The Ontario Smart
Metering Initiative:
Will Time-of-Use Pricing
Work in Ontario?

by Sabina Postolek

An Honours essay submitted to
Carleton University in fulfillment
of the requirements for the course
ECON 4908, as credit toward
the degree of Bachelor of Arts with
Honours in Economics.

Department of Economics
Carleton University

Ottawa, Ontario

August 13, 2007

CONTENTS

Chapter Four – Assessment

TABLES

FIGURES

INTRODUCTION

In July 2004, the Minister of Energy requested that the Ontario Energy Board (OEB) devise a plan to implement smart meter technology in Ontario. The OEB target plan aims at installing 800,000 smart electricity meters in Ontario by December 31, 2007 and to all electricity users by December 31, 2010.

The proposed goal of the Smart Metering Initiative is to reduce consumption during peak periods, reduce transmission congestion, conserve electricity (thus reducing the necessity for immediate new generation creation and imports), and lower overall peak electricity prices. The Initiative hopes to achieve these proposed goals through the use of a marginal pricing plan known as *peak-load pricing*. By implementing this type of pricing plan, consumers would be paying a more realistic electricity price. That is, this type of pricing plan permits electricity utilities to charge higher prices to consumers when the demand for electricity is high. The benefit of these pricing plans is that there is an expectation that consumers will chose to shift electricity consumption from higher priced periods toward lower priced periods thus reducing the overall amount of generation and transmission capacity required.

Although the goals of the Initiative would definitely benefit all involved and theoretically, peak-load pricing should result in decreases in electricity demand during peak periods[1], the implementation costs associated with the Initiative have been estimated at an initial $1 billion with net increases in annual cost of $50 million (Ontario Energy Board 2005). Additionally, consumers will be responsible for both the initial and ongoing costs of the Initiative via a monthly charge on their electric bill of between $3.00 and $4.00 (Ontario Energy Board 2005).

---

[1] A peak period is defined as a period when electricity demand is high, resulting in higher marginal costs, and consequently, higher electricity prices.

With such a hefty price tag there have been some concerns as to the true feasibility and merit of the entire Initiative. Empirical studies in the United States and worldwide have been implemented over the years to assess whether peak-load pricing is in fact effective at achieving the goals proposed for the Initiative. Some studies found that electricity re-distribution did occur in the short run (e.g. Holland and Mansur 2006; Boisvert et al. 2007). That is, there were shifts of consumption from peak to off-peak periods, but little research has been conducted on the long run effects of these types of pricing plans. Furthermore, there have been concerns about the validity of data obtained from consumers who have chosen to volunteer for peak-load pricing plans, the transferability of findings from different utilities, users, and climates, and the fact that research in the area tends to show an inconsistent and wide range of values with respect to the true effectiveness of peak-load pricing.

Time-of-use pricing is not a new or innovative concept. Many utilities have used similar mandatory metering systems with commercial and industrial consumers over the last several decades and although there are findings to support the use of such pricing schemes with these types of users, the extensive body of research conducted on small commercial and residential users has failed to produce consistent, precise, and reliable conclusions. With such vague findings pertaining to these smaller users, there is skepticism as to whether any benefits gained from smart metering are sufficient to justify the investment so that one can meter energy on small intervals for every house, condo, and small business in Ontario.

In order to assess the Ontario Smart Metering Initiative this paper will begin by establishing a framework from which to evaluate the Initiative. This paper will begin with a review of the basic economic concepts of peak-load pricing. This will be followed by a review of the relevant literature pertaining to peak-load pricing programs with emphasize on the issues raised and the implications for Ontario. Subsequently, a detailed description of the Smart Metering Implementation Plan will be presented. Once the above framework has been established, a thorough assessment of the Ontario Smart Metering Initiative will be undertaken in light of past developments and experiences as well as through the recent results of the Smart Meter Pricing Pilot conducted in Ontario. Lastly, some general conclusions will be reached and policy recommendations will be presented.

CHAPTER ONE

ECONOMIC PRINCIPLES OF PEAK LOAD PRICING

Economic Efficiency

The goal of the electricity market, as in any market, is to achieve *economic efficiency*. Economic efficiency implies cost minimization for a given level of output. In terms of prices[2], the economically efficient price is the minimum cost achieved when price is equal to marginal cost, where marginal cost is defined as "a change in the total cost for a unit change in quantity" (Rothwell and Gomez 2003 p.47). On the other hand, when price does not equal marginal cost, the market is said to have not produced efficient prices. Economically efficient prices inform customers of the costs associated of producing another unit of the output. For example, if the market price of electricity were set below the marginal cost, that is, not at the economically efficient price, one would observe that customers would demand more output than economically efficient and producers would supply less output then the economically efficient level. Conversely, if the market price were to be set above the efficient price, one would find that consumers would responded by demanding less output then is economically efficient and producers would supply more than the efficient level (Rothwell and Gomez 2003).

As stated above, achieving economically efficient prices ensures that the electricity market clears and that costs have been minimized. However this is only the case when markets are able to monitor themselves, one finds that when prices, be it for electricity or another commodity, are set under regulation, they are seldom found to be economically efficient. As a

[2] To simplify the discussion, a competitive electricity market is assumed.

result, a type of marginal cost pricing, known as *peak-load pricing* has become a key concept in terms of electric power.

Peak Load Pricing

Peak-load pricing, commonly referred to as *time of use (TOU) pricing*, is currently being offered to large and medium-sized commercial and industrial users in Canada. Similar policies are also commonly found around the world in nations such as Great Britain and the United States.

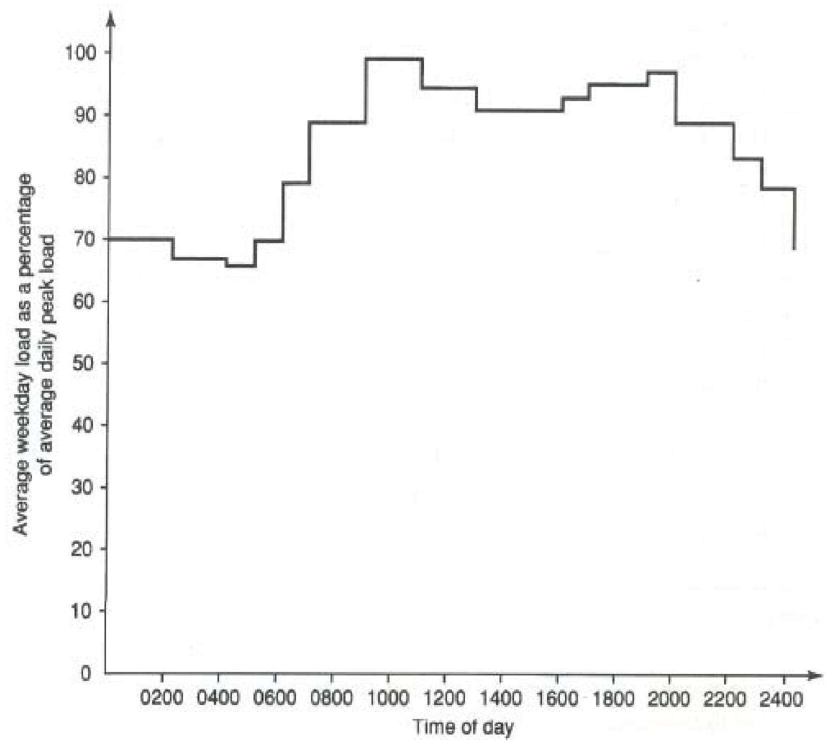
Peak-load pricing refers to the changing of price based on time of use. In terms of electricity, one expects more electricity to be demanded mid-day than in the middle of the night as most production, manufacturing, and residential use occurs during this time. This increased mid-day demand, results in marginal costs that are higher in the middle of the day than mid-night. Consequently, one finds that mid-day prices are higher than mid-night prices. This argument is the basis for one of the most common forms of peak-load pricing in which prices change throughout the course of the day in proportion to the variation in the marginal cost of production (Viscusi, Vernon, and Harrington 2000).

As mentioned above, more electricity is demanded during the middle of the day than in the middle of the night. Figure 1.1 depicts a typical weekday load curve[3], where peak demand appears to occur in the middle of the morning and by mid-night demand is only approximately 70% of the mid-morning amount (Viscusi, Vernon, and Harrington 2000).

---

[3] In general, the demand for electricity tends to follow a predictable cyclical pattern not only daily, but also weekly, monthly, and seasonally (Viscusi, Vernon, and Harrington 2000).

FIGURE 1.1 – AVERAGE DAILY LOAD CURVE FOR ELECTRICITY



Source: Viscusi, Vernon, and Harrington (2005)

According to such a load curve, a consumer could expect to pay "peak" prices during this mid-morning period when demand for the typical consumer is high, and pay "off-peak" prices during the mid-night period. Since peak prices are higher than off-peak prices, one would expect consumers to either conserve electricity during these high price periods or shift their usage to off-peak price periods. These conserving and shifting actions could cause a decrease in peak demand and consequently, could decrease the burden placed on the power system during peak load (Viscusi, Vernon, and Harrington 2000). That is, time-varying prices reflect more accurately the time-varying costs of electricity production and thus can be expected to improve the efficiency of resource allocation in the economy (Faruqui and Malko 1983).

