income and senior-headed households would change electricity consumption behaviour because they would want to save money under the new rate regime.

On the other hand, other interview participants thought that there was a serious risk for lower-income and senior-headed households to have an increase in their electricity bill. Other participants believed that the impact would be marginal. The interview participants who expressed a concern about TOU rates believed that lower-income and senior-headed households had fewer discretionary electrical loads and a more fixed schedule. In other words, these interview participants did not believe that lower-income and senior-headed households had the ability to take full advantage of TOU rates because they have limited access to household appliances and because their schedules were thought to be inflexible.

For example, these households might not have access to appliances and would therefore be unable to move the use of electrical loads from on-peak periods to off-peak periods to take advantage of cheaper off-peak rates. Likewise, lower-income households with family members who work shifts may have less flexibility in their schedule, which makes them less able to choose to use appliances during off-peak periods. Similarly, seniors who are at home during the day may require the use of air conditioning for medical reasons and will chose to use it regardless of the price. This mixed-opinion from the interview participants is similar to the mixed-opinion within the present body of literature. For example, Blocker (1985) reports that senior-headed households should benefit immediately from the implementation of TOU rates, while Warriner (1981) shows concern that senior-headed households are vulnerable to electricity bill increases under the TOU rate structure.

Many of the interview participants expressed concern about the limited awareness of TOU rates and energy conservation options within the households. This lack of awareness can limit the household's ability to conserve electricity effectively and can limit the household's ability to shift electricity to off-peak periods. This finding is also consistent with the academic literature. For example, studies by Stern (1986), Lutzenhiser (1993), and Samuelson (1990) all express concern that people make poor decisions with respect to conservation because they have limited or incomplete information to make educated choices. As Stern (1986) highlights, electricity users, within the general population, might not have a good understanding about the best way to reduce electricity consumption. In other words, people respond to changes in price because they have an awareness of the price signal.

All of the interview participants expected that lower-income and senior-headed households would not be able to conserve as well as other more affluent households because they had limited access to capital, which is needed to make investments in energy efficiency. This finding is consistent with Dillman and Dillman (1983), who found that lower-income households are less likely to invest in energy efficient technologies and are more likely to engage in curtailment behaviour when faced with rising energy costs. Access to capital to cover upfront costs of energy efficient technologies is recognized as a barrier to conservation, as discussed the literature review.

The tenant-landlord relationship was also a reoccurring point throughout the interviews. Participants generally thought that tenants were less able to invest in energy efficiency and less able to respond to TOU rates due to lack of control over their living environment. This finding is again consistent with the literature. For example, the Public Interest Advocacy Center (2006) reported that property owners lack an incentive to invest in energy efficiency measures in the household when electricity costs are paid for by a tenant. Further, Tienda and Aborampah (1981) found that renters were less likely to invest in energy efficiency because they did not consider their house a permanent living space.

Another finding from the interviews was that households with children and households with seniors were thought to be more likely to experience negative impacts because of TOU rates, which is consistent with several studies found in the literature. For example, Samuelson (1990) explains that households with children may have greater difficulty conserving because children tend to use energy wastefully and do not understand the costs associated with its use. Additionally, Solano and Sparling (1985) report that senior-headed households with fixed incomes are at greater risk to increases in electricity costs and may have fewer options for conservation. Warriner (1981) also reports that seniors pay proportionately more of their income on electricity compared to other demographics.

Overall, the findings from the literature and the findings from the elite-level interviews conducted for this study are generally consistent with each other. In a sense, this is not a surprising occurrence. The interview participants in this study were all respected in their sector and all highly educated. As a result, their opinions on the issues related to energy consumption, conservation and lower-income and senior-headed households were likely influenced by the current body of academic literature.

5.2 Comparison of quantitative findings and the literature

The results from the quantitative analysis are consistent with Warriner's (1981) study that evaluated the impacts of TOU rates on senior-headed households. Similar to this study, Warriner (1981) found that senior-headed households use less electricity than non-senior-headed households. The senior-headed households in Site A and Site B in this study did not benefit naturally from the implementation of TOU rates; they had less of a conservation effect than Site C and Site D, and had little to no shift in electricity use patterns. These sites were also at greater risk of a bill increase than Site C and Site D.

The results from this study are to some extent inconsistent with the study performed by Blocker (1985), which evaluated the ability of TOU rates to reduce the electricity bill of lower-income and senior-headed households. Blocker (1985) stated that senior-headed households were likely to see an immediate benefit from the implementation of TOU rates. The findings from this thesis are different from Blocker's (1985) results; the senior-headed households (Site A and Site B) are shown not to benefit naturally - at least not during the pre-TOU period, and summer TOU period that was studied. Households at Site A were shown to have an increase in their electricity bill during the post-TOU period. On the other hand, households at Site B were shown to have increases in their electricity bill during the summer post-TOU period and savings during the winter post-TOU period.

Blocker (1985) also concludes that lower-income households would be required to change their existing energy consumption behaviour in order to benefit from TOU rates. The results of this thesis imply that lower-income households would have to change their electricity consumption behaviour during the summer TOU period in order to benefit from TOU rates. However, their electricity consumption behaviour during the winter TOU period would not need to be altered in order to benefit from TOU rates.

The findings presented in this thesis are not consistent with the findings reported by Mountain and Lawson (1995) or Baladi et al (1998). In their Ontario based study, Mountain and Lawson (1995) found that participants on a TOU rate structure were more likely to shift electricity consumption during the summer. Baladi et al (1998) also reported that the participants in their study responded to the implementation of TOU rates by shifting electricity consumption to off-peak periods. Contrary to these two studies, the findings from this thesis indicate that there is almost no change in the proportion of electricity consumed during the summer on-peak periods because of the implementation of TOU rates. However, in this thesis it is unknown whether the individuals within the study sites adjusted their electricity consumption behaviour prior to the implementation of TOU rates (e.g., in May when they received the pamphlets and information about the new rate regime).

For the same reason the findings from this thesis are inconsistent with California's SPP, as reported by Faruqui and George (2003) and Faruqui and George (2005). In the California experiment, households were shown to be responsive to TOU rates by shifting electricity usage away from on-peak periods. None of these studies, however, focused specifically on lower-income households, therefore it is not surprising that the studies are inconsistent given that lower-income and senior-headed households are expected to have different energy consumption behaviour.

The findings from this thesis are somewhat consistent with the findings reported by Herter (2007). Herter (2007) reported that, on average, lower-income households do not pay more under CPP rates. In this thesis, one of the lower-income sites, Site D, was shown to have no change in the costs of electricity during the summer TOU period. Conversely, the other lower-income site, Site C, was shown to have some increase in the costs of electricity during the summer TOU period. However, during the winter TOU period, both Site C and Site D paid less under the TOU rate regime than they would have under the tiered rate regime.

Worthy of note is the conservation effect shown within the study sites. Although Site A showed a minimal conservation effect, Site B and Site C showed moderate conservation effects. Site D, most surprisingly, showed a conservation effect for all corresponding billing periods. This conservation effect is surprising because households at Site D were not responsible for paying their own electricity bill (refer back to Table 4). Further, this result contradicts some of the present body of literature. For example, Faruqui and George (2005) noted in the California SPP that TOU rates prompted a change in electricity usage patterns, but that on-peak reductions were met with off-peak increases. As a result, no conservation effect was observed. On the other hand, the conservation effect observed in this study is consistent with the Ontario Energy Board Smart Price Pilot, which also saw a notable conservation effect attributed to the implementation of TOU rates.

Overall, the results of the quantitative analysis performed in this thesis are slightly surprising when compared to the existing academic literature. For one thing, there was an almost negligible shift in electricity use patterns (e.g., from on- to off-peak) after the implementation of TOU rates. Further, although it was first demonstrated that lower-income and senior-headed households would have to change their electricity consumption behaviours in order to benefit from TOU rates given their pre-TOU electricity consumption behaviour, it is interesting to note that some lower-income and senior-headed households would benefit from TOU rates given their winter post-TOU behaviour.

5.3 Comparison of elite-level interviews and quantitative findings

In general, the interview participants were concerned about the impacts of TOU rates on lower-income and senior-headed households. They were concerned that lower-income and senior-headed households would have a limited ability to shift electricity consumption from on-peak periods to off-peak periods. Further, the interview participants were concerned about the risk of these households to experience an increase in their electricity bill upon the implementation of TOU rates.

Consistent with the predictions from the interview participants, the lower-income and senior-headed households within the study sites did not appear to significantly shift their electricity usage to off-peak periods in response to TOU rates. The interview participants predicted this response because they believed that lower-income and senior-headed households were less likely to own appliances. However, based on feedback from the household questionnaire, many of the participants had access to some appliances. In particular, many of the senior-headed households had air conditioning. Some interview participants believed that senior-headed households would be less likely to take advantage of TOU rates because of health reasons – in other words, they would be less likely to turn down their air conditioning because they would be less able to cope with the heat. This may be a reason why the senior-headed households studied show little or no shift in their electricity consumption behaviour.

The concern about the risk of electricity bill increases was reflected in some ways in the findings from this thesis – particularly for the summer period and particularly for senior-headed households where an increase in the cost of electricity was observed. However, not all study sites were shown to be at risk of a bill increase. Notably, households within Site D (lower-income) were shown to have no change in the costs associated with TOU rates based on their electricity consumption behaviour during the summer TOU period. On the other hand, three out of the four study sites were shown to benefit from TOU rates given their electricity consumption behaviour in the winter TOU period. Again, not all the households experienced this benefit – Site A was still shown to have electricity costs greater under the TOU rates than they would have if they had continued under the tiered rate regime, however the differences in costs between the two rate regimes were less during the winter TOU period. The interview participants did not predict that the winter TOU period would be better financially (e.g., less impact or positive impact) than the summer TOU period.

Some interview participants expressed concern that the implementation of TOU rates would not promote conservation within the households. The interview participants believed that lower-income and senior-headed households had less ability to conserve. For example, lower-income and senior-headed households were thought to have less ability to invest in energy conservation measures and they were thought to have fewer electrical loads that could be reduced. However, the findings from the quantitative analysis indicate that several households experienced a conservation effect when comparing 2006 consumption to 2007 consumption.

However, this conservation effect is surprising and it should be interpreted with caution. It is unclear whether the conservation effect can be completely attributed to the implementation of TOU rates. It is difficult to know whether TOU rates or other factors caused the households to conserve. For example, the households could have responded to another energy conservation campaign. As noted by several of the interview participants, lower-income and senior-headed households are exposed to the same environmental messaging that encourages them to change their behaviour. It is quite possible that TOU rates had little impact on the energy conservation behaviour of the households. However, facts to support this belief are unknown to the researcher.

5.4 Conclusions

As a reminder, the overarching question that this thesis attempts to answer is: What are the behavioural responses to, and financial impacts of, TOU electricity rates on lower-income and senior-headed households? This leads to two sub-questions:

a) Do lower-income and senior-headed households respond to TOU electricity rates? More specifically, do they reduce electricity consumption or shift the time electricity is consumed?
b) In either the presence or absence of behavioural change, do lower-income and senior-headed households experience a change in the amount of their electricity bill upon the implementation of TOU rates?

The study sites in Milton Ontario do not significantly shift the proportion of electricity consumed during the on-, mid, and off-peak periods in response to the implementation of TOU rates. However, it is unknown if any shift occurred before TOU rates were implemented – for example, if the individuals adjusted their behaviour after receiving the notice that they were about to be retrofitted with smart meters. Despite the lack of a shift to off-peak periods, a conservation effect was observed, particularly within the study sites representing lower-income households. The conservation effect, if observed, appeared to be greater initially after the implementation of TOU rates, but then gradually decreased as the households moved towards the winter TOU period. The average conservation effect observed at the study sites ranged from 9% to 35% between corresponding 2006 and 2007 billing periods. Unfortunately, it is unclear whether the conservation effect can be attributed to the implementation of TOU rates.

During the pre-TOU period, which occurred during June 2007, it was determined that these lower-income and senior-headed households would have to change their electricity consumption behaviour in order to benefit from TOU rates. Three out of the four study sites – two sites representing senior-headed households and one site representing lower-income households – would have paid more under the TOU rates structure than under the tiered rate structure. The average increase in costs ranged from \$0.15 to \$0.61 per week. One of the sites representing lower-income households would not see any change in their electricity bill by moving from tiered rates to TOU rates.