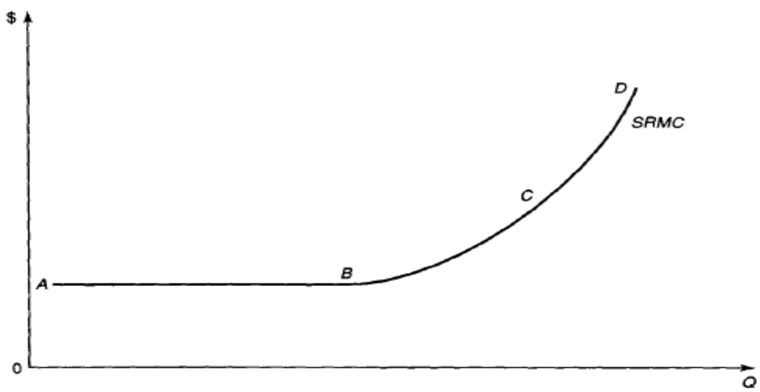
In order to fully comprehend TOU pricing, it is essential to understand the costs associated with power production. Electricity is not a commodity that can generally be stored cost efficiently, thus at all times there needs to be sufficient supply to meet consumer demand[4] (Viscusi, Vernon, and Harrington 2000). Moreover, a typical power system uses a variety of plant types to supply the electricity needed to satisfy the variable pattern of demand. While the purpose of the power system is to generate electricity, like any firm, the power systems primary goal is to ensure cost minimization. For instance, nuclear power plants tend to have higher fixed costs, but have lower variable costs than other plant types. As a result, nuclear power plants are usually used as “base-load” plants, that is, these types of plants are used first and for as many hours a year as possible. Alternatively, there are peak-load plants (such as combustion turbines); these plants tend to have lower fixed costs, but high variable costs. The purpose of peak-load plants is to supplement supply when the “base-load” plants cannot meet demand and are used only when necessary (only a small numbers of hours per year) (Viscusi, Vernon, and Harrington 2000).

By summarizing the above power production costs, one can find a short run marginal cost curve that looks similar to the curve illustrated in Figure 1.2.

Referring to Figure 1.2, the portion of the short run marginal cost curve labeled AB could represent the power system’s nuclear power plant costs; whereas segment BC might represent the cost associated with coal-powered plants of differing ages and efficiency levels and lastly, portion CD of the curve could represent the costs associated with the peaking plants (Viscusi, Vernon, and Harrington 2005). This is known as *merit ordering*.

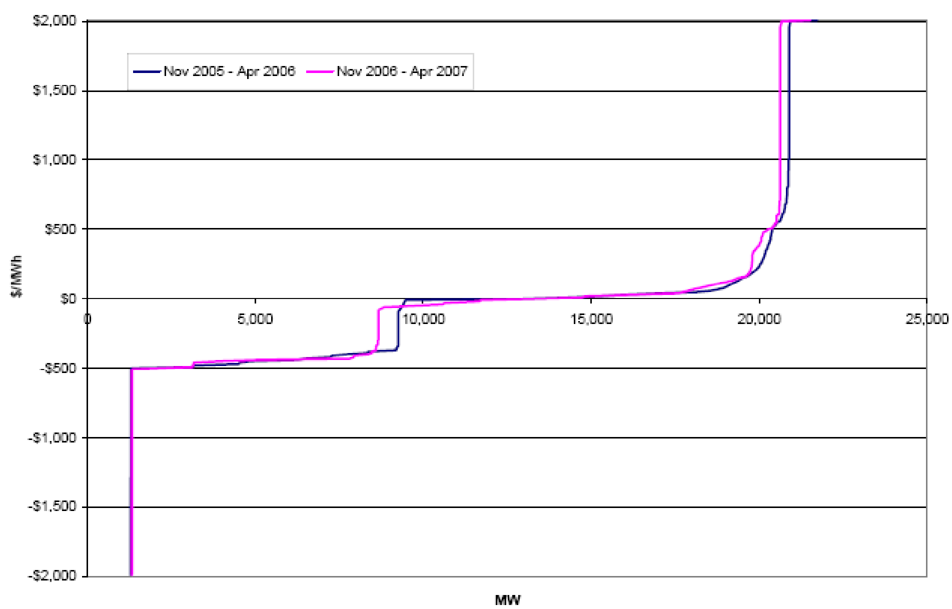
[4] In reality, power systems need to generate their peak demand capacity, plus an additional amount of capacity to allow for uncertainty in demand and unplanned events such as power outages. The combination of these two types of capacity is referred to as” installed capacity”.

FIGURE 1.2 – SHORT RUN MARGINAL COST CURVE FOR AN ELECTRIC POWER SYSTEM



Source: Viscusi, Vernon, and Harrington (2005)

FIGURE 1.3 – AVERAGE DOMESTIC OFFER CURVE (NOVEMBER 2005/2006 – APRIL 2006/2007)



Source: Campbell, McFetridge, and Rusnov (2007)

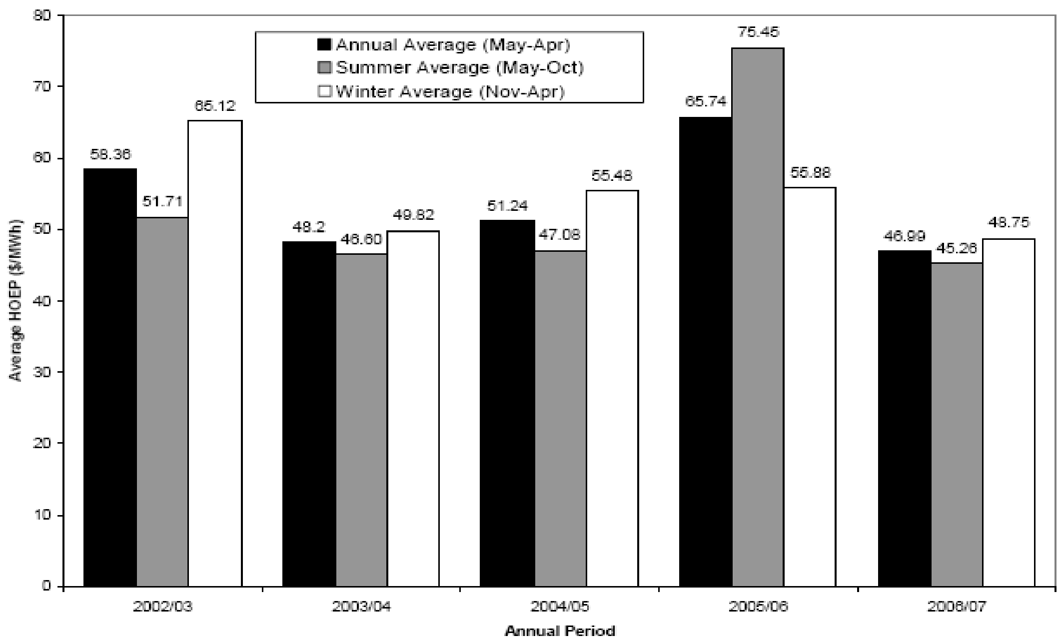
With reference to Ontario, Figure 1.3 shows the average domestic offer curve from November 2006 until April 2006 and also from November 2007 to April 2007. Nuclear and “base-load” hydro plants in Ontario supply power at a marginal cost which is very low, say $10/MWh. Coal plants however have higher marginal costs, somewhere closer to $50/MWh; while gas plants offer power at their marginal cost which is $70-$80 depending on the turbine used and gas prices. The peaking plants would offer their supply at prices above $80/MWh.

The market price for electricity is determined by the intersection of the demand schedule for electricity with the supply schedule. Therefore, the market price in any hour (called the hourly Ontario energy price or HOEP) depends on the demand for electricity in that hour. During spring evenings, demand is very low and only the least expensive “base-load” plants will be operating (such as nuclear and some hydro plants) and the HOEP will be around $10MWh as discussed above. However, during a spring or fall day, the more expensive “base-load” plants such as coal plants will also be required to meet demand and then the HOEP will be closer to $50MWh. Lastly, late summer and winter afternoons are notorious for high electricity demand and thus all power generation will be required and the HOEP will be $80 or above. Figure 1.4 shows how the average HOEP varies in Ontario depending on the time of year, which is linked (as discussed above) with the quantity of power demanded.

From the discussion above, one can see that since the demand for electricity varies continuously, in order to charge a price that is equal to the short run marginal cost at any given time would require continuously changing the price associated with electricity.

In summary, due to the nature of manufacturing, production, and residential use, more electricity is demanded in the middle of the day than in the middle of the night. This results in marginal costs which are higher mid-day than mid-night (and seasonally) since power producers need to use more costly plants in order to satisfy consumer demand. Therefore, in the context of peak-load pricing, where marginal cost is equal to price, mid-day prices are higher than mid-night prices. Accordingly, one would expect that consumers would either move electricity consumption away from high priced peak periods to low priced periods or decrease consumption in these peak periods all together (Viscusi, Vernon, and Harrington 2000).

FIGURE 1.4 – AVERAGE HOEP COMPARISON OVER SUMMER, WINTER, AND ALL MONTHS (MAY 2002 – APRIL 2007)



Source: Campbell, McFetridge, and Rusnov (2007)

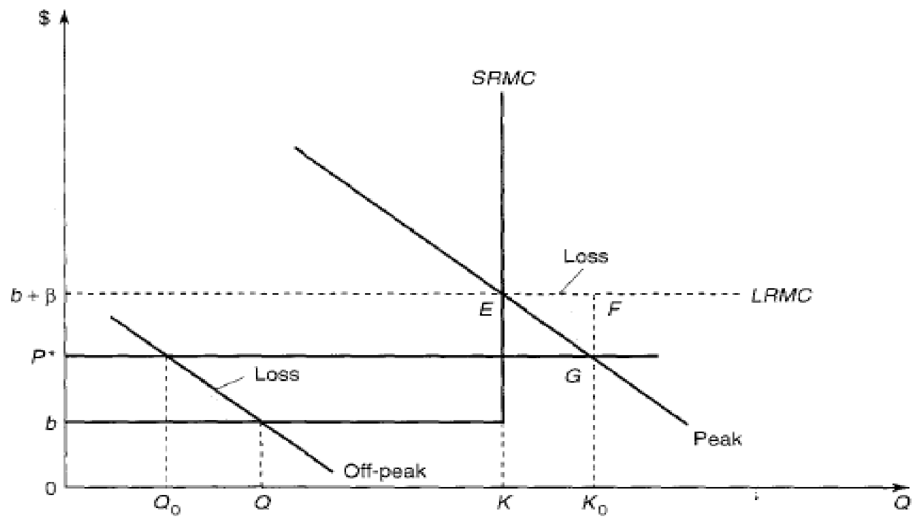
Efficiency Gains

The allocative economic efficiency gains from peak-load pricing may occur if users choose to consume less during high priced peak periods, shift consumption to off-peak periods, or reduce total consumption. The amount customers respond to higher peak-prices depends on how price-responsive they are. That is, how elastic their demand for electricity is. Productive efficiency gains from peak-load pricing occur in the short run as utilities operate their more efficient generating plants more often. Long-run efficiency gains also occur from avoiding the strain of peak capacity use and thus delay the need for replacing existing generating units (Lafferty et al. 2001).