In the absence of a shift in the proportion of electricity consumed during each peak period, both sites representing senior-headed households and one of the sites representing lower-income households saw an increase in the cost of electricity under the TOU rate structure during the summer TOU period, compared to what they would have paid under the tiered rate structure. The average increase in costs ranged from \$0.16 to \$0.51 per week. One of the sites, a site representing lower-income households, did not see any change in their electricity bill by moving from tiered rates to summer TOU rates.

However, during the winter post-TOU period, three out of the four study sites – one site representing senior-headed households and both sites representing lower-income households - had costs associated with TOU rates that were less than what they would have been had the households remained on tiered rates. The average savings ranged from \$0.16 to \$1.76 per week. For one of the senior headed households, the costs associated with TOU rates were remained greater than what they would have been under tiered rates during the winter post-TOU period (on average $0.18 per week); however, the cost difference between the two rate regimes was less during the winter post-TOU period compared to the summer post-TOU period.

A noteworthy finding from this study is that impacts of TOU rates on lower-income and senior-headed households appear to be different during the summer post-TOU period and winter post-TOU impact (refer back to Table 54). In general, TOU rates in the winter appear to be more beneficial than TOU rates in the summer; although, as noted above, not all sites realized savings during the winter post-TOU period. This difference in impact is likely attributed to both the change in the TOU rate structure (e.g., timing of the on-, mid- and off-peak period) and a change in electricity use patterns within the households.

Since the households did not significantly shift their electricity use patterns, it can be assumed that the winter TOU rates may benefit some lower-income and senior-headed households based on their existing electricity consumption patterns. The costs and savings during the post-TOU period do not reflect any savings that may be attributed to conservation nor do they reflect any additional costs that might be attributed to the Smart Metering Initiative.

Possible explanations for the above result can be found in the elite-level interviews conducted with experts from government, environmental non-profit groups, affordable housing organizations and citizen advocacy organizations. The experts believed that lower-income and senior-headed households would be less able to respond to TOU rates primarily because they had limited discretionary electrical loads that could be shifted away from on-peak periods. Another explanation is that lower-income and senior-headed households do not have access to upfront capital that may be required in order to invest in energy efficient devices. Further, lower-income and senior-headed households may have inflexible household schedules or they may be unwilling to reduce their comfort levels for health reasons.

5.5 Recommendations

Although there was a fair amount of anxiety expressed from interview participants from citizen advocacy and non-profit organizations, the results show that there is a possibility of savings under the TOU rate regime – particularly under the winter TOU schedule. While it cannot be said that lower-income and senior-headed households benefit from TOU rates based on the summer schedule, the evidence from this study suggests any increases in the electricity bill are likely going to be minimal.

It may be concerning to some researchers to find that lower-income and senior-headed households do not respond to TOU rates by shifting the proportion of electricity consumed during each peak period. This research does not disprove the effectiveness of TOU rates to motivate a change in electricity consumption behaviour in the general population - those with mid- to higher-incomes – as they were not evaluated in this study. Only lower-income and senior-headed households were studied in this thesis, therefore the response by wealthier, or younger, families is not questioned.

This thesis was presented as exploratory research. Some of the findings presented in this thesis are tentative, due to limited participation in the household questionnaire. Therefore, it is recommended that further studies be conducted to learn more about the impacts of various household characteristics on the ability to respond to TOU rates. In addition, this study only used data over a six-month period. Therefore, it is recommended that a similar study should be conducted which expands the study period over a full year in order to get a better sense of annual electricity use patterns.

The pre-TOU period for this study was short and accounted for only a few weeks during the summer. Another recommendation would be to lengthen this period as much as possible and to determine if there are any ‘natural benefits’ on weekly or monthly basis. Allowing the researcher more time to observe a ‘shift’ or a ‘conservation effect’ would be ideal. Some of the findings from this study were unexpected, particularly the conservation effect observed at some of the study sites. It is unclear if this effect can be attributed to TOU rates; therefore, it is recommended that this effect be explored during future studies on the impacts of TOU rates.

Policy makers, regulators and electricity utilities should note that some lower-income and senior-headed households may experience an increase in their electricity bill upon the implementation of TOU rates. It is interesting to note that there was some discrepancy in responses across the different households. In addition, it should be noted that households appear to be better off financially under the winter TOU rate schedule compared to the summer TOU rate schedule. This research provides some evidence that the impacts of TOU on lower-income and senior-headed households rates may differ based on season or rate design.

Further research to explore the finding from this thesis is recommended. Some possible methods include focus groups or energy audits. Focus group sessions would be helpful in learning about the experiences of participants within this study. It would be helpful to learn about their opinion of TOU rates and how much effort they made to change their electricity consumption patterns. Energy audits would give researchers a better opportunity to explore the relationship between the ability to shift and conserve electricity and structural characteristics of the households.

This thesis is based in a framework of sustainability. The concept of sustainability recognizes the interactions between social policy and environmental policy. TOU rates are meant to provide a financial incentive to shift electricity consumption towards off-peak periods – this shift would mean that less electricity is consumed from polluting and expensive sources of fuel. However, TOU rates appear to be ineffective at motivating the sites studied in this thesis. TOU rates may, however, have caused a reduction in electricity usage. In any case, it is important to note that some of the lower-income and senior-headed households saw an increase in their electricity bill, particularly during the summer TOU period. Lower-income and senior-headed households are thought to be less able to shift electricity consumption; therefore, it is important to develop mechanisms to identify lower-income and senior-headed households that are at risk of bill increases. The researchers contributing to the development of this thesis hope that this research contributes to the understanding of the impacts of TOU rates, and leads to future research related to this topic.

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Appendix A: Ethics documentation

Telephone recruitment script.

P = Potential Participant; Sarah = Sarah Ivy Simmons

Sarah - May I please speak to [name of potential participant]?

P - Hello, [name of potential participant] speaking. How may I help you?

Sarah - My name is Sarah Simmons and I am a Masters student in the Department of Environment and Resource Studies at the University of Waterloo. I am currently conducting research under the supervision of Dr. Ian Rowlands on energy conservation and vulnerable citizens in Ontario. As part of my thesis research, I am conducting interviews with professionals currently advocating for vulnerable energy users to discover their perspectives on how current energy conservation programs and policies are affecting vulnerable citizens in Ontario.

As you play a key role in this issue, I would like to speak with you about your perspectives on the effects of energy conservation programs and policies on vulnerable households in Ontario. Is this a convenient time to give you further information about the interview?

P - No, could you call back later (agree on a more convenient time to call person back).

OR

P - Yes, could you provide me with some more information regarding the interviews you will be conducting?

Sarah - Background Information:

• I will be undertaking interviews starting in June 2007.

• The interview would last about a half hour, and would be arranged for a time convenient to your schedule.

• Involvement in this interview is entirely voluntary and there are no known or anticipated risks to participation in this study.

• The questions are quite general (for example, how do you think the introduction of a time-of-use electricity rate structure in Ontario will affect vulnerable households?).

• You may decline to answer any of the interview questions you do not wish to answer and may terminate the interview at any time.

• With your permission, the interview will be tape-recorded to facilitate collection of information, and later summarized for analysis.

• All information you provide will be considered confidential.

• With your permission, anonymous quotations may be used in the thesis or any resulting publications.

• The data collected will be kept in a secure location and disposed of in 1 year's time.

• If you have any questions regarding this study, or would like additional information to assist you in reaching a decision about participation, please feel free to contact Dr. Ian Rowlands at 519-888-4567, Ext. 32574.

• I would like to assure you that this study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. However, the final decision about participation is yours. Should you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes in the Office of Research Ethics at 519-888-4567, Ext. 36005.

•After all of the data have been analyzed, you will receive an executive summary of the research results.

With your permission, I would like to email/mail you an information letter which has all of these details along with contact names and numbers on it to help assist you in making a decision about your participation in this study.

P - No thank you.

OR

P - Sure (get contact information from potential participant i.e., mailing address/fax number/email).

Sarah - Thank you very much for your time. May I call you in 2 or 3 days to see if you are interested in being interviewed? Once again, if you have any questions or concerns please do not hesitate to contact me via email at sisimmon@fes.uwaterloo.ca.

P - Good-bye.

Sarah - Good-bye.

Template letter of information for interview participant.

RE: Letter of Information - Energy Conservation for Vulnerable Households in Ontario

Dear [name],

This study is being conducted by Master's student Sarah Ivy Simmons (sisimmon@fes.uwaterloo.ca) under the supervision of Dr. Ian Rowlands (519-888-4567, Ext. 32574) of the Department of Environment and Resource Studies at the University of Waterloo.

To meet Ontario's future energy requirements, politicians and environmentalists are calling for the establishment of a 'culture of conservation' amongst Ontario's citizens. Conservation has been touted as a cornerstone to the formation of a sustainable society. However, conservation measures implemented must not disproportionately affect the most vulnerable citizens; equity is a fundamental criterion of sustainability. Therefore, policymakers must ensure that all members of society have the means to participate in a culture of energy conservation by ensuring that the barriers to participation in energy conservation programs and policies are minimized.

The purpose of this research is to determine how current energy conservation programs and policies affect vulnerable households. In this study, the term "vulnerable households" is used to describe low-income households (as defined by Statistics Canada's Low-Income Cut-Offs), households with one or more senior citizen or person with disabilities, single parent households or households that are rented. Further, this research will endeavor to identify the characteristics of energy conservation programs and policies that will both help improve the quality of life of vulnerable citizens and help Ontario meet its energy conservation targets. This will be done using theories and concepts such as political ecology, community-based social marketing and capacity building and will result in policy recommendations.

As a participant in this study, you will be asked to participate in a semi-structured interview with Master's student Sarah Ivy Simmons. Participation in this interview is expected to take a half hour of your time and will be scheduled at a time that is convenient for you. It is preferred to conduct the interview in-person; however, telephone interviews can be arranged if in-person interviews are not possible.

You may not benefit personally from your participation in this study. However, the information obtained from this research may contribute to the development of energy conservation programs and policies that may help vulnerable households reduce energy consumption.

You may refuse to participate or withdraw from the interview at any time by advising the researcher of this decision. In addition, you may refuse to respond to any question you prefer not to answer. The type of questions you will be asked will be similar to the following: How do you think the introduction of a time-of-use electricity rate structure in Ontario will affect vulnerable households?

With your permission, the interview will be audio-taped. Anonymous quotations may be used in the thesis or any resulting publications with your permission. You will have an opportunity to review sections of the thesis where you have been quoted anonymously.

All information collected from participants in this study will be aggregated. Thus, your name will not appear in any report, publication or presentation resulting from this study. The data, with identifying information removed, will be kept for a period of one year and will be securely stored in a locked office at the University of Waterloo. After one year, the data and electronic files will be confidentially destroyed.

In appreciation for the time you have given to this study, you will receive an executive summary of the research results.

If you have any questions about participation in this study, please feel free to ask the researchers. If you have additional questions at a later date, please contact Dr. Ian Rowlands at (519) 888-4567 ext. 32574 or by email at irowland@fes.uwaterloo.ca.

For in-person interviews, the participants will be asked to complete a consent form just prior to the interview (i.e. at the same session). For telephone interviews, a consent form will be sent to the participants via email.

This project has been reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. In the event you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes at 519-888-4567, Ext. 36005.

Sincerely,

Sarah Ivy Simmons
Masters Candidate
sisimmon@fes.uwaterloo.ca
(519) 212-1321

Template letter of consent.

I have read the information presented in the information letter about a study being conducted by Master's Student Sarah Ivy Simmons of the Department of Environment and Resource Studies at the University of Waterloo. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted.

I am aware that I have the option of allowing my interview to be audio recorded to ensure an accurate recording of my responses.

I am also aware that excerpts from the interview may be included in the thesis and/or publications to come from this research, with the understanding that the quotations will be anonymous.

I was informed that I may withdraw my consent at any time without penalty by advising the researcher.

This project has been reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact the Director, Office of Research Ethics at 519-888-4567 ext. 36005.

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

☐ Yes ☐ No

I agree to have my interview audio recorded.

☐ Yes ☐ No

I agree to the use of anonymous quotations in any thesis or publication that comes of this research.

☐ Yes ☐ No

Participant Name: ____ (Please print)

Participant Signature: ____

Witness Name: ____ (Please print)

Witness Signature: ____

Date: ____

<u>Template Feedback letter to interview participants .</u>

Dear [Name],

I would like to thank you for your participation in my thesis research. As a reminder, the purpose of this study is to determine how current energy conservation programs and policies in Ontario affect vulnerable households.

The data collected from the interviews will contribute to the development of focus groups and questionnaires to identify the barriers to participation in current energy conservation programs and to learn about the experiences of vulnerable citizens with energy conservation issues. Additionally, this information will contribute to the design of programs and policies to help vulnerable households reduce energy consumption.