Peak-Load Pricing Model

In order for the market to be efficient, utilities need to be charging a price for electricity that represents the marginal costs of production; however, in Ontario consumers are being charged, for simplicity, a single price which is leading to deadweight losses. Consider this very simplified model, assume that the electric utility charges a single price that does not change throughout the day, say, a price of P^*; this situation is depicted in Figure 1.5. In order to meet the demand at the peak at this set price, capacity of K_0 is required. Since the optimal capacity is K, where price is equal to LRMC, the single-price plan leads to too much capacity. The deadweight loss associated with this is represented by triangle EFG. This deadweight loss equals the difference between the cost of the excess capacity (rectangle EFK_0K) and the willingness to pay for the additional capacity, EGK_0K. The peak-period consumers are not charged enough for the actual costs that they bring about (Viscusi, Vernon, and Harrington 2005). The second deadweight loss triangle is associated with the use of plants in the off-peak period. Namely, with the price P* charged in the off-peak period, consumption in this period is low. It is at Q_0 rather than at Q (where price would equal SRMC) (Viscusi, Vernon, and Harrington 2005).

FIGURE 1.5 – DEADWEIGHT LOSSES DUE TO NON-PEAKING PRICING



Source: Viscusi, Vernon, and Harrington (2005)

Peak-Load Pricing Application

In order to truly implement peak-load pricing one needs to allow prices to change throughout the course of the day as variations in short run marginal cost occur. However, in practice it is difficult to achieve this result while maintaining customer satisfaction, particularly when considering small electricity users who do not have as much control over their power usage as large commercial and industrial users. This section briefly discusses some of the aspects required in the application of peak-load pricing to small-load users.

As depicted in Figure 1.1, demand changes throughout the day as well as weekly and seasonally. Due to these constant changes, in order to implement peak-load pricing effectively, careful consideration needs to be taken when assessing metering demand and period duration and pricing (Viscusi, Vernon, and Harrington 2000). These considerations are essential since it is not very practical for small users to have prices that change every few minutes. Moreover, the cost associated with metering consumption in such a manner might prove too large (Viscusi, Vernon, and Harrington 2000). Therefore, rather than having prices vary frequently throughout the day, a typical peak-load pricing program for a residential customer might look similar to the one presented in Table 1.1:

TABLE 1.1

TYPICAL PEAK-LOAD PRICING PLAN

Day	Time Period	Price / kWh
Weekdays	10 pm to 6am	$0.04
Weekdays	6 am to 11 am	$0.07
Weekdays	5 pm to 10pm	$0.07
Weekdays	11 am to 5pm	$0.14
Weekends	All times	$0.04

Referring to the rates in Table 1.1, for this particular plan, the peak period would be weekdays from 11am to 5pm and the off-peak period would be from 10pm to 6am on weekdays and on the weekend.

Taking into account seasonal changes, one might also find that the summer peak exceeds the winter peak. This result is primarily due to the use of air conditioners (Philipson and Willis 2006). Due to these seasonal demand changes, utilities might have rates that are in effect for the winter period (November to April) and then have a different rate structure, with slightly higher rates, for the summer period (May to October).

Peak-pricing plans that have several price periods throughout the day help reduce the price volatility that consumers would experience if in fact electricity prices varied according to marginal costs, while still allowing utilities to charge their users a more realistic electricity price.

Demand Response[5]

In order to full understand the theory behind peak loading pricing and why utilities around the world are interested in pursuing such ventures, one must first understand the broader concept of which peak loading pricing is a part of – demand response.

As mentioned above, the rates that most electricity customer are accustomed to are those which are based on average electricity costs (rather than marginal cost) and thus bear little relation to the true costs of electricity production which vary over time. Demand response is a program which is established to help motivate users to change their electricity usage in response to changes in the price of electricity, or to give consumer an incentive payment to induce lower electricity consumption when market prices are high or when system reliability is in jeopardy (US Department of Energy 2006).

Demand response tends to be broken down into two different programs: price –based demand response programs and incentive-based demand response programs. Price-based demand response programs provide customers with electricity rates which vary to reflect the value and the cost of electricity at different times throughout the day (and/or season). Examples of these types of demand responses programs are real-time pricing (RTP), critical-peak pricing (CPP) and time of use (TOU) pricing. Incentive-based demand response programs rebate customers when they reduce their load at specific times announced by the utility, usually referred to as *critical peak periods*. These critical periods are usually triggered by grid reliability problems or high electricity prices stemming from a variety of variables (extreme temperatures, supply problems, equipment malfunction) (Ontario Energy Board 2004; US Department of Energy 2006).

[5] All information in this section was obtained from the report to the United States Congress by the U.S. Department of Energy (2006) and from sections of the OEB "Demand-Side Management and Demand Response in the Ontario Electricity Sector" report to the Minister of Energy (2004).

There has been a recent surge of interest in demand response program in North America as demand continues to increase and supply is being pushed to capacity. The majority of utilities in North America charge consumers flat, average-cost electricity rates which do not reflect the true cost of electricity, in an electricity market like Ontario's, this leads to inefficient capital investment in new generation, transmission, and distributional equipment and consequently higher electric bills for consumers (Ontario Energy Board 2004). Although price-based demand response programs tend to be more effective at altering consumer consumption patterns, these types of demand response programs require special metering equipment and billing system and most customers are not able to make substantial electricity decisions on an hourly or even daily basis. Thus incentive-based programs tend to be the first line action when considering the application of demand response programs as they can be set up fairly rapidly and at a much smaller cost than price-based programs, however these types of programs tend to be limited to large industrial and commercial consumers and thus are difficult to implement with residential users (US Department of Energy 2006).

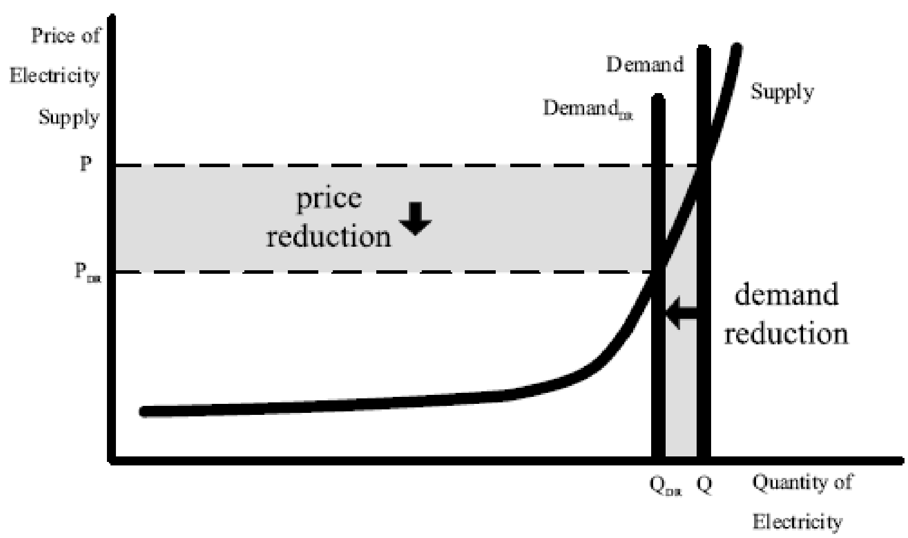
As mentioned previously, it is thought that the most important benefit from demand response programs is the improved resource-efficiency of electricity production due to the closer alignment between customers' electricity pries and the value they place on it. This increased efficiency is said to create a variety of benefits that can be categorized into four primary groups:

- Participant financial benefits: the bill savings and incentive payments earned by consumers who adjust their consumption in response to time varying prices or incentive-based programs (US Department of Energy 2006).
- Market-wide financial benefits: In the short-run, these are the lower wholesale market prices which occur since demand response avert the need to use the most

costly power plans during peak periods. These lower wholesale prices drive production costs and prices down for all wholesale electricity buyers. Over the long run, sustained demand response lowers the overall system requirements, allowing suppliers to purchase or build less new capacity. Eventually it is thought that these savings may be passed onto most retail customers as bill savings. Figure 1.4 shows how significantly prices can change as a result of decreases in demand (US Department of Energy 2006).

- Reliability benefits are the operational security that results because demand response lowers the likelihood of forced outages that impose financial costs and inconvenience on customers (US Department of Energy 2006).
- Market performance benefits refer to demand response's value in mitigating suppliers' ability to exercise market power by raising power prices significantly above production costs (US Department of Energy 2006).

FIGURE 1.6: ELECTRICITY PRICE/DEMAND CURVE FOR SHIFTED LOAD



Source: U.S. Department of Energy (2006)

Due to the complexity of demand response and how it applies to the various components of the electricity market, this paper will focus only on the element of price-based demand response programs such as peak-load pricing.

Elasticity of Demand[6]

One of the ways in which this shift from peak to off-peak periods is measured is through the use of elasticities. The responsiveness of customers to changes in prices is known as *price elasticity of demand*. Own-price elasticity refers to the users change in consumption in the same period in which the price changed occurred. For instance, if the price of electricity decreased from $0.15/kWh to $0.12/kWh within the peak period and consumers subsequently increased their consumption during the same period, one could calculate this user's own-price elasticity.

Another measurement of elasticity is known as the *elasticity of substitution*. This elasticity measures the customer's shift in consumption across time periods (from a peak to off-peak period) in response to price changes that alter the price ratio between the two periods (e.g., changing the price relationship from 2:1 to 4:1) (King 2005).

Own Price Elasticity

Own-price elasticity is a critical concept in the analysis of peak-load pricing since most examination of consumer's responsiveness to pricing involves estimating the magnitude of demand changes as well as estimating the values of elasticity parameters that characterize users degree of price responsiveness (King 2005).

---

[6] All information in this section was obtained from the report to the Ontario Power Authority by King (2005) and from select chapters in Eaton, Eaton, and Allen (2004).

Own-price elasticity is simply the percentage change in consumption due to a percentage change in price, in either the peak or off-peak period. For example, if the price was to double and a consumer decreased consumption by 40%, then the own-price elasticity for that consumer would be -0.40 (Eaton, Eaton, and Allen 2004; King 2005).

Elasticity of Substitution

Most investigations of consumer's responsiveness to prices have focused on a single parameter that characterizes the customer's shifting of consumption between periods. In terms of electricity, this could be a shift from the peak to the off-peak period.

The elasticity of substitution is the percentage change in the ratio of consumption in two periods that occurs in reaction to a given percentage change in the relative price between these periods. For example, in terms of TOU rates, the peak to off-peak elasticity of substitution represents the percentage change in the ratio of peak to off-peak usage that occurs in response to a given change in the ratio of peak to off-peak prices, all else held constant:

$$\sigma = \left[\%\Delta\left(Q_P / Q_O\right)\right] / \left[\%\Delta\left(P_P / P_O\right)\right]$$

where σ is the elasticity of substitution, Q_P and Q_O are peak and off-peak usage, and P_P and P_O are peak and off-peak prices, respectively (King 2005).

To help illustrate with an example, an elasticity of substitution value of 0.10 implies that a peak to off-peak price ratio of 150% (e.g., peak and off-peak prices are $0.25/kWh and $0.10/kWh respectively) will produce a reduction in peak to off-peak usage of 15% relative to the flat-rate case (King 2005).

In terms of comparing own-price elasticities and substitution elasticities, it can be done when the appropriate data is available. For example, Caves and Christensen (1980) showed that, on average, residential customers who volunteered for time-based rates in the Wisconsin Pricing Experiment, had an elasticity of substitution of 0.17 which was consistent with a peak-period own-price elasticity of -0.30 (King 2005).

CHAPTER TWO

LITERATURE REVIEW

In this chapter a review of the relevant literature pertaining to peak-load pricing will be conducted. The amount of literature available on this topic is vast and broad; therefore the focus of this chapter will be to examine empirical studies which have direct implications for Ontario. This chapter begins with a brief history on peak-load pricing experiments, followed by a review of the literature pertaining to consumer responsiveness to TOU rates, as well as a review of the effects of TOU pricing when differing socio-demographic variables are considered. Lastly, a brief section on the findings regarding voluntary versus mandatory peak-load pricing programs will be presented.

Brief History of Peak-Load Pricing Experiments

In the last 15 years or so there has been a limited amount of valid research presented on the topic of peak-load pricing. The research that has been conducted has focused on residential user's response to TOU pricing. Unfortunately, much of these studies, which were generated in Great Britain, Japan, Canada, and Sweden, are limited in a variety of ways (short data periods, aggregated consumption data, small sample sizes, single TOU tariff plans, etc.) and thus affects the conclusions that can be drawn from them (e.g., Henley and Peirson 1994; Filippini 1995; Matsukawa 2001; and Mountain and Lawson 1995).

To this day, the most extensive research on peak-load pricing for residential and small commercial users was actually conducted over a five to seven year period in the mid 1970's in the United States by the Department of Energy (DOE). In total there were approximately 15 residential pricing projects that were launched which involved the use of time of day and seasonally varying prices.

The goal of this DOE program was to establish whether the implementation of peak-load pricing schemes sufficiently altered residential load curves and thus warranted mandatory implementation. More specifically, the DOE had three main objectives in terms of TOU pricing: (1) to demonstrate the administrative and technical feasibility of implementing TOU rates, (2) to demonstrate and gauge users acceptance of TOU rates, and (3) to gather and provide data to analyze the impacts of these rates on customer and class load patterns (Faruqui and Malko 1983). The DOE would suggest implementation of such residential pricing schemes if the amount of capacity reduction was sufficient, the revenue impact of the utility was acceptable, and changes to consumer welfare were appropriate. Although the design of each study differed, each study was designed in such a manner that it could address at least one of the above objectives (e.g. Aigner and Leamer 1984; Atkinson 1979; Faruqui and Malko 1983).

Although the studies were able to address the research goals outlined by the DOE, due to their design differences, the ultimate usefulness of the experimental data has been limited. The main cause of these limits is due to the fact that most of the studies conducted during the DOE project only used one set of peak-load prices (Aigner and Leamer 1984). By only having one set of TOU prices, inferences were limited to single comparisons between the control group and the experimental households. When studies are conducted in such a manner, very often findings cannot be generalized to situations where peak-period prices differ. As a result of this initial concern surrounding generalizability, researchers began analyzing whether the findings from the DOE experiments could in fact be transferred to other areas, utilities, climates, etc. despite their use of single TOU tariffs. However it was found that in most cases transferability of findings was not possible when single TOU tariff data was used. Moreover, transferability of findings from experiments that used multiple TOU tariffs was only marginally successful (Kohler and Bridger 1984).

In addition to the issues relating to the transferability and generalization of results, other design or sampling issues have also been identified. These include, the type of stratification used, sample size, voluntary participation, the influence of incentive or compensation payments, the methods used to deal with attrition, the nature of the experimental environment, etc. (e.g. Aigner and Leamer 1984; Atkinson, 1979; Faruqui and Malko 1983). Due to these design and sample concerns, midway through the program the DOE addressed these issues by releasing a set of guidelines pertaining to sampling, methodology, and design that would need to be followed by all new TOU price experiments. However by this point many of the projects had already begun and upon further analysis, the guidelines themselves were rather minimal and thus did not appropriately remedy the problems at hand[7]. The general consensus among evaluators is that of the 15 TOU pricing projects conducted, only approximately six offer the wide price variation needed to estimate TOU price response appropriately.

With only six reasonably well-designed studies generated in the 70's, there is some concern as to the validity of analysis done in the last 30 years using this data. These concerns primarily stem from the issues surrounding the design and sampling methodology used as well as the use of single TOU tariffs in many of the experiments; thus research findings acquired through the utilization of this data should be carefully examined.

[7] For a detailed description and evaluation of the design aspects of the experiments, see the Research Triangle Institute report (U.S. Department of Energy 1978) and the report by the University of Michigan's Survey Research Center (Hill et al. 1979). Evaluations of these report findings can be found in Hendricks and Koenker (1979), Meidema et al. (1981) and Aigner (1981).

Peak-Load Price Responsiveness of Residential Consumers[8]

Most of the research conducted on peak-load pricing is interested in examining the effects that TOU prices have on consumption, most notably on the elasticity of substitution between peak and off-peak periods and on own-price elasticity. As a result, almost every empirical study conducted on peak-load pricing addresses consumer responsiveness to price changes. Therefore, this section will only highlight some of the more prominent and comprehensive literature on the topic.

Atkinson (1979) was one of first researchers to present empirical results following the completion of some of the U.S. DOE experiments. Unfortunately due to the nature and availability of data, he was only able to use results obtained from the Arizona project. Despite only using one set of data, he found that the most important variables that explained expenditure shares were: peak-load prices, monthly expenditure share (lagged by one period), and weather (Atkinson 1979). Additionally, he found that appliance stock, income, and other demographic variables were generally insignificant for Arizona residents (Atkinson 1979). In terms of short run own-price elasticity for peak, mid-peak, and off-peak periods, his results are presented in Table 2.1.

TABLE 2.1
RANGE OF ESTIMATES OF RESIDENTIAL OWN-PRICE ELASTICITIES OF DEMAND (ARIZONA)

Peak Period		Mid Peak Period		Off Peak Period	
Low	High	Low	High	Low	High
-0.6404	-0.7864	-0.3783	-0.6958	-0.2308	-0.5748

[8] In general the same findings would apply to small-sized commercial and industrial users.

Atkinson's (1979) results show that in general individuals reduced consumption most significantly in the peak period, followed by the mid-peak period and lastly in the off-peak period. These results are somewhat expected since one would assume that consumers would try to reduce consumption when prices are at their highest. However, Atkinson (1979) did not find that consumers were substituting consumption between peak, off-peak, and mid-peak periods, rather they were just reducing their consumption level during peak periods. These initial findings were somewhat surprising, as one would expect consumers to shift consumption from high priced to low price periods.

By the early 80's however, most of the DOE experiments had been completed and data was highly accessible. Researchers across the U.S. and the world were interested in analyzing the effects of TOU pricing on own-price elasticity and on the elasticity of substitution between periods. In 1983, Faruqui and Malko (1983) pooled and reviewed 12 of the 15 DOE pricing experiments, which involved over 7000 U.S. customers in a variety of geographical areas. They found, like Atkinson (1979), that generally residential peak period consumption was price sensitive, that is, peak-load pricing generally reduced peak period electricity usage. However, the reductions ranged from high values in Arkansas (42%), Connecticut (31%), and Ohio (38%), to more intermediate values in Wisconsin (26%), Arizona (16%), and Puerto Rico (14%), while in Northern Carolina, Oklahoma, and Rhode Island, statistically insignificant reductions were observed (Faruqui and Malko 1983). They found that the experiments that produced the largest reductions were generally those that offered greater financial incentives though higher peak to off-peak price ratios as well as shorter peak periods (Faruqui and Malko 1983). Since most of the experiments conducting in the DOE project lasted for only a few years, only short run statistical inferences could be made. Faruqui and Malko (1983) found that the short run own-price elasticities of peak consumption ranged from 0 to -0.45. Though less statistically significant, a similar range was found for off-peak consumption. They attributed this wide range of values to the fact that the elasticities were not fixed but rather varied according to a number of factors such as the ownership of certain household appliances, the duration of price periods, and the total daily electricity use (Faruqui and Malko 1983).

With respect to load reduction and load shifting, Faruqui and Malko (1983) found that load reduction seemed to dominate in users with peak-load tariffs. That is, households tended to respond to peak-load prices by making "once and for all" changes, such as adjusting the thermostat, rather than shifting everyday activities such as cooking and laundry to off-peak periods.