Please remember that any data pertaining to yourself as an individual participant will be kept confidential. Once all the data are collected and analyzed for this project, I plan on sharing this information with the research community through seminars, conferences, presentations, and journal articles. If you are interested in receiving more information regarding the results of this study, or if you have any questions or concerns, please contact me at either the phone number or email address listed at the bottom of the page. If you would like a summary of the results, please let me know. When the study is completed, I will send it to you. The study is expected to be completed by June 2008.

As with all University of Waterloo projects involving human participants, this project was reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. Should you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes in the Office of Research Ethics at 519-888-4567, Ext., 36005.

Sincerely,

Sarah Ivy Simmons
Masters Candidate
sisimmon@fes.uwaterloo.ca
519 212-1321

Template letter of information for household questionnaire.

[Milton Hydro letterhead]

Thursday, October 4, 2007

Dear Resident:

Through the Smart Metering Initiative, the Government of Ontario is implementing a new time-of-use (TOU) rate scheme for electricity. As part of this initiative, each household in Ontario will be retrofitted with a 'smart meter' by the year 2010. Under the TOU rate scheme, customers will be charged lower rates for electricity consumed during 'off-peak' periods and higher rates for electricity consumed during 'on-peak' periods. Thus, TOU rates give customers an economic incentive to conserve electricity during on-peak periods and to shift electricity usage to off-peak periods. Although the TOU rate scheme is designed to give customers greater control over their electricity bill, some research suggests that this new rate scheme may affect customers differently depending on their household's socioeconomic characteristics.

In an effort to understand the effects of TOU rates on people who live in affordable housing, Milton Hydro has developed a partnership with researchers from the University of Waterloo. We are conducting a collaborative study throughout the summer and fall of 2007 to determine how the implementation of TOU rates affects these households.

Your household, along with the other households located at **[Address]** has recently been retrofitted with a smart meter, and therefore has been chosen as a study site for this research project. The smart meters allow Milton Hydro to collect electricity consumption data from the units in your property. This data will be used to evaluate the change in each household's electricity consumption behaviour in response to TOU rates.

As part of this research, we need to determine some basic information about the households within this study, such as household income and the age of the household head. We have therefore developed the enclosed questionnaire, and we would very much appreciate your participation.

If you do decide to complete the attached questionnaire, as a token of our appreciation, participants who mail the completed questionnaire by **Friday, October 20, 2007** using the enclosed postage-paid return envelope will be entered into a draw to win one of two **$50 gift certificates to a restaurant of the winner's choice**. The winner will be contacted by phone in November.

Your participation in the questionnaire would of course be voluntary, and should take approximately **five minutes** of your time. Most questions use a multiple choice format, and you may skip any question you prefer not to answer. All the information that you provide will be considered confidential, and will be used for research purposes only. None of your identifying information will appear in any report, publication, or presentation resulting from this research. The questionnaires will be kept in a locked office at Milton Hydro for a period of one year, after which time they will be destroyed. Electronic data, with personal identifiers removed, will be kept indefinitely in a secure location. As such, there are no known or anticipated risks to your participation in this study. However, if you have any questions or you would like additional information to assist you in reaching a decision to participate, please feel free to contact Mary-Jo Corkum at Milton Hydro at 905-878-3483 ext. 236, or Dr. Ian Rowlands at the University of Waterloo at 519-888-4567 ext. 32574.

Finally, I would like to assure you that, in addition to receiving approval from Milton Hydro, this study has been reviewed and received ethics clearance through the Office of Research Ethics at the University of Waterloo. Should you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes in the Office of Research Ethics at 519-888-4567 ext. 36005.

Thank you in advance for your interest in this project.

Yours sincerely,

[Signature]

D.R. Thorne, P. Eng.
President / CEO

Template draw form sent with household questionnaire.

Thank you for your participation in this questionnaire!

Please use the postage-paid envelope provided to mail the completed questionnaire to us by **Friday October 20, 2007** and you will be entered into a draw to receive one of two **$50 gift certificates to a restaurant of the winner's choice!** If you wish to be entered, please provide your name, address and phone number below so that we can contact the winner.

☐ **Enter my name in the draw for one of two $50 gift certificates**

Name: ____

Address: ____

____

Phone: ____

Template letter of congratulations sent to draw winners.

Thank you for completing the in Milton Hydro – University of Waterloo questionnaire.

As one of the draw winners, here is a $50 gift card. It is valid for the following restaurants:

- Kelsey's
- Montana's
- Swiss Chalet
- Milestones
- Second Cup
- Harvey's

Thanks again, and Enjoy!

Sincerely,

Sarah Ivy Simmons (Masters Student)

Template feedback letter sent to those who completed a household questionnaire.

[Milton Hydro letterhead]

November 30, 2007

Dear Resident,

Thank you for completing our questionnaire. As a reminder, this questionnaire was part of a collaborative research project between Milton Hydro and researchers at the University of Waterloo. One of the main objectives of this study is to determine how the implementation of time-of-use rates for electricity affects people living in affordable housing. The data collected from the questionnaire will help researchers evaluate the household electricity consumption patterns of each home with respect to various household characteristics.

Please remember that any data pertaining to yourself as an individual participant will be kept confidential. Once all the data are collected, analyzed and aggregated for this project, the information will be shared with the research community through seminars, conferences, presentations, and journal articles. If you are interested in receiving an executive summary of the results of this study, or if you have any questions or concerns, please contact Mary-Jo Corkum at Milton Hydro at 905-878-3483 ext. 236, or Dr. Ian Rowlands at the University of Waterloo at 519-888-4567 ext. 32574. The study is expected to be completed by June 2008.

As with all University of Waterloo projects involving human participants, this project was reviewed by, and received ethics clearance through, the Office of Research Ethics at the University of Waterloo. Should you have any comments or concerns resulting from your participation in this study, please contact Dr. Susan Sykes in the Office of Research Ethics at 519-888-4567, Ext., 36005.

Yours sincerely,

D.R. Thorne, P. Eng.
President / CEO

Appendix B: Literature rationale for household questionnaire

Socio economic characteristics.

Characteristic	Justification	Reference
Household income	Income was attributed to 17.6% of the total variation in electricity use.	Blocker, 1985, pg 75
	Family income was a contextual variable used to describes the energy consumers' environment	Black, 1985, pg 6
	Electrical loads changes in annual bill and satisfaction upon the implementation of CPP was categorized by historical usage and income level.	Herter, 2007, pg 2122
	Households with a higher income showed a greater response to CPP.	Faruqui & George, 2005, pg 56
	TOU rates could cause the greatest hardship for low-income households	SHSC, 2006, pg 20
Number of persons in the household	The second most important variable that attributed significantly to the variation in electricity use was the number of persons in the household.	Blocker, 1985, pg 75
	Family size was a contextual variable used to describe the energy consumers' environment	Black, 1985, pg 6
	Persons per household was negatively correlated to responsiveness of CPP rates	Faruqui & George, 2005, pg 56
Number of people at home during the day	The presence of people home during normal work and school hours was a contextual variable used to describe the energy consumers' environment.	Black, 1985, pg 6
	The number of persons at home during the daytime was a family structure variable used to help determine the potential benefit of the TOU rate structure.	Blocker, 1985, pg 69
Age of household head	The second most important variable that attributed significantly to the variation in electricity use was the age of the household head.	Blocker, 1985, pg 75
	The age of oldest household member was a contextual variable used to describe the energy consumers' environment.	Black, 1985, pg 6
Education	Highest level of education in the household was a contextual variable used to describe the energy consumers' environment	Black, 1985, pg 6
	Households headed by college educated person had a greater response to CPP	Faruqui & George, 2005, pg 56

Structural Characteristics

Characteristic	Justification	Reference
Dwelling type (apartment, townhouse, etc)	Single family households were more responsive to CPP rates than multi-family households.	Faruqui & George, 2005, pg 56
Number of bedrooms	The size of the residence (number of bedrooms) was a contextual variable used to describes the energy consumers' environment	Black, 1985, pg 6
	Number of bedrooms in the household is positively correlated with responsiveness to CPP rates	Faruqui & George, 2005, pg 56
Appliances, air conditioning, thermostat	The potential of TOU rates to provide price relief to low-income households depended on the households' current appliance use patterns and/or willingness to shift electricity use to off-peak hours.	Blocker, 1985, pg 69
	The households that volunteered for TOU rates tended to use AC more at night time and were more likely to only use it on the hottest days than non-volunteers	Baladi et al, 1998, pg 233-234
	The effects of electricity price and appliance ownership on off-peak electricity use were mediated by knowledge about the time-of-use rates and by behavioral commitment to shift usage to off-peak times.	Heberlein and Warriner, 1982 as cited by Black et al, 1985, pg 5
	The presence of an electric room air conditioner and/or an electric clothes dryer raises the peak to off-peak usage ratio.	Matsukawa, 2001, pg 264
	Air conditioning ownership was positively correlated with response to CPP	Faruqui & George, 2005, pg 56
	Electric cooking was negatively correlated to the response to CPP rates	Faruqui & George, 2005, pg 56
	Low income households are less likely to have air conditioning than higher income households	SHSC, 2006, pg 19

Appendix C: Sample questionnaire

Milton Hydro

University of Waterloo

The following questionnaire was developed by Milton Hydro and researchers at the University of Waterloo. All information provided below will be considered confidential and will be used for research purposes only.

This questionnaire should be completed by the person who takes care of the household electricity bill, or a household head. If you would like to provide the researchers with additional comments, please do on the space provided.

One of the main objectives of this study is to determine the effects of time-of-use rates for electricity on people who live in ***[senior's housing/affordable housing]*** *units. The questions below will help researchers evaluate the electricity consumption patterns of each home with respect to various household characteristics.*

Although we encourage participants to answer all the questions, you may skip any questions you prefer not to answer.

To be eligible for the draw for one of two ***$50 restaurant gift certificates****, please mail the completed questionnaire in the* ***enclosed stamped envelope*** *by* ***October 20, 2007.***

We appreciate your participation!

---

1. Please specify the year you were born: 19___

2. Including yourself, please indicate the number of people in each of the following age groups that live in your home.

___10 years or younger ___ 11 to 20 years
___ 21 to 30 years ___ 31 to 40 years
___ 41 to 50 years ___ 51 to 60 years
___ 61 to 70 years ___ 71 to 80 years
___ 81 years or more

3. Including yourself, please indicate the number of people in each of the following age groups that are at home anytime during a typical **weekday** between **11am and 5pm**.

___10 years or younger ___ 11 to 20 years
___ 21 to 30 years ___ 31 to 40 years
___ 41 to 50 years ___ 51 to 60 years
___ 61 to 70 years ___ 71 to 80 years
___ 81 years or more

Please see over

4. Please indicate the number of bedrooms in your unit.
   ☐ 1 ☐ 2 ☐ 3 ☐ 4

5. What is the approximate annual income of your household (after taxes) from all sources, including social assistance?
   ☐ Less than $10,000
   ☐ $10,000 - $14,999
   ☐ $15,000 - $19,999
   ☐ $20,000 - $24,999
   ☐ $25,000 - $29,999
   ☐ $30,000 - $34,999
   ☐ $35,000 - $39,999
   ☐ $40,000 - $44,999
   ☐ $45,000 - $49,999
   ☐ $50,000 - $54,999
   ☐ $55,000 - $59,999
   ☐ $60,000 - $64,999
   ☐ $65,000 - $69,999
   ☐ $70,000 or more

6. Please indicate the highest level of education obtained by any member of your household.
   ☐ Some grade school
   ☐ Completed grade school
   ☐ Some high school
   ☐ Completed high school
   ☐ Some college/technical diploma
   ☐ Completed college/technical diploma
   ☐ Some university
   ☐ Completed university degree(s)

7. Please indicate if you have the following appliances or devices available in your unit. (Check all that apply)
   ☐ Electric stove
   ☐ Electric dishwasher
   ☐ Electric laundry machine
   ☐ Electric drying machine
   ☐ Programmable thermostat
   ☐ Freezer
   ☐ Central air conditioning
   ☐ Air conditioning window unit

Comments or Questions:

____
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Again, please feel free to contact Mary-Jo Corkum at Milton Hydro (905-878-3483 ext. 236) or Dr. Ian Rowlands at the University of Waterloo (519-888-4567 ext. 32574) if you have any questions about this research.

Appendix D: Week schedule of test period

Week Number	Dates (2007)	Holiday or other event
1	June 3 – June 9	
2	June 10 – June 16	
3	June 17 – June 23	Start of TOU rates for Site C Start of TOU rates for Site D
4	June 24 – June 30	Start of TOU rates for Site A
5	July 1 – July 7	Canada Day, Start of TOU rates for Site B
6	July 8 – July 14	
7	July 15 – July 21	
8	July 22 – July 28	
9	July 29 – August 4	
10	August 5 – August 11	Civic Holiday
11	August 12 – August 18	
12	August 19 – August 25	
13	August 26 – September 1	
14	September 2 – September 8	Labour Day
15	September 9 – September 15	
16	September 16 – September 22	
17	September 23 – September 29	
18	September 30 – October 6	
19	October 7 – October 13	Thanksgiving
20	October 14 – October 20	
21	October 21 – October 27	
22	October 28 – November 3	Switch to Winter TOU Rates
23	November 4 – November 10	Switch to Standard Time
24	November 11 – November 17	
25	November 18 – November 24	
26	November 25 – December 1	
27	December 2 – December 8	
28	December 9 – December 15	
29	December 16 – December 22	
30	December 23 – December 29	Christmas/Boxing Day

Appendix E: 2006 Billing periods

Note:
PRN = Project reference number
Ex. = Exception

Site A – Billing Periods

Bill #	Start Date	Actual End Date	Calc. End Date
7 **Ex. PRN 197**	27/06/2006 27/06/2006	27/07/2006 31/07/2006	26/07/2006 30/07/2006
8 **Ex. PRN 197**	27/07/2006 31/07/2006	28/08/2006 01/09/2006	27/08/2006 31/08/2006
9 **Ex. PRN 197**	28/08/2006 01/09/2006	27/09/2006 27/09/2006	26/09/2008 26/09/2008
10	27/09/2006	27/10/2006	26/10/2006
11	27/10/2006	27/11/2006	26/11/2006
12	27/11/2006	28/12/2006	27/12/2006

Site B – Billing Periods, Ex. PRN 169 - 172

Bill #	Start Date	Actual End Date	Calc. End Date
8	29/06/2006	31/07/2006	30/07/2006
9	31/07/2006	30/08/2006	29/08/2006
10	30/08/2006	29/09/2006	28/09/2006
11	29/09/2006	31/10/2006	30/10/2006
12	31/10/2006	29/11/1006	28/11/1006

Site B – Billing Periods, Only PRN 169 - 172

Bill #	Start Date	Actual End Date	Calc. End Date
10	29/06/2006	31/07/2006	30/07/2006
11	31/07/2006	30/08/2006	29/08/2006
12	30/08/2006	29/09/2006	28/09/2006
13	29/09/2006	31/10/2006	30/10/2006
14	31/10/2006	29/11/1006	28/11/1006

*****Note – Actual bill number is 'offset' – assumed the same bill number in analysis.*

Site C – Billing Periods

Bill #	Start Date	Actual End Date	Calc. End Date
7	19/06/2006	19/07/2006	18/07/2006
8	19/07/2006	18/08/2006	17/08/2006
9	18/08/2006	19/09/2006	18/09/2006
10	19/09/2006	19/10/2006	18/10/2006
11	19/10/2006	17/11/2006	16/11/2006
12	17/11/2006	15/12/2006	14/12/2006

Site C – Billing Periods – Exceptions

PRN	Bill #	Start Date	Actual End Date	Calc End Date
72	7	19/06/2006	30/06/2006	29/06/2006
	8	30/06/2006	22/07/2006	21/07/2006
	9	22/07/2006	18/08/2006	17/08/2006
	10	18/08/2006	19/09/2006	18/09/2006
	11	19/09/2006	19/10/2006	18/10/2006
	12	19/10/2006	17/11/2006	16/11/2006
	13	17/11/2006	15/12/2006	14/12/2006
111	7	30/06/2006	21/07/2006	20/07/2006
	8	21/07/2006	18/08/2006	17/08/2006
	9	18/08/2006	19/09/2006	18/09/2006
	10	19/09/2006	19/10/2006	18/10/2006
	11	19/10/2006	17/11/2006	16/11/2006
	12	17/11/2006	15/12/2006	14/12/2006
128	7	23/06/2006	19/07/2006	18/07/2006
	8	19/07/2006	18/08/2006	17/08/2006
	9	18/08/2006	19/09/2006	18/09/2006
	10	19/09/2006	19/10/2006	18/10/2006
	11	19/10/2006	17/11/2006	16/11/2006
	12	17/11/2006	15/12/2006	14/12/2006
119	7	19/06/2006	19/09/2006	18/09/2006
	8	19/09/2006	31/10/2006	30/10/2006
	9	31/10/2006	17/11/2006	16/11/2006
136	8	19/06/2006	19/07/2006	18/07/2006
87	9	19/07/2006	18/08/2006	17/08/2006
	10	18/08/2006	19/09/2006	18/09/2006
	11	19/09/2006	19/10/2006	18/10/2006
	12	19/10/2006	17/11/2006	16/11/2006
	13	17/11/2006	15/12/2006	14/12/2006
106	7	19/06/2006	19/07/2006	18/07/2006
	8	19/07/2006	31/08/2006	30/08/2006
	9	31/08/2006	19/09/2006	18/09/2006
	10	19/09/2006	19/10/2006	18/10/2006
	11	19/10/2006	17/11/2006	16/11/2006
	12	17/11/2006	15/12/2006	14/12/2006
118	7	19/06/2006	19/07/2006	18/07/2006
62	8	19/07/2006	19/09/2006	18/09/2006
	9	19/09/2006	19/10/2006	18/10/2006
	10	19/10/2006	17/11/2006	16/11/2006
	11	17/11/2006	15/12/2006	14/12/2006
70	7	19/06/2006	19/07/2006	18/07/2006
	8	19/07/2006	18/08/2006	17/08/2006

	9	18/08/2006	11/09/2006	10/09/2006
	10	11/09/2006	18/09/2006	17/09/2006
	11	18/09/2006	18/10/2006	17/10/2006
	12	18/10/2006	17/11/2006	16/11/2006
	13	17/11/2006	15/12/2006	14/12/2006
69	7	19/06/2006	19/07/2006	18/07/2006
	8	19/07/2006	18/08/2006	17/08/2006
	9	18/08/2006	12/09/2006	11/09/2006
	10	12/09/2006	18/09/2006	17/09/2006
	11	18/09/2006	19/10/2006	18/10/2006
	12	19/10/2006	17/11/2006	16/11/2006
	13	17/11/2006	15/12/2006	14/12/2006
51	7	19/06/2006	19/07/2006	18/07/2006
	8	19/07/2006	18/08/2006	17/08/2006
	9	18/08/2006	30/09/2006	29/09/2006
	10	30/09/2006	19/10/2006	18/10/2006
	11	19/10/2006	17/11/2006	16/11/2006
	12	17/11/2006	15/12/2006	14/12/2006
67	7	19/06/2006	19/07/2006	18/07/2006
	8	19/07/2006	18/08/2006	17/08/2006
	9	18/08/2006	30/09/2006	30/09/2006
	10	01/10/2006	06/10/2006	05/10/2006
	11	06/10/2006	19/10/2006	18/10/2006
	12	19/10/2006	17/11/2006	16/11/2006
	13	17/11/2006	15/12/2006	14/12/2006
127	7	19/06/2006	19/07/2006	18/07/2006
	8	19/07/2006	18/08/2006	17/08/2006
	9	18/08/2006	19/09/2006	18/09/2006
	10	19/09/2006	31/10/2006	30/10/2006
	11	31/10/2006	17/11/2006	16/11/2006
	12	17/11/2006	15/12/2006	14/12/2006
34	7	19/06/2006	19/07/2006	18/07/2006
	8	19/07/2006	18/08/2006	17/08/2006
	9	18/08/2006	19/09/2006	18/09/2006
	10	19/09/2006	31/10/2006	30/10/2006
	11	31/10/2006	17/11/2006	16/11/2006
	12	17/11/2006	15/12/2006	14/12/2006
41	7	19/06/2006	19/07/2006	18/07/2006
	8	19/07/2006	18/08/2006	17/08/2006
	9	18/08/2006	19/09/2006	18/09/2006
	10	19/09/2006	19/10/2006	18/10/2006
	11	19/10/2006	30/11/2006	29/11/2006
	12	30/11/2006	15/12/2006	14/12/2006

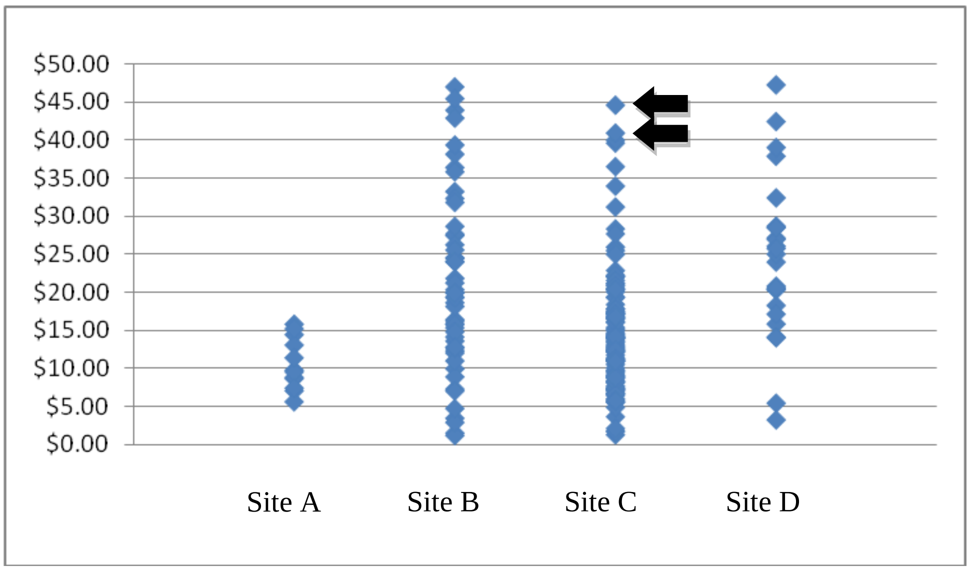
Site D – Billing Periods

Bill #	Start Date	Actual End Date	Calc. End Date
7	21/06/2006	21/07/2006	20/07/2006
8	21/07/2006	22/08/2006	21/08/2006
9	22/08/2006	21/09/2006	20/09/2006
10	21/09/2006	23/10/2006	22/10/2006
11	23/10/2006	21/11/2006	20/11/2006
12	21/11/2006	19/12/2006	18/12/2006

Appendix F: Scatter plots from quantitative analysis

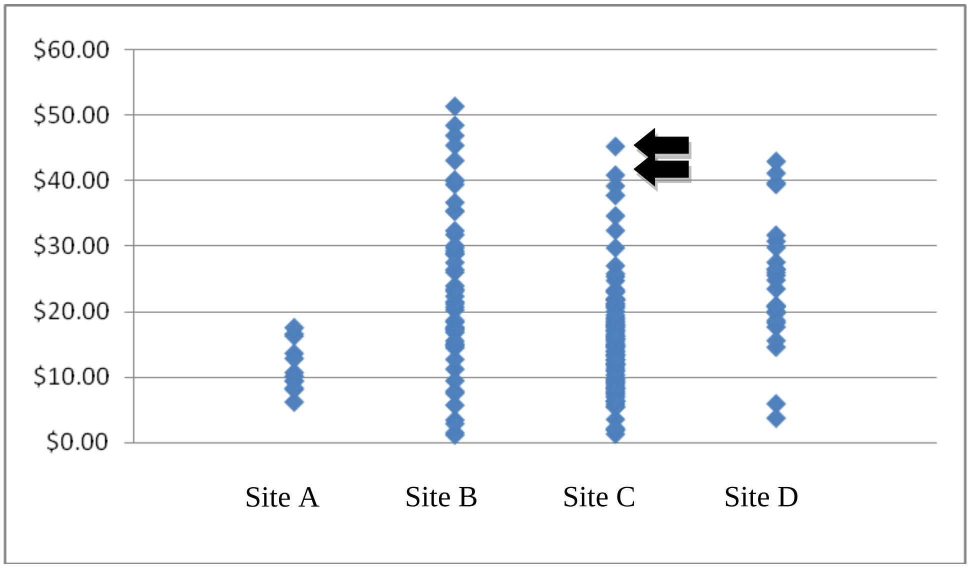
Presented in this appendix are data scatter plots from each of the four questions evaluated in Chapter 4 of this thesis. The purpose of presenting this data is to acknowledge the existence of outliers in the sample. An outlier is a data point that is observed to be outside the normal range of the sample (Osborne and Overbay, 2004). For the purpose of this analysis, an outlier is considered to be a data point that is more than three standard deviations away from the mean of the sample (Osborne and Overbay, 2004).