While Faruqui and Malko (1983) were conducting their analysis, Caves, Christensen, and Harriges (1984) were also in the process of working with some of the 12 DOE experiments. They focused on five of the utilities used in the project (Connecticut, Los Angeles, Southern California, Carolina, and Wisconsin) and found results similar to those of Faruqui and Malko (1983) in terms of peak period total elasticity. They found elasticities that varied from as much as zero to -0.61, that is, a 10% increase in the peak/off peak price ratio would lead to a 6.1% consumption reduction in the peak period. Likewise, off-peak total elasticities varied from zero to -0.45 (Caves, Christensen, and Harriges 1984). Furthermore, they found that customers were more apt to shift consumption away from peak periods during "critical" days (days with extreme temperatures and higher peak to off-peak ratios) particularly during the summer months compared to non-"critical" days. Additionally, they also found significant reductions in electricity consumption during peak hours for consumers on time-based pricing schemes. Furthermore, while Faruqui and Malko (1983) were unable to find significant shifting from peak to off-peak periods, Caves, Christensen, and Harriges (1984) found that time-based pricing customers did shift consumption among periods and that the single most important variable effect these shifts was the difference between period prices. That is, the higher the price differential between peak and off-peak prices, the greater the substitution of peak to off-peak electricity. They found that the typical consumer had an elasticity of substitution of 0.14 between off-peak and peak consumption on a typical summer day (i.e., a 10% increase in the peak/off-peak price ratio leads the average consumer to substitute 1.4% of on-peak consumption for off-peak) (Caves, Christensen, and Harriges 1984). However, this substitution effect is not that substantial and thus may explain why Faruqui and Malko (1983) did not report it.

In 1984, Acton and Park (as cited in King 2005) reviewed 34 published studies from across North America where estimates of overall "short run" and "long run" elasticity were calculated. They defined the "short run" as a period in which consumers could not change their appliance holdings, while the "long run" allowed for appliance variation. This is one of the only empirical studies which attempts to present findings pertaining to the long run effects of peak-load pricing. Table 2.2 summarizes their findings:

TABLE 2.2
RANGE OF ESTIMATES OF RESIDENTIAL PRICE ELASTICITIES OF DEMAND*

Short Run			Long Run		
Low	Medium	High	Low	Medium	High
-0.12	-0.20	-0.35	-0.60	-0.90	-1.20

* The Low and High Values Bracket the 80% confidence interval

Source: King (2005)

One can see that Acton and Park (as cited in King 2005) found results similar to those of Faruqui and Malko (1983) in the short run. Additionally, Acton and Park (as cited in King 2005) report elasticities that substantially increase when households are given the opportunity to vary their appliance holdings and thus conclude that in the long run TOU tariffs do substantially decrease peak-load consumption. However one should be critical of this conclusion as only appliance holdings were considered in their long run analysis.

Although the numerous research findings presented above used the DOE project data, a similar range of own-price elasticities and elasticities of substitution were found in studies presented using data from Great Britain, Japan, Canada, and Sweden (e.g., Braithwait 2000; Charles River Associates 2005; Filippini 1995; Henley and Peirson 1994; Matsukawa 2004; Mountain and Lawson 1995).

Recently, King (2005) took 56 papers published since 1980, which had expanded on earlier studies by using previously unused methodologies for analyzing price response and which examined the effects of additional peak-load pricing structures such as critical peak prices[9], and compared their own-price elasticities. Twenty of the studies that King used did not report own-price elasticity and thus these missing elasticities were calculated and are presented with the elasticities of the other 36 studies in Table 2.3.

TABLE 2.3
SUMMARY STATISTICS FROM KINGS ELASTICITY ANALYSES

Geography	Sample Size	Short Run Own-Price Elasticities		
		Low	Medium	High
California	13	-0.13	-0.21	-0.28
U.S.	36	-0.23	-0.28	-0.34
Other Industrialized Countries (Canada, U.K., France, Switzerland, and Denmark)	7	-0.28	-0.47	-0.66

The Low and High Values Bracket the 95% confidence interval

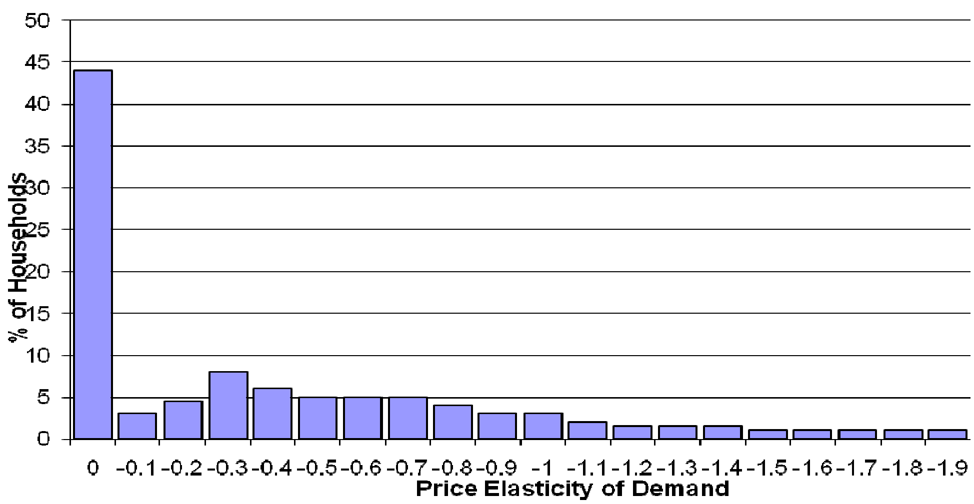
Source: King (2005)

[9] Critical peak prices are utilized when the peak-load demand is expected to be exceptionally high; this usually occurs during hot summer days when air conditioners are running constantly or during cold winter snaps when heaters, lights, and ovens are being used. Critical peak prices occur only 15 to 20 times a year, last for only3-4hours, and are usually dispatched to consumers a day prior to taking effect (Ontario Energy Board 2004).

Not surprisingly, King's results do not vary significantly from the findings presented by other researchers - own-price elasticities seem to vary dramatically among users on peak-load tariffs.

In 2002, Reiss and White (2002) presented some interesting findings using data from a statewide California survey. They suggest that households either show some price elasticity in terms of electricity demand or they show none, that is, they are price insensitive.
Figure 2.1 illustrates the distribution of price elasticities for California households according to Reiss and White (2002).

FIGURE 2.1
ESTIMATED DISTRIBUTION OF HOUSEHOLDS ELECTRICITY PRICE ELASTICITIES



Source: Reiss and White (2002)

The above distribution clearly depicts the large heterogeneity in household's price sensitivities. About half of all households will not make any changes in their electricity consumption in response to price changes, while the other half would in fact respond to prices changes.

It would appear that on average consumers do respond to price changes both within a period and between periods but findings vary significantly among researchers even when similar or identical data is used (e.g., anywhere from a zero response to price changes upwards of a 7% decrease for every 10% price increase). Furthermore, as Reiss and White (2002) showed, in some areas only approximately half of all consumers would respond to electricity price changes, despite how appealing price differentials may be.

Conditioning Variables on the Peak-Load Price Responsiveness of Residential Consumers[10]

Besides basic consumer price responsiveness, the strength of consumer responses is also usually affected by several conditioning variables such as total electricity consumption, appliance holdings, weather, and other socio-demographic factors.

Even in the early stages of time-based pricing research, signs that other variables affected consumer responsiveness to these pricing schemes were apparent. Referring back to Atkinson's (1979) findings, he noted that appliance stock, income, and other demographic variables were generally insignificant for the Arizona project; however, weather did in fact significantly affect consumer response. That is, on days which were significantly hotter or colder than average, consumer demand for electricity increased. Similarly, Faruqui and Malko (1983) did find that weather affected consumer response, but unlike Atkinson (1970), they reported significant differences in price response as a result of factors besides price and weather. For example, in some of the experiments that Faruqui and Malko (1983) analyzed, peak-period own-price elasticity increased with factors such as daily electricity usage while in others it increased with factors such as the magnitude of the peak/off peak price ratio or ownership of major appliances. However as mentioned previously, Faruqui and Malko (1984) found that most consumers on

[10] In general the same findings would apply to small-sized commercial and industrial users

time-based prices reduced overall consumption in peak periods, but did not shift this usage from peak to off-peak periods.

While Faruqui and Malko (1983) were unable to show shifting from peak to off-peak periods, Caves, Christensen, and Herriges (1984) found that the most important influences on the substitution of peak to off-peak periods, aside from relative peak/off-peak prices, were major appliance ownership, specifically the ownership of dishwashers and air conditioners. They found that holding climate constant, the more major appliances within a household, the greater the responsiveness to TOD rates, especially when an air conditioner was owned.

More recently, Baladi, Herriges, and Sweeney (1998) estimated the price responsiveness of voluntary peak-load pricing consumers at the Midwest Power System (MWP) in Iowa. There results were analogous to those of previous researchers (e.g., Faruqui and Malko 1984; Caves, Christensen, and Herriges 1984). More specifically, responsiveness to prices was influenced significantly by the ownership of major appliances such as air conditioners and dishwashers. Furthermore, having more appliances and being on a time-based pricing plan resulted in a higher percentage reduction in on-peak electricity demand.

Reiss and White (2002) used data from a California statewide survey to estimate consumer responsiveness to electricity prices. They found, as Baladi, Herriges, and Sweeney (1998) had, that consumers on time-based prices who owned electric space heating or air conditioners exhibited higher own-price elasticity than households without such holdings. This finding is shown in Table 2.4.

TABLE 2.4
PRICE ELASTICITIES FOR CALIFORNIA HOUSEHOLDS AS A FUNCTION OF APPLIANCE HOLDINGS

Segment	Estimate of Price Elasticity
All households	-0.39
Household with:	
Electric space heating	-1.02
No electric space heating	-0.20
Central or room air conditioning	-0.64
No air conditioning	-0.20
No air conditioning nor electric space heating	-0.08

Source: Reiss and White (2002)

Reiss and White (2002) also looked at the effect of another conditioning variable on price responsiveness of consumers on time-based prices – income. They found that own-price elasticities varied moderately among different income levels and that as household income increased, price responsiveness decreased. These results are depicted in Table 2.5 and are not surprising; one would expect that higher income households would be less concerned about electricity consumption during peak price periods.

TABLE 2.5
ELASTICITIES FOR CALIFORNIA HOUSEHOLDS AS A FUNCTION OF INCOME

Quartile	Range	Estimate of Price Elasticity
1st	Less than $18,000 per year	-0.49
2nd	$18,000 to 37,000 per year	-0.34
3rd	$37,000 to $60,000 per year	-0.37
4th	More than 60,000 per year	-0.29

Source: Reiss and White (2002)

Peak-Load Price Responsiveness of Commercial and Industrial Consumers

In general there has been significantly less research conducted on the responsiveness of commercial and industrial electricity users to peak-load prices as most of these users are on some form of mandatory peak-load pricing schedule due to the high demand that these consumers place on the system and consequently are not as often analyzed. This paper will not specifically consider commercial and industrial consumers, but it is felt a brief discussion on the literature in this area will help provide a clearer and more complete picture of peak-load price responsiveness.

Some of the early research on the topic was conducted in Britain by Acton et al. (1980), where peak-load prices have been in effect for industrial users since the mid 1960's. The British rates typically have seasonal features and industrial users can opt to participate in critical peak prices. The study interviewed several major companies in England and Wales which reflect some 35% of all industrial electricity purchases in Britain. Their findings showed that there was significant variability in price responsiveness from user to user and from industry to industry. Furthermore, they found that users who could shift operations to less costly time periods would do so, but that this response varied directly with the potential cost savings relative to the value of the production output (Acton et al. 1980). As with residential users, firms were found to modulate their electricity demand based on numerous factors including price differentials, flexibility of technology, plant configuration, costs of electricity relative to other energy inputs, the overall demand for the firm's output, and lastly the flexibility of the firms customers in accepting delayed deliveries (Acton et al. 1980). In general it was found that firms were most responsive when they had a production process that could be interrupted, had excess production capacity, could store intermediate products, and who had the capability to self-generate electricity for its own use (Acton et al. 1980).

In light of Britain's apparent success with TOU industrial consumers, the exact magnitude of responsiveness in other situations, nations, or industries would likely depend on various factors as shown in the Acton et al. (1980) findings, thus one needs to be cautious, as with all time-of use experiments, in generalizing results.

In the mid 1980's, approximately 4000 commercial and industrial customers (average hourly consumption greater than 200 kWh) from 10 utilities across the U.S. who were on mandatory peak-load pricing schedules were evaluated by Park and Acton (1984). They found that, on average, relative peak loads declined by approximately 1% when peak-load prices were introduced, but that only a small fraction of the users examined actually reduced their peak loads substantially (Park and Acton 1984). Moreover, the amount of peak reduction differed substantially by utility, year, industry, weather, and customer size, and the terms of the time-of-use tariffs. These findings are similar to those found for residential users- socio-demographic variables seem to have a significant impact on consumer price responsiveness. Despite what appears to be a small percentage change in peak-load demand, peak-load prices in the Park and Acton (1984) evaluation were justified via a cost-benefit analysis. In addition, they also extended their results and considered the implication of TOU pricing on medium commercial users. They found that as long as a consumer's monthly consumption exceeded 15,000 kWh, the benefits of time-based prices should exceed the metering costs (Acton et al. 1980).

In a more focused study of small and medium-sized commercial users, Aigner and Hirschberg (1985) examined over 700 Southern California Edison Co. consumers over a two year period in the early 1980's. Their study involved 574 customers who volunteered for time-based rates and a control group of 159 firms. They found that due to the nature of electricity consumption for commercial and industrial customers (i.e. fixed production patterns, production requirements, etc.), larger price differentials are required to entice these users to decrease or shift peak period consumption (Aigner and Hirschberg 1985). They found that generally for the "large" medium and small commercial/industrial users on the peak-load prices (200 to 500 kW), a significant and moderate substitution effect between peak and off-peak usage was found in the summer months only. Furthermore, they noted a small welfare gain of approximately 1% for these "larger" users when they moved from a flat rate to a 2:5:1 time-of-use price ratio (Aigner and Hirschberg 1985).

More recently, Aigner, Newman, and Tishler (1994) considered 460 medium-sized (at least 40 000 kWh per year) firms facing mandatory TOU rates in the commercial and industrial sector in Israel. The data used was collected over a 24 month period from May 1990 to May 1992 and a control group of 185 flat-rate users in the sector was used.

Their analysis showed that there were small shifts from peak, to mid-peak, to off-peak periods through the year with more noticeable shifting occurring during the winter months. They also found that factors such as labour shifts during the day and weather were important in influencing the response of demand for TOU tariff users (Aigner, Newman, and Tishler 1994). Moreover, price elasticities varied substantial between seasons and industry groups, but these were not influenced by consumer size. They concluded based on their findings that the gains from peak-load pricing were sufficient to justify investment in this type of metering system for both small and medium-sizes customers in the industrial and commercial sector in Israel (Aigner, Newman, and Tishler 1994).

The general conclusion over the last several decades appears to be that TOU pricing is effective for medium and large commercial and industry sector firms in a variety of nations. Similar to residential users, these types of consumer are also affected significantly by factors besides TOU prices such as industry, size, weather, and technology.

Voluntary versus Mandatory Peak-Load Pricing Programs

Distinguishing whether a peak-load pricing program was established on a voluntary basis or was mandatory is a factor that should be considered when assessing the effectiveness of peak-load pricing programs on consumption shifting and conservation. Concerns have been raised by several researchers that volunteers for TOU tariffs are usually those who already consume a relatively large share of their electricity during off-peak hours, and consequently are likely to change consumption from peak to off-peak periods in response price changes (See Aigner and Leamer, 1984; Hill 1991). Unfortunately, credible research on voluntary versus mandatory peak-load pricing programs is very limited.

Researchers find it challenging to assess the viability of a peak-load pricing system accurately when the data being collected represents individuals who are choosing to participate in the program. The concern with self-selection bias is that it ultimately affects the quality of the inferences that can be made in terms of mandatory peak-load pricing programs. Moreover, very few mandatory peak-load pricing systems are in effect in areas where one can also volunteer to participate in such a program. That is, either a utility has all users on mandatory TOU tariffs, or the utility has some users on a voluntary tariff while the others remain on the usual flat-rate pricing system; consequently, comparisons between volunteer users and mandatory users in the same utility are rare and hard to find.

After the completion of the DOE experiments, there was a concern that self-selection bias may have effected and ultimately inflated the true responsiveness of consumers to peak-load prices. Aigner and Ghali (1989) pooled the results from the five best DOE experiments (Carolina, Connecticut, Los Angeles, Southern California, Wisconsin) and addressed the problem of self-selection bias. They found selection bias as high as 24% for some utilities resulting in significant overstatement when applied to mandatory peak-load price consumers. They conclude that research findings pertaining to the DOE experiments which did not correct for selection bias were largely inflating the true benefits of TOU pricing in mandatory users. Hartman (1988) found similar selection bias when energy conservation programs were evaluated. In one study conducting by Caves, Herriges, and Kuester (as cited in Hall 1991), voluntary peak-load prices were offered to 1000 residential consumers who used over 1000/kWh of electricity per month. These volunteers were evaluated over a 1 year period (1983 – 1984). The study concluded that consumers who voluntarily selected the tariff had approximately the same peak period consumption as the average residential user (Caves, Herriges, and Kuester as cited in Hall 1991). Additionally, the responsiveness to peak-load prices for the consumers who were on the voluntary TOU tariff was larger than for those on the mandatory TOU tariff. The 0.37 elasticity of substitution between off-peak and peak consumption is significantly larger than the 0.14 elasticity of substitution of mandatory users (Caves, Herriges, and Kuester as cited in Hall 1991). The study suggests that even if voluntary and mandatory TOU tariff consumers consume approximately the same amount of electricity during peak periods, more peak to off-peak response occurs in the voluntary consumers. In an unrelated follow up survey of the volunteer peak-load tariff experiment described above, Keane and Goett (as cited in Hall 1991), provided some reasons for why voluntary users might be more responsive to prices. They found that generally personal characteristics, peak period duration, and personal views on TOU rates results in users who would be more apt to reduce or shift consumption away from peak periods (Keane and Goett as cited in Hall 1991). Those consumers who volunteered for the tariff generally had a higher income, fewer children, were better educated, and were older than the average household. Moreover, they found characteristics of the tariff which helped entice people to accept the tariff;

for instance, the timing of the peak period (peak-load prices past 6pm where not alluring) and the perception that the consumer had control of their electric bill by allowing them to shift usage to off-peak periods.

Another more recent study was conducted on voluntary versus mandatory TOU programs by Baladi, Herriges, and Sweeney (1994). They found that the decision of residential consumers to volunteer for peak-load pricing was found to be unrelated to the household's appliance holdings or electricity consumption pattern. Similar to the findings of Caves, Herriges, and Kuester, Baladi, Herriges, and Sweeney (1994) found that consumption between volunteers and non-volunteers was almost identical. However, they found that volunteers reduced their peak consumption by approximately 24%, which was not deemed significantly different than that of mandatory users, although seems particularly large compared to other comparable studies.

Although there have been mixed results in terms of whether results from voluntary TOU pricing experiments (which have not been correct for selection bias) result in overly optimistic responsiveness levels, for the most part research indicates that selection bias is a concern in voluntary TOU pricing programs and thus caution needs to be taken when generalizing these results to mandatory TOU pricing consumers.

While the literature reviewed in this chapter is by no means exhaustive, a significant sample of the most prevalent and influential empirical studies conducted on peak-load pricing have been examined. From this survey, it is felt that one can draw a general picture of the major lines of research that have been explored in this area over the last 30 years.

Conclusion

Some general conclusions can be drawn from the literature conducted on TOU prices over the last several decades. Despite mixed results, researchers have shown that the overall key factor in determining the success of a TOU price program is the ratio of peak to off-peak prices (elasticity of demand). The larger this price differential, despite all other conditioning variables, the greater the responsiveness of consumers. These findings are generally consistent when data from industrial and commercial consumers is analyzed.