Question 1: Will the households benefit naturally from the implementation of TOU rates?



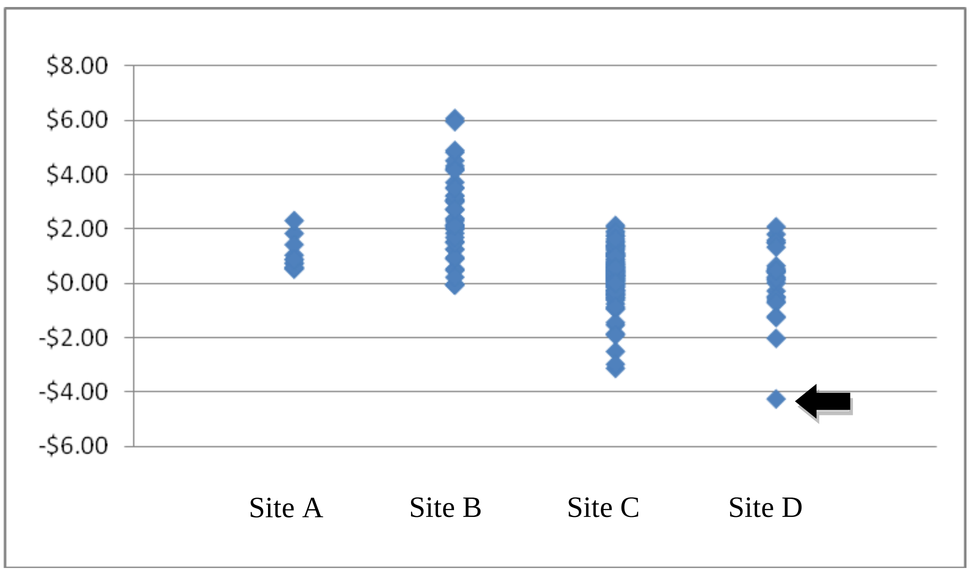
Appendix F - Figure 1. C_{Tier} during the pre-TOU period.

The two outliers indicated at Site C have caused an increase in the average pre-TOU costs associated with tiered rates at Site C.



Appendix F - Figure 2. C_{TOU} rates during the pre-TOU period.

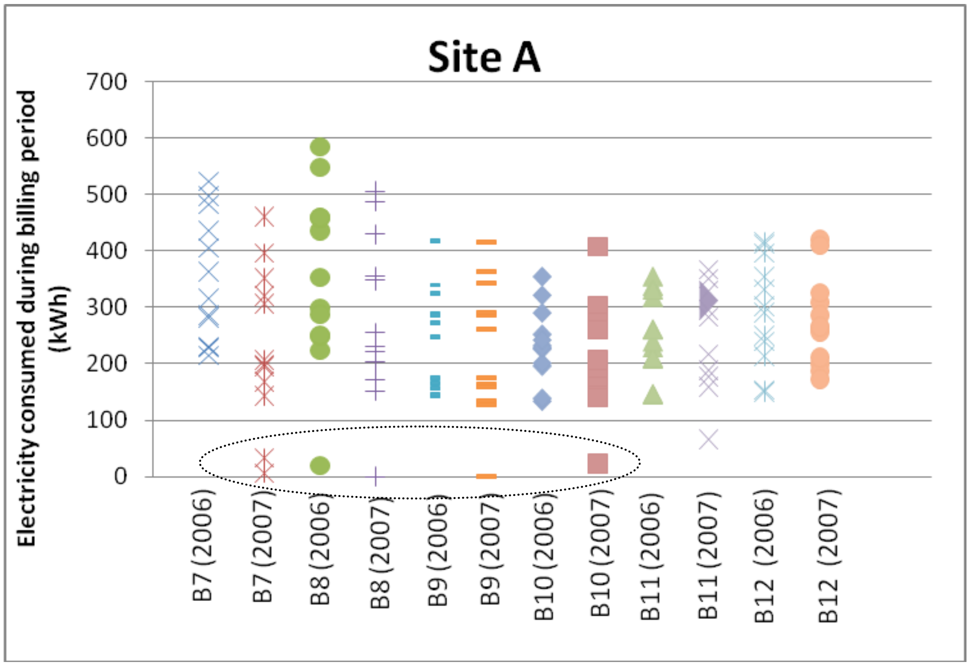
The two outliers indicated at Site C have caused an increase in the average pre-TOU costs associated with TOU rates at Site C.



Appendix F - Figure 3. C_{TOU} minus C_{Tier} during the pre-TOU period.

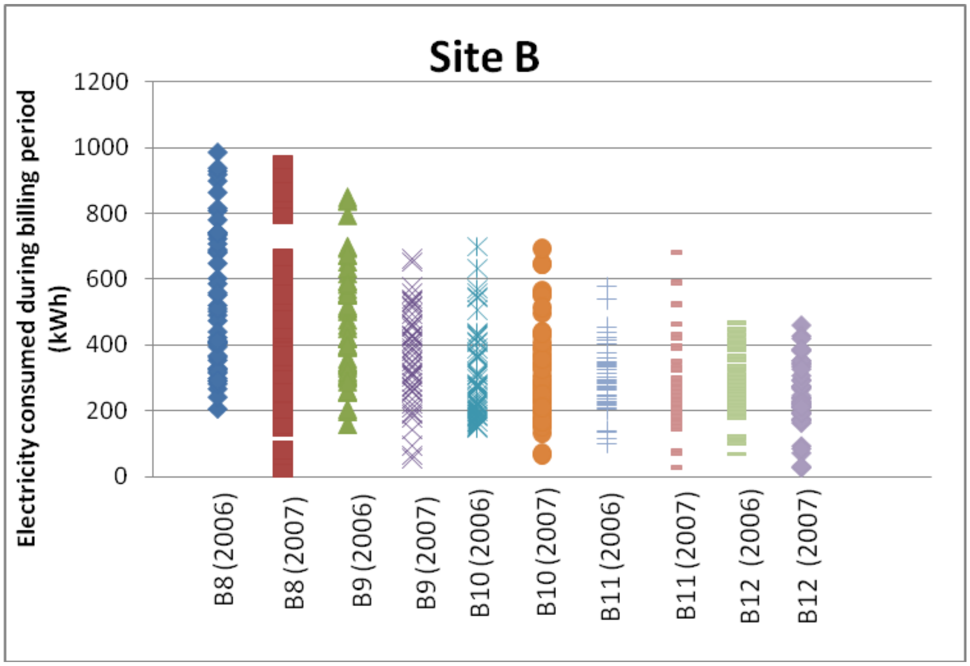
The outlier indicated at Site D has caused a decrease in the average $C_{TOU} – C_{Tier}$ at Site D during the pre-TOU period.

Question 2: Do the households conserve electricity upon the implementation of TOU rates?



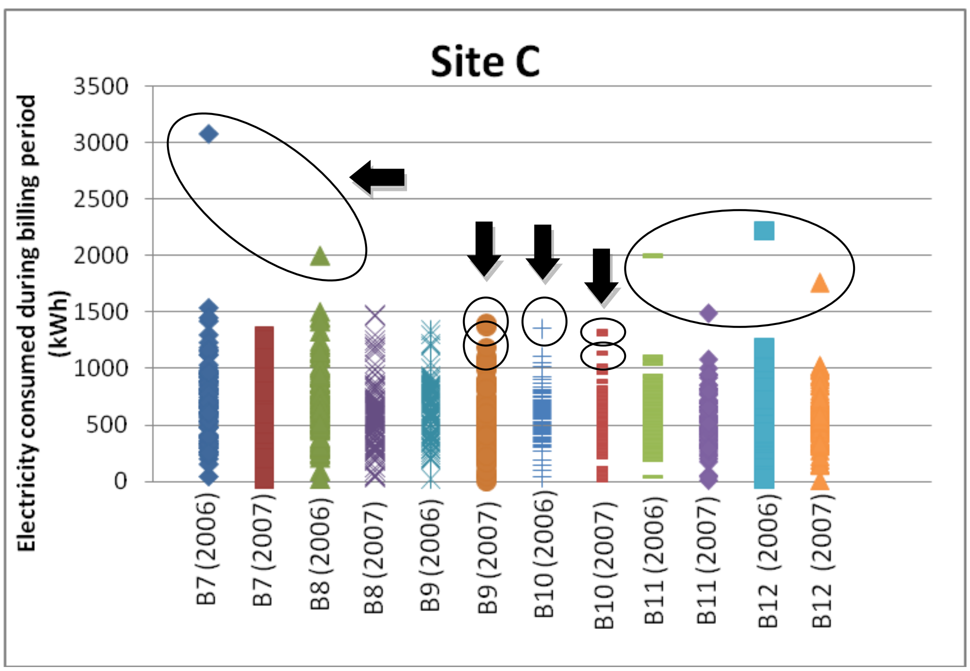
Appendix F - Figure 4. Electricity consumed during billing periods in 2006 and corresponding billing periods during 2007 at Site A.

Although there are no outliers based on the definition provided above, there are some data points that are lower than expected. These data points, highlighted above using a dashed oval, would cause a decrease in the average electricity consumption for their respective billing periods.



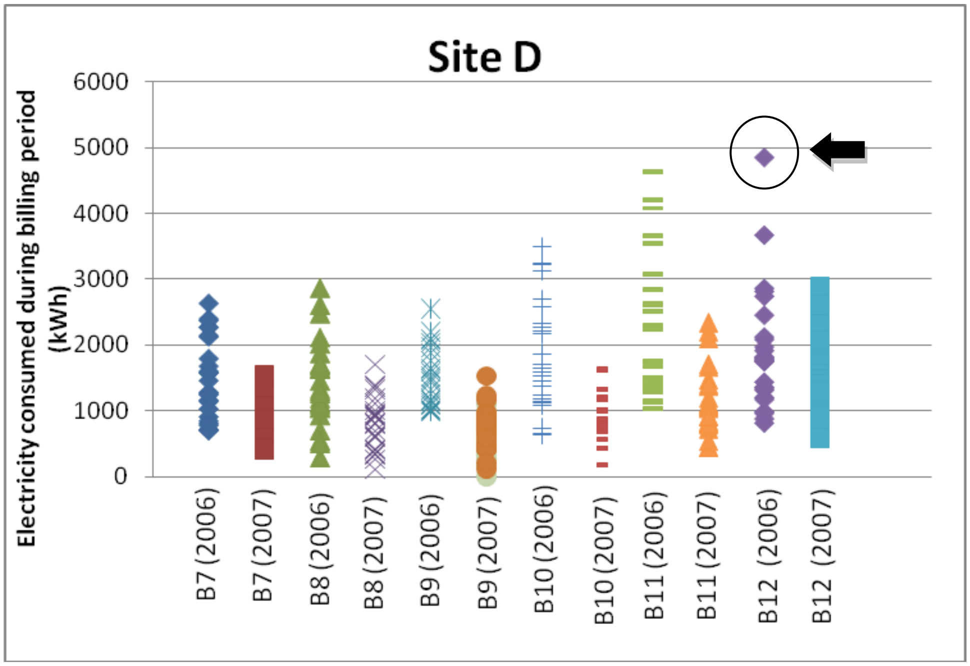
Appendix F - Figure 5. Electricity consumed during billing periods in 2006 and corresponding billing periods during 2007 at Site B.

There are no outliers are identified within the sample data for Site B based on the definition provided above.



Appendix F - Figure 6. Electricity consumed during billing periods in 2006 and corresponding billing periods during 2007 at Site C.

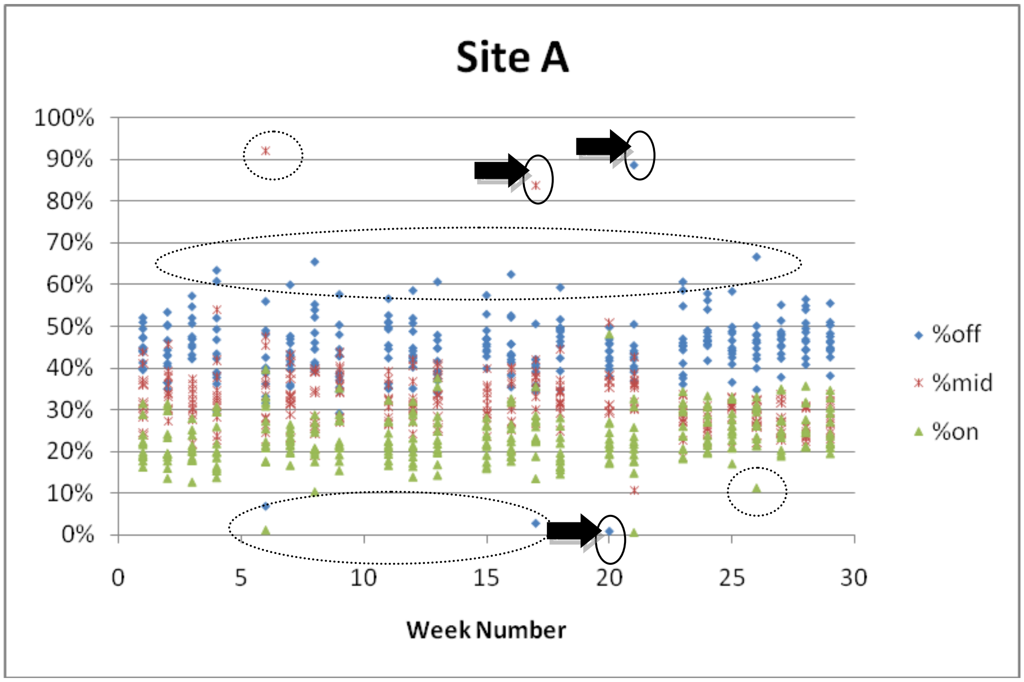
The outliers, indicated above with arrows and ovals, have caused an increase in the average electricity consumption during certain billing periods at Site B.



Appendix F - Figure 7. Electricity consumed during billing periods in 2006 and corresponding billing periods during 2007 at Site D.

The outlier above has caused an increase in the average electricity consumption during the twelfth billing period of 2006 at Site B.

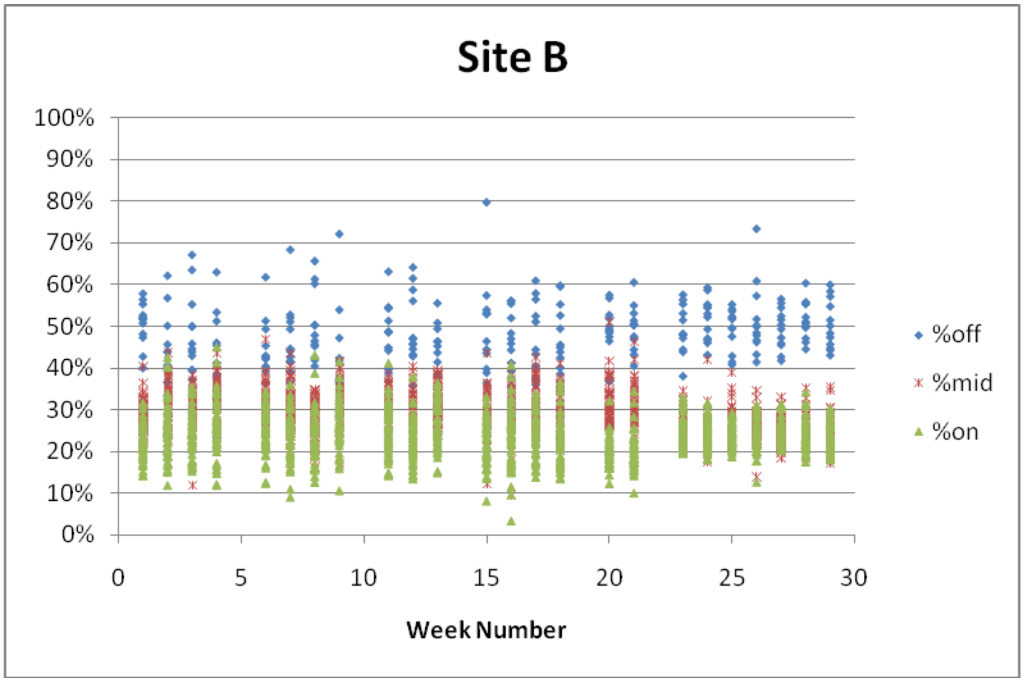
Question 3: Do the households shift the time when they consume electricity upon the implementation of TOU rates?



Appendix F - Figure 8. Percentage of electricity consumed during the on-, mid-, and off-peak periods for each week at Site A.

Per the definition of outlier provided above, there are three outliers identified. These points are indicated with arrows above. During the off-peak period, there is an outlier below the normal rate for Week 20 and an outlier above the normal range during Week 21. During the mid-peak period, there is an outlier above the normal range during Week 17.

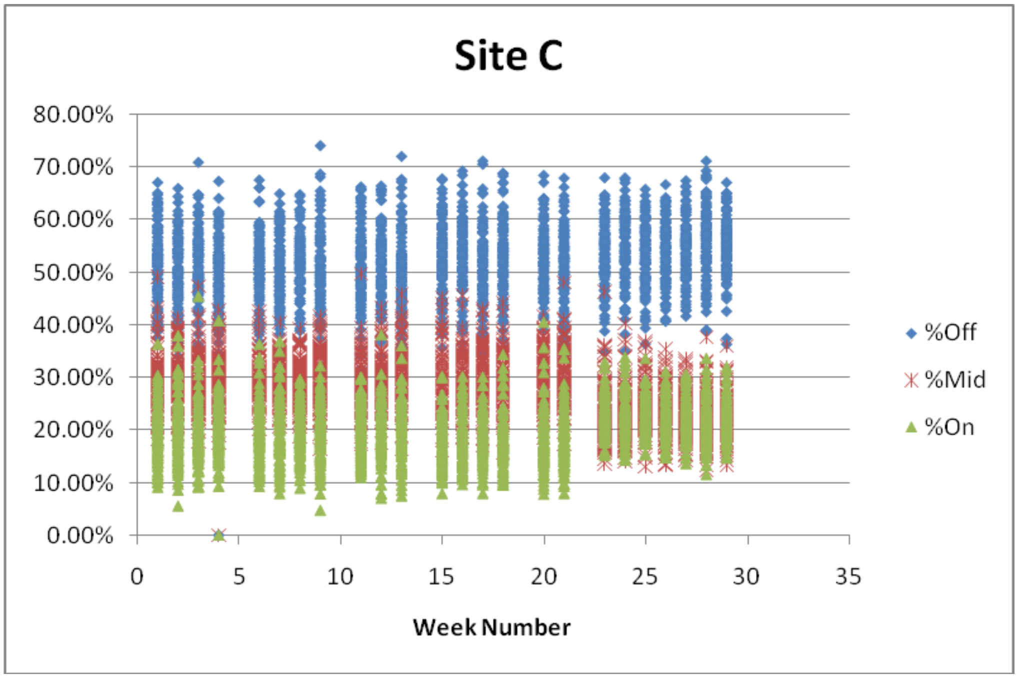
In addition to these outliers, there are several data points that appear to be lower or higher than the rest of the sample data. These points are indicated generally using dashed ovals above.



Appendix F - Figure 9. Percentage of electricity consumed during the on-, mid-, and off-peak periods for each week at Site B.

Per the definition provided above, there are many outliers in the sample data above. For clarity, instead of using arrows the outliers are presented in the table below:

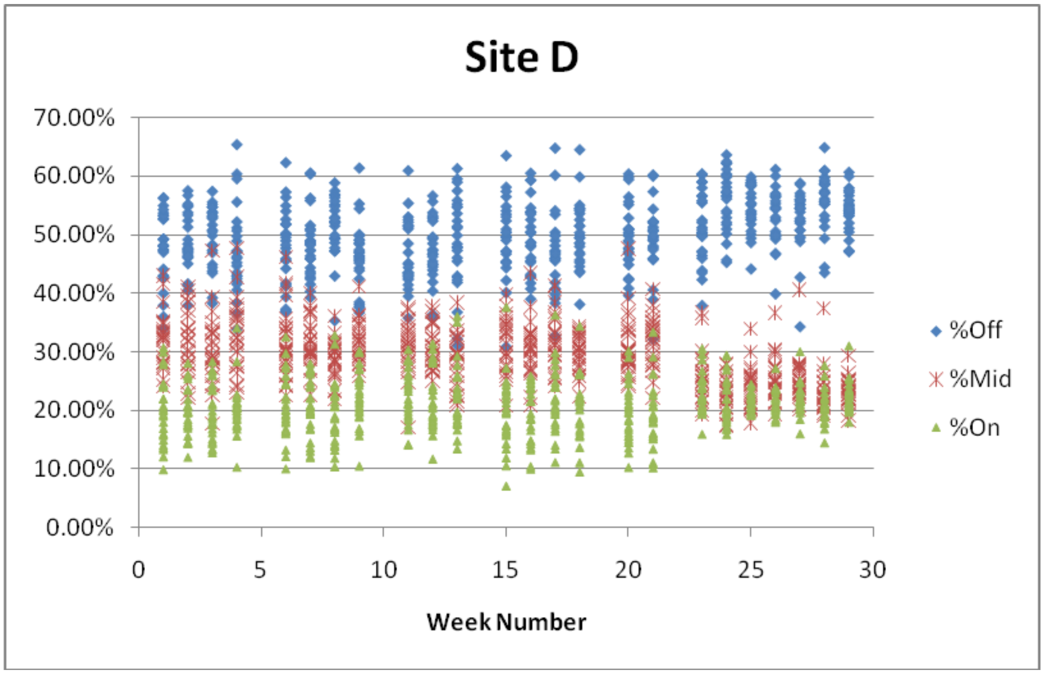
	On-peak	Mid-Peak	Off-peak
Weeks with an outlier above normal range	8, 21, and 22.	1, 6, 20, 24 and 25.	3, 9, 15, 16, 21 and 26.
Weeks with an outlier below the normal range	26.	3, 9, 15, 16 and 26.	24.



Appendix F - Figure 10. Percentage of electricity consumed during the on-, mid-, and off-peak periods for each week at Site C.

Per the definition provided above, there are many outliers in the sample data above. For clarity, instead of using arrows the outliers are presented in the table below:

	On-peak	Mid-Peak	Off-peak
Weeks with an outlier above normal range	1, 2, 3, 4, 6, 12, 13, 18, 20 (two outliers), 21 (three outliers), 25, 28 and 29.	1, 3, 6, 11, 15, 16, 21, 23, 24 (two outliers), 28 and 29.	9.
Weeks with an outlier below the normal range	None.	None.	1, 3, 20 (two outliers), 23, 29 (two outliers).

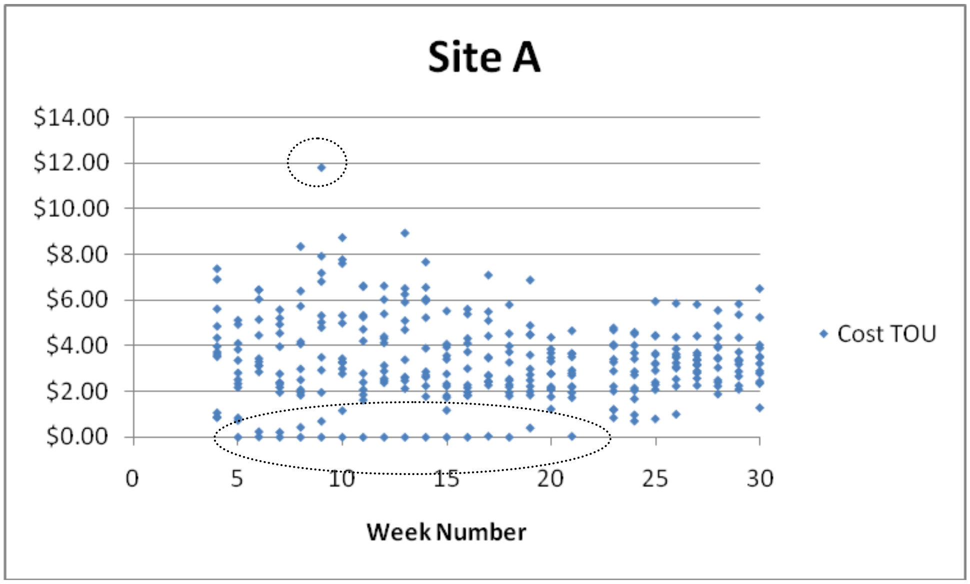


Appendix F - Figure 11. Percentage of electricity consumed during the on-, mid-, and off-peak periods for each week at Site D.