Although price ratios are a key determinant of responsiveness to time-varying price programs, conditioning variables also have a significant impact. Researchers have shown that there are a variety of variables besides price which affects the responsiveness of consumers to TOU pricing programs. These variables range from weather to appliance holdings to income levels. Despite the variety of factors which may affect consumer's reactions, there appears to be consensus among researchers that weather and the ownership of electric heating and air conditioners are the main variables effecting consumers' responsiveness. More specifically, electricity users in areas with extreme temperatures and who own both electric heating and air conditioners are more apt to reduce their electricity consumption and/or shift consumption from peak to off-peak periods. In terms of industrial and commercial customers, they too have a array of operational variables which affect their responsiveness to time-varying prices though these tend to be more difficult to classify as they vary with each consumer and industry.

Lastly, in terms of voluntary TOU pricing programs, as a basis for statistical analysis and generalizability, several researchers have shown that results obtained from volunteer users may be significantly biased and therefore should not be used to predict the outcome of mandatory programs unless corrections are made.

The history of such programs reveals key aspects which need to be examined before Ontario moves forward with the Initiative.

CHAPTER THREE

THE SMART METERING IMPLEMENTATION PLAN

On July 16 2004, the Minister of Energy directed the Ontario Energy Board (OEB) to provide a plan to implement smart meter targets for Ontario. This policy plans to install 800,000 smart meters in Ontario by December 31, 2007 and for all Ontario customers by December 31, 2010[11].

The government has stated that it is desirable to implement a smart meter system in Ontario as it will help to manage the demand for electricity in the province by reducing Ontario's reliance on external electricity sources and it will allow the province to use the current supply of electricity in a more efficient manner.

The scope of the Ontario Initiative will make the province the first in North America to:

- automate the reading of all meters as well as having the ability to reprogram read periods using two-way communication within a region;
- ensure that the system is able to record data for every customer on an hourly basis; and
- provide customers with their previous day's electricity usage information so that they are able to review and comprehend how energy is billed based on their own consumption levels.

As discussed in chapter one, smart metering is viewed as being important to efficient electricity use because it allows for the matching of consumption with the true costs of electricity, which can vary substantially with daily and seasonal peak demand. The smart meter measures both how much electricity a consumer uses as well as when it is used. This gives

---

[11] The information in this chapter is drawn from the Ontario Energy Board (2005) report and the Ontario Energy Board website located at http://www.oeb.gov.on.ca

consumers the information needed to help control usage during peak periods when the price is at its highest. By conserving electricity during these peak times, this reduces the amount of electricity generation needed in the province and thus lowers the costs for everyone.

When designing the implementation plan, the OEB considered how many meter systems would be required, the technology that would need to be used, and who should bear the costs associated with the system. Additionally, the OEB needed to consider some of the limitations affecting the plan such as the need to begin the implementation of smart meters immediately in order to meet target deadlines, the changing Ontario distribution system, and the desire to keep costs at a minimum. The focus of this chapter will be on the more significant and pertinent issues covered in the implementation plan.

Smart Meter System

The OEB proposes a meter system that would record how much electricity a consumer uses each hour of the day. Every day the gathered data would be sent to the distributor via wireless technology. This data would then be used to charge the consumer an electricity price that corresponded to when the energy was used. Additionally, consumers would be able to access their consumption data the following day either via Internet or telephone. In terms of consumers who have signed on with retailers, it would be the distributor responsibility to ensure that consumption data was transmitted to the appropriate retailer.

Although the proposed metering system is vastly different in nature (as it pertains solely to residential and small business users), its implementation would not substantially affect the electricity charges of larger customers. That is, some larger commercial and industrial customers pay a delivery charge on their maximum electricity demand, rather than on total consumption, which is the basis used to determine the delivery charges for residential and smaller commercial customers.

The implementation plan does not mandate a specific system or particular vendor. The type of system that is best for any distribution area depends on many factors including consumer density and geographical factors. Each electricity distributor can determine what works best for their designated area as long as the system selected meets the minimum technical standards outlined by the OEB.

The basic system proposed by the OEB is based on two-way communication between the meter and the distributor and does not include advanced technology such as digital consumer interfaces, load limiting, remote cut-off capabilities, etc. The only OEB requirement in terms of advanced technologies is that that all smart meter systems are equipped with open network interfaces which are connected to the wide area network (WAN). It is expected that retailers and other companies will be prepared to provide consumers with advanced services such as those listed above for a fee.

Distribution of Smart Meters

As mentioned previously, all new and existing residential and small commercial customers in Ontario will have some type of smart meter by December 31, 2010. Additionally, general service customers with peak electricity demand between 50 and 200 kW will also be equipped with a smart meter. Industrial and general service customers with demand over 200 kW of peak demand (the maximum electricity use at any point in the month) will get interval meters that measure consumption in 15 minute intervals rather than hourly.

Large customers that have peak demand above 200 kW will be the first to receive the meters. The reason that these consumers will be serviced first is that the smart meter installation for these customers can be done quickly since large customers in Ontario currently have meters which are almost identical to the new smart meter technology and thus would essentially only be upgrading their meter.

The OEB proposes a two-phased installation plan that focuses on the large urban distribution companies until the end of 2007 (for example, Ottawa Hydro) and the remainder of the province starting in 2008. The rationale for this is that by focusing efforts in such a way, the 2007 target of 800, 000 meters will be achieved by the deadline while minimizing technology or implementation risks that could threaten the overall success of the Initiative. Since the large urban distributors collectively serve more than 40% of customers in the province, it would be capable of meeting the deadline as discussed above, but it would also act as a controlled pilot project from which the OEB and others could learn.

In the second-phase, the balance of the distributors in the province would install meters for their commercial and residential customers. It is expected that the lessons learned in the first stage of implementation will significantly ease these later installations.

Impact on Customers

Simply put, only two things will change for consumers with smart meters. They will be able to receive timely data on consumption and distributors will offer pricing plans that will feature time-varying electricity prices.

The OEB proposes that consumers be able to recover their consumption data by the following day either via the Internet or telephone and potentially, at an additional cost, via an in-home dynamic display. Furthermore, historical data will also be available to consumers.

The OEB recently created a regulated price plan that will be available to residential and other approved customers. This regulated price plan, as expected, features prices that vary by time of use. This combination of time of use rates and smart meters will provide customers with the incentives and information required to control their electricity costs through the shifting of peak usage to off-peak periods or at a minimum, lowering energy use during peak periods. Customers will be able to shift there electricity usages manually or through a contract with an energy services company that can automatically control devices based on the price or demand level of the system. However the latter would not be an option that would be available at the onset of the Initiative due to the limits of the proposed technology. The smart meters and "smart" pricing plans allow consumers to pay according to what they use and when they use it and those who conserve will not be subsidizing those who do not.

Although not part of the "smart" pricing plan as of yet, in the future the OEB may include special pricing for critical days when the electricity system is at capacity and the wholesale commodity prices are very high[12]. These tend to be hot summer days when air conditioners are running constantly or in the evenings during cold periods when heaters, ovens, and lights are all in use. Although in general there are no more than 15 or so events like this a year, when they do occur electricity at these times if very expensive. To implement this special pricing for critical days, the IESO would issue a critical peak call to signal that the following day would have critical peak pricing (CPP). Consumer would be alerted via the media, email, or telephone of the

[12] This pricing plan was incorporated into the Smart Meter Pricing Pilot and will be discussed in a subsequent section

IESO critical peak call. Consumers with smart meters will be able to save by cutting back their use during these critical days. However, due to the infrequency and short duration of these critical peak events, customers' total bill savings may actually be less than 2%, however studies have shown that the effects on the overall system could be quite large.

The OEB has also considered the impact of higher peak winter prices on consumers who rely one electric heating and have limited ability to shift demand. Conservation programs may focus on support for mitigating technologies like thermal storage, heat pumps, or conversion to natural gas heating.

In terms of large commercial and industrial customers who have not signed with retailers, these consumers are currently paying the hourly wholesale spot price for their electricity. If these consumers do not have interval meters, they are being charged based on a system-wide load profile, which may have little resemblance to their own actual hourly consumption, that is, their own hourly consumption could be higher or lower than the system-wide load profile. However, with the smart meter system, these consumers will pay the hourly price based on their actual hourly consumption, not that of the system-wide profile.

Many stakeholders and ratepayers expressed concern over the lack of available cost/benefit analysis surrounding smart meters and were, in particular, concerned that smart meters would not be justified for low-volume users. Despite these concerns, the OEB feels that in order to maintain accumulated meters for low-volume users, these consumers would have to support the full cost of the manual reading system. This in the end might cost more than the smart meter installation. Additionally, these consumers would likely be faced with higher fixed-rate plans to help cover the actual electricity prices. Therefore, the OEB recommends that no consumers, despite consumption level, be exempt from the smart meter Initiative.

Cost

The capital and operating costs associated with the implementation plan are intended to be included in the distributor's delivery rates and will be charged to all customers that belong to a certain rate class, whether they currently have a smart meter or not. Furthermore, the costs related to old or obsolete meters will continue to be included in distribution charges.

The OEB proposes that these costs be added to the delivery rate as soon as smart meter installation begins. The initial impact on consumer's bills should be minimal since it will take several years to complete the entire smart meter installation program in a given area. During this initial stage, the incremental costs will include some data management, billing system changes, and a portion of the meter and communication infrastructure. Stranded costs during this period should be low since most manual readers will still be in service until 2010 at which time all non-smart meters will become obsolete.

The total capital cost of the proposed system is estimated at $1 billion. This would be the total cost through to 2010 and includes the meters, communications, installation, and distributor system charges. Once all meters have been installed, the net increase in annual operating costs is estimated to be $50 million. As mentioned previously, once the entire project is complete, a monthly charge of between $3.00- $4.00 to cover capital and operating costs will be charged to all consumers. This estimated total capital cost is devoted primarily to residential and small business consumers as most of these users are not presently equipped with the required metering technology. Almost all large and medium-sized industrial and commercial consumers in Ontario already have some form of interval meter. These consumers are already paying either some form of time-varying price or the wholesale market price. Additionally, for those large and medium-sized consumers who are not presently equipped with an interval meter, the costs associated with equipping these consumers by 2010 would be less than $50 million.