Per the definition provided above, there are many outliers in the sample data above. For clarity, instead of using arrows the outliers are presented in the table below:

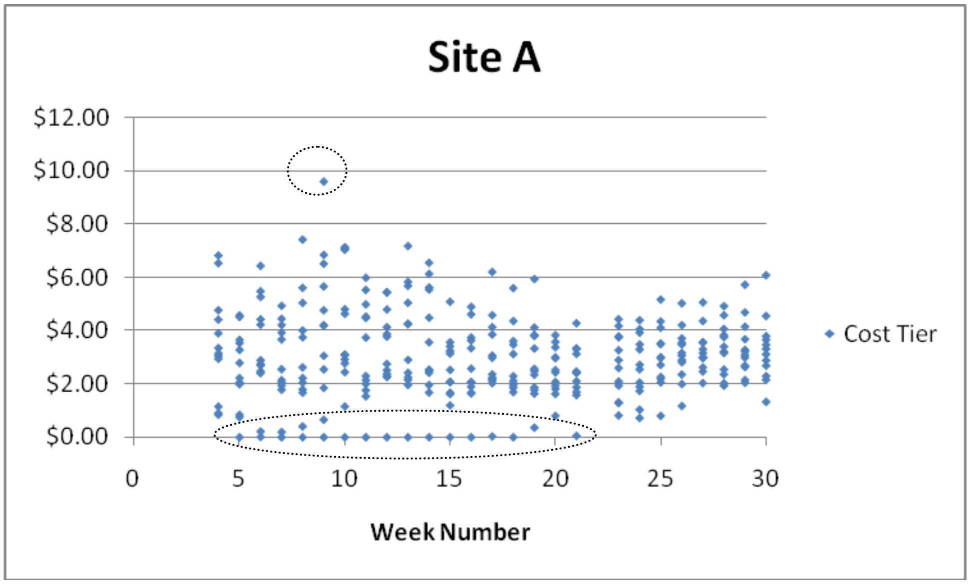
	On-peak	Mid-Peak	Off-peak
Weeks with an outlier above normal range	4, 27 and 29.	20, 26, 27, and 28.	14
Weeks with an outlier below the normal range	None.	11.	8 and 27.

Question 4: Do TOU rates change the costs of the household electricity bill?



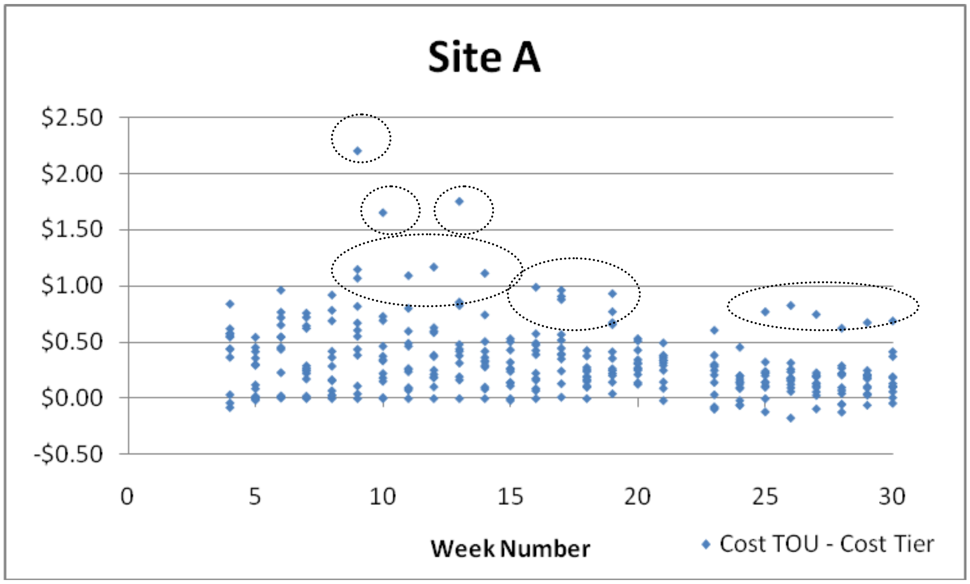
Appendix F - Figure 12. C_{TOU} for each week during the post-TOU period at Site A.

Although there are no outliers identified using the definition provided above, there are several data points that appear to be lower or higher than the rest of the sample data. These points are indicated generally using dashed ovals above.



Appendix F - Figure 13. C_{Tier} for each week during the post-TOU period at Site A.

Although there are no outliers identified using the definition provided above, there are several data points that appear to be lower or higher than the rest of the sample data. These points are indicated generally using dashed ovals above.



Appendix F - Figure 14. C_{TOU} minus C_{Tier} for each week during the post-TOU period at Site A.

Although there are no outliers identified using the definition provided above, there are several data points that appear to be lower or higher than the rest of the sample data. These points are indicated generally using dashed ovals above.

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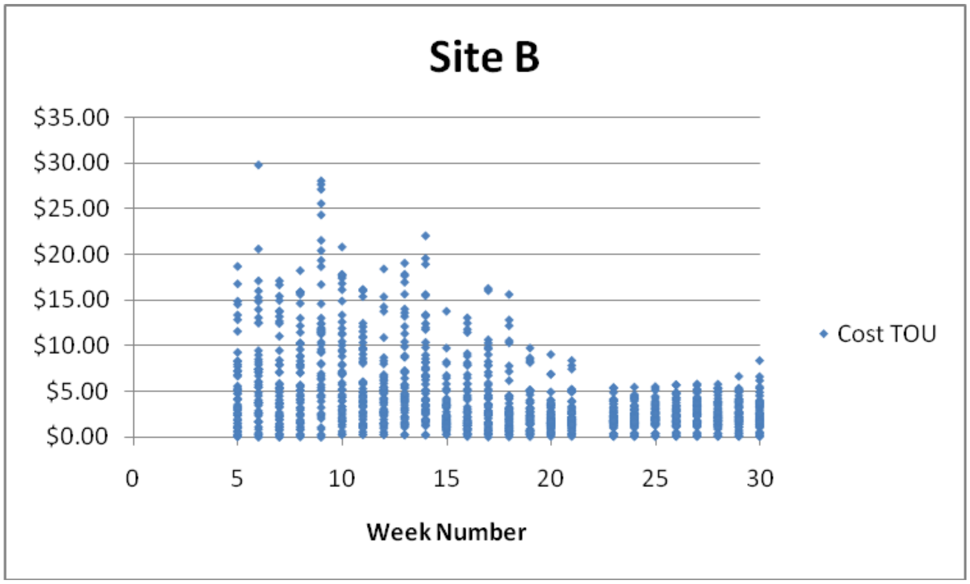
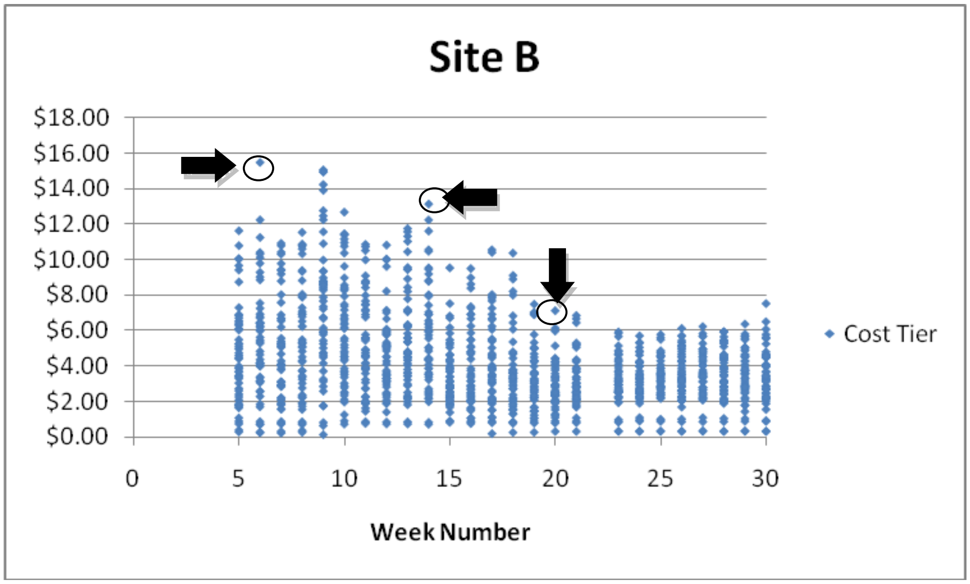


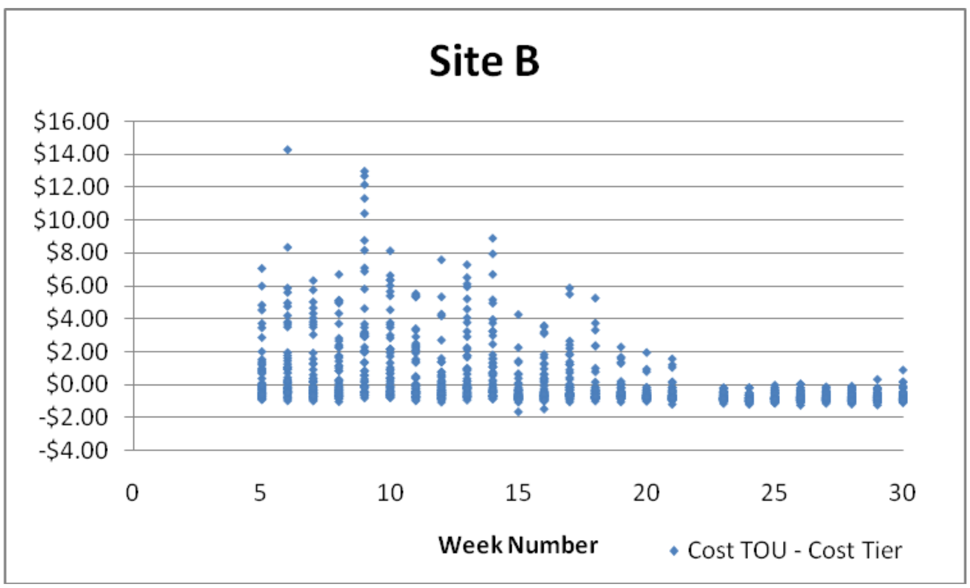
Appendix F - Figure 15. C_{TOU} for each week during the post-TOU period at Site B

Per the definition provided above, there are many outliers in the sample data above. For clarity, instead of using arrows the outliers are listed as follows. The Weeks with outliers above the normal range: Week 6, Week 12, Week 15, Week 17 (two outliers), Week 18, Week 20, Week 21, and Week 30.



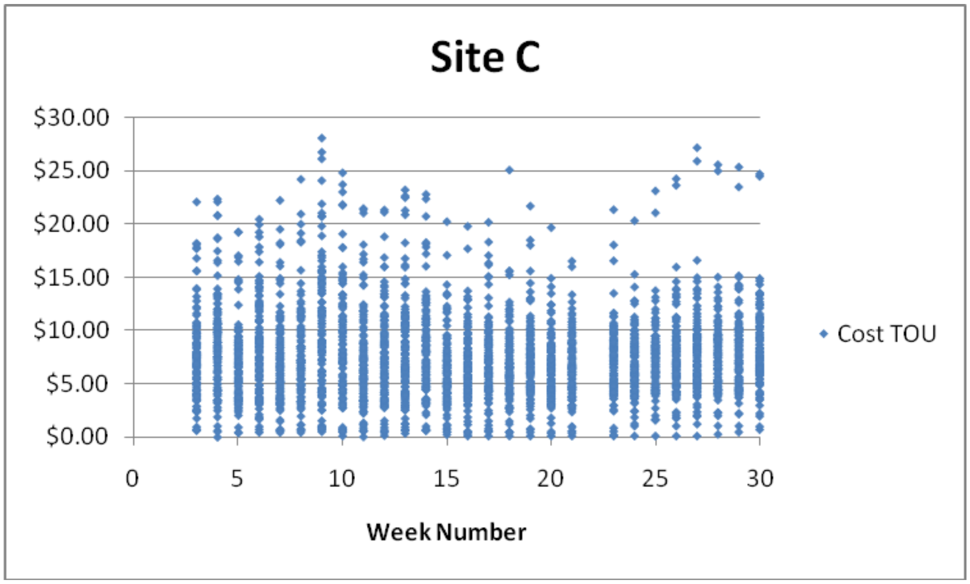
Appendix F - Figure 16. C_{Tier} for each week during the post-TOU period at Site B

Per the definition of outlier provided above, there are three outliers identified. These points are indicated with arrows above.



Appendix F - Figure 17. C_{TOU} minus C_{Tier} for each week during the post-TOU period at Site B.

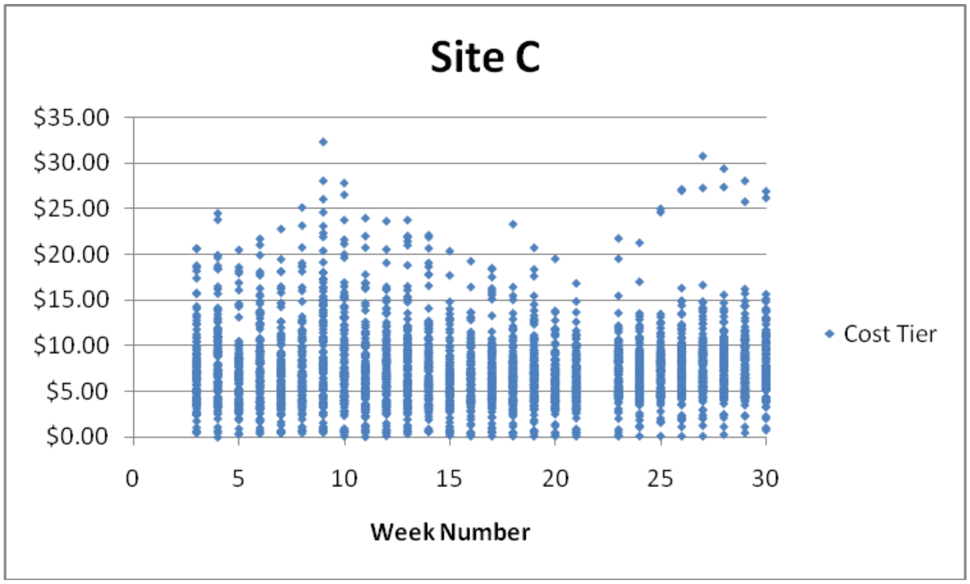
Per the definition provided above, there are many outliers in the sample data above. For clarity, instead of using arrows the outliers are listed as follows. The Weeks with outliers above the normal range: Week 5, Week 6, Week 12, Week 14, Week 15, Week 17 (two outliers), Week 18 (two outliers), Week 19, Week 20, Week 21(two outliers), Week 25, Week 29 and Week 30.



Appendix F - Figure 18. C_{TOU} for each week during the post-TOU period at Site C.

Per the definition provided above, there are many outliers in the sample data above. For clarity, instead of using arrows the outliers are listed as follows. The weeks with outliers above the normal range:

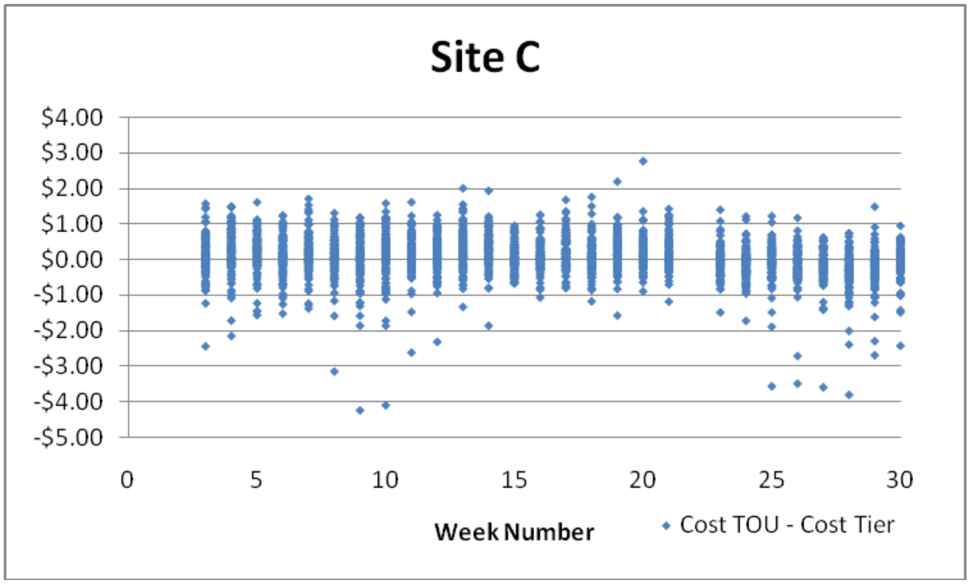
- Week 5 (two outliers)
- Week 10
- Week 11 (three outliers)
- Week 12 (two outliers)
- Week 13
- Week 14 (two outliers)
- Week 15 (two outliers)
- Week 16 (two outliers)
- Week 17
- Week 18
- Week 19 (two outliers)
- Week 20
- Week 21 (two outliers)
- Week 23 (two outliers)
- Week 24 (two outliers)
- Week 25 (two outliers)
- Week 26 (two outliers)
- Week 27 (two outliers)
- Week 28
- Week 29 (two outliers)
- Week 30 (two outliers)



Appendix F - Figure 19. C_{Tier} for each week during the post-TOU period at Site C.

Per the definition provided above, there are many outliers in the sample data above. For clarity, instead of using arrows the outliers are listed as follows. The weeks with outliers above the normal range:

- Week 3 (two outliers)
- Week 4 (two outliers)
- Week 5 (two outliers)
- Week 8 (two outliers)
- Week 9
- Week 10 (two outliers)
- Week 11 (two outliers)
- Week 12
- Week 13
- Week 14 (two outliers)
- Week 15 (two outliers)
- Week 16 (two outliers)
- Week 17 (two outliers)
- Week 18
- Week19 (two outliers)
- Week 20
- Week 21
- Week 23 (two outliers)
- Week 24 (two outliers)
- Week 25 (two outliers)
- Week 26 (two outliers)
- Week 27 (two outliers)
- Week 28 (two outliers)
- Week 29 (two outliers)
- Week 30 (two outliers)



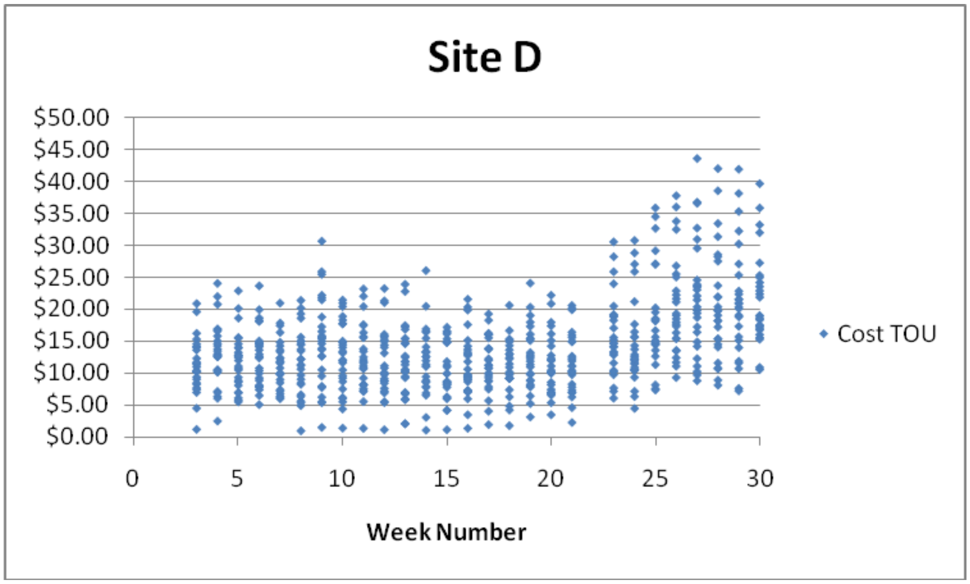
Appendix F - Figure 20. C_{TOU} minus C_{Tier} for each week during the post-TOU period at Site C.

Per the definition provided above, there are many outliers in the sample data above. For clarity, instead of using arrows the outliers are listed as follows.

The weeks with outliers above the normal range: Week 13, Week 14, Week 17, Week 18, Week 19, Week 20, Week 23, Week 24 and Week 29.

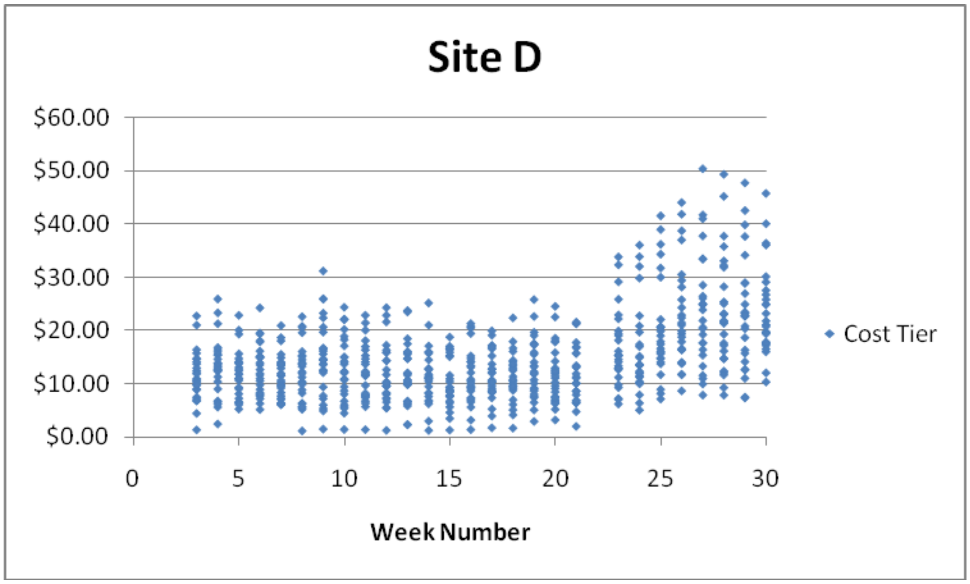
The Weeks with outliers below the normal range include:

- Week 3
- Week 4 (two outliers)
- Week 5 (three outliers)
- Week 6 (two outliers)
- Week 8 (two outliers)
- Week 9
- Week 10
- Week 11 (two outliers)
- Week 12
- Week 13
- Week 14
- Week 18
- Week 19
- Week 21
- Week 22
- Week 23
- Week 24
- Week 25 (two outliers)
- Week 26 (two outliers)
- Week 27
- Week 28 (two outliers)
- Week 29 (two outliers)



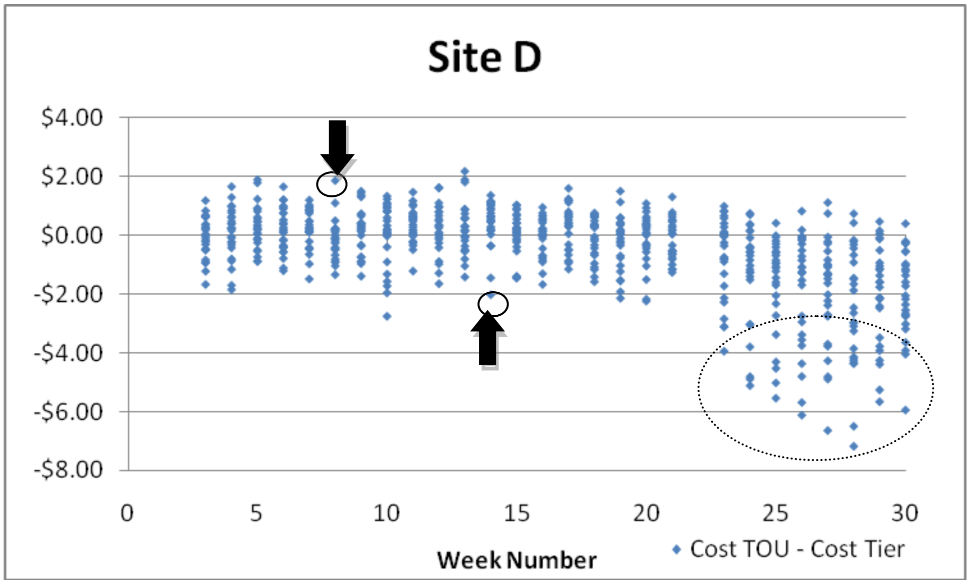
Appendix F - Figure 21. C_{TOU} for each week during the post-TOU period at Site D.

There are no outliers are identified within the sample data for Site D based on the definition provided above.



Appendix F - Figure 22. C_{Tier} for each week during the post-TOU period at Site D.

There are no outliers are identified within the sample data for Site D based on the definition provided above.



Appendix F - Figure 23. C_{TOU} minus C_{Tier} for each week during the post-TOU period at Site D.

Per the definition of outlier provided above, there are two outliers identified. These points are indicated with arrows above. In addition to these outliers, there are several data points that appear to be lower the rest of the sample data. These points are indicated generally using a dashed oval.