Pricing Plan

The OEB proposes the following smart metering rate structure (Table 3.1) for all low-volume users, such as residential and small business customers as well as some designated users such as municipalities, hospitals, farms, schools, colleges, and universities. However, this rate structure will only remain as such until April 1, 2008, at which point the rate structure will be limited to residential consumers and those that are classified as "general service less than 50 kilowatt demand" by their utility (Duncan 2005).

TABLE 3.1
ONTARIO SMART METER PRICING PLAN[13]

Day of the Week	Time	Time-of-Use	Price (cents/kWh)
Weekends & holidays	All day	Off-peak	3.2
Summer Weekdays (May 1st - Oct 31st)	7:00 a.m. to 11:00 a.m.	Mid-peak	7.2
	11:00 a.m. to 5:00 p.m.	On-peak	9.2
	5:00 p.m. to 10:00 p.m.	Mid-peak	7.2
	10:00 p.m. to 7:00 a.m.	Off-peak	3.2
Winter Weekdays (Nov 1st - Apr 30th)	7:00 a.m. to 11:00 a.m.	On-peak	9.2
	11:00 a.m. to 5:00 p.m.	Mid-peak	7.2
	5:00 p.m. to 8:00 p.m.	On-peak	9.2
	8:00 p.m. to 10:00 p.m.	Mid-peak	7.2
	10:00 p.m. to 7:00 a.m.	Off-peak	3.2

Tariffs accurate as of August 2007

Source: The Ontario Energy Board website (www.oeb.on.ca)

[13] This seasonally varying pricing plan is expected for Ontario as summer peak exceeds the winter peak, primarily due to the high ownership of air conditioners and low ownership of electric heaters in the province (Statistics Canada 2005).

CHAPTER FOUR

ASSESSMENT

Since an initiative of this type and scale has never been attempted before in North America, there is no data or empirical studies which can be used directly to assess the potential viability of the Initiative. As presented in chapter one, past studies on TOU tariffs have been criticized for conflicting results, varying findings, and lack of generalizability. Despite these shortcomings, this past empirical knowledge is essential in shedding light on Ontario's proposed plan and helping gauge whether it makes economic sense to implement a province-wide mandatory TOU pricing plan. In order to assess the Smart Metering Initiative this chapter will rely heavily on a recent Ontario pilot study which was conducted over a 6 month period in 2006. This is currently the only available information on the response of Ontario residents to the proposed Initiative. This chapter will attempt to evaluate whether the Initiative can reach its proposed goals and thus justify the costs associated with it.

Since there is general consensus that TOU programs are effective in industrial and commercial electricity consumers, this chapter will focus on residential users. Residential consumers are said to make up approximately one third of Ontario's electricity load and thus are critical in the management of it (Natural Resources Canada 2006). Furthermore, almost all large electricity consumers in Ontario are already on some form of interval metering and consequently either on TOU rates or wholesale market prices.

This chapter will begin by presenting the Smart Meter Price Pilot and its results. This will be followed by an assessment of the Initiative in light of the pilot project and international experience. A simple discussion about the Initiative's cost effectiveness will also be addressed.

Lastly, the chapter will conclude with some general recommendations as to how Ontario should proceed with the Smart Metering Initiative.

Ontario Smart Meter Pricing Pilot[14]: Overview

The pilot was initiated in June 2006 with hopes of providing the OEB with some vital insight into the success of the proposed Initiative. Its primary purpose was to: (1) assess the demand response of consumers to various pricing structures (TOU, TOU with CPP, and TOU with Critical Peak Rebates [CPR]); (2) assess the extent to which each price structure results in consumers shifting consumption away from on-peak periods as well as any change to overall monthly usage; (3) assess how well residential consumers understand the different price structures and the communications associated with each, and (4) assess consumer acceptance of the different price structures.

The pilot was conducted in Ottawa as it held several vital components to its success. Ottawa has a large distribution of residential smart meters and allows for generalizability to other Ontario distributors particularly those in the Greater Toronto Area (Strapp, King, and Talbott 2007).

Pricing Structure

The initial Initiative had proposed that the smart meter pricing for Ontario should follow simple TOU prices; however the Board decided to test three price structures during the pilot:

- existing only-TOU prices

[14] All information from this section was taken from Strapp, King, and Talbott (2007).

- existing TOU prices with a CPP[15]
- existing TOU prices with a critical peak rebate (consumers are subject to the same TOU rates but are provided a rebate when their usage during critical peak hours is reduced below their "baseline".[16])

With respect to the control group, they were offered the conventional meter prices in two tiers, one price for monthly consumption below a tier threshold (T_1) (600 kWh/month in the summer and 1000 kWh/month in the winter) and a higher price (T_2) for consumption above this tier threshold. The tier prices used in the pilot are as follows (Strapp, King, and Talbott 2007):

- T_1 = $0.058/kWh
- T_2 = $0.067/kWh.

Consumer participation

Participants were randomly selected from the Ottawa population of residents who would have a smart meter in Hydro Ottawa's territory by August 1, 2006. Recruitment letters were sent to 1800 eligible Ottawa residents of which the OEB got 459 respondents by the enrolment deadline.

The result was 373 participants in the pilot - 125 in the CPR price group, and 124 each in the TOU-only and TOU + CPR groups. The control group consisted of 125 customers selected randomly from the population of Hydro Ottawa consumers who had a smart meter but who continued to pay the two-tier pricing (not TOU prices).

---

[15] The CPP was set at $0.30/kWh, with off-peak prices set at $0.031; mid-peak prices set at $0.075; and peak-prices set at $0.105. Off-peak, mid-peak, and peak prices for this pricing structure were set as such to ensure that all three pricing structures were revenue neutral.

[16] That is, a participant making no change in response to the critical peak events will pay the same amount as someone on the only-TOU plan.

Participants in the pilot had the significant operational variables discussed in chapter one. That is, they live in an area with extreme temperature and most participants (93%) had air conditioners and some had electric heating (10%). Furthermore, they had numerous large and small appliances such as laundry machines, dishwashers, microwaves, stoves, personal computers, and televisions.

Pilot Operation

Upon enrolment in the pilot, all participants were provided with an informational package which included a refrigerator magnet[17] and a PowerWise electricity conservation brochure.

Throughout the pilot, participants continued to receive and pay their "normal" bi-monthly electricity bill; however, also received monthly Electricity Usage Statements that showed their electricity supply charges (calculated based on their respective pilot price plan). These Usage Statements were mailed to participants on a monthly basis.

As an incentive to enroll in the pilot, participants received a "thank you payment" of approximately $75.00 at the end of the pilot. This base payment of $75.00 was adjusted at the end of the pilot by the amount of the participant's savings or losses on the TOU pricing. That is, participants faced actual economic gains or losses based on their response, or lack thereof, to TOU prices.

Ontario Smart Meter Pricing Pilot: Results[18]

In order to assess the demand response resulting from the pilot, the following were analyzed:

[17] The magnet had a table of TOU prices, periods, and seasons for that participants specific price plan on it.
[18] For a detailed account of Wolak's methodology, models, and results, see Wolak (2007).

1) The demand response of load shifting away from critical peak hours to either the mid-peak or off-peak hours on critical peak days only.
2) The demand response of load shifting away from on-peak hours to either mid-peak or off-peak hours on all non-holiday weekdays.

These effects were determined by comparing the consumption behaviour between the treatment groups (those on TOU, TOU + CPP, and TOU + CPR tariffs) and the control group (those who are on the two-tier prices) (Strapp, King, and Talbott 2007).

Methodology

The demand response analysis used a nonparametric conditional mean estimation framework. The framework used customer-level fixed effects and day-of-sample fixed effects. The demand response impacts were determined using hourly data for the pilot period of August 2006 through February 2007, while the conservation effect was determined using bi-monthly billing consumption data for the treatment and control customers for the 12 months preceding the pilot in combination with the hourly data during the pilot (Wolak 2007).

Although both areas of analysis are of interest in assessing the demand response of consumers in the pilot, the latter is of particular interest because it will show how consumers respond to all the TOU pricing structures during regular weekday on-peak periods. Critical peak days make up only a small percentage of days and although the strain on the power system during these times is significant, the reaction of consumers during regular weekdays is essential as system reliability concerns occur daily during on-peak periods.

Load Impact

Critical Peak Day Results

Although the pilot had been prepared for nine critical peak days, only seven were announced throughout the course of the pilot. Table 4.1 below has the combined total for all participants (all pricing structures) of the amount of load shifting during critical peak days for the entire on-peak period.

TABLE 4.1:
AMOUNT OF LOAD SHIFTING ON INDIVIDUAL CRITICAL PEAK DAYS FOR ALL PRICE GROUPS COMBINED FOR THE ENTIRE ON-PEAK PERIOD

Critical Peak Day (Entire Peak Period)	Summertime Load Shifting	Actual Max Temp (°C)	Actual Max Humidex
Friday, August 18	27.7%	30.0	35
Tuesday, August 29	10.1%	25.2	28
Thursday, September 7	n/s	22.4	n/a
Friday, September 8	n/s	26.5	31
	Wintertime Load Shifting	**Actual Min Temp (°C) During Peak Period**	
Tuesday, January 16	n/s	-18.7	
Wednesday, January 17	-7.2%	-16.1	
Friday, January 26	n/s	-21.3	

Statistically significant load shifting was detected for the first two summertime and the second wintertime critical peak events – though the winter result is counterintuitive. Seven critical peak events (against a target of nine) were called during the pilot using forecast temperature thresholds of 28°C in summer (or a Humidex above 30°C) and -14°C in winter Results are statistically significant at the 90% level, unless denoted by "n/s".

Source: Strapp, King, and Talbott (2007)

A statistically significant load shift was observed on only three of the critical days, one of which actually showed an uncharacteristic increase in load shift to on-peak hours. Upon further examination, one finds that the majority of this load shifting was conducted by consumers on the CPP program, followed by the CPR program, and lastly the classic TOU program (Strapp, King, and Talbott 2007).

Regular Non-Holiday Weekday Results

When a critical day was not announced, all pilot participants were essentially on the classic TOU-only pricing structure. Wolak (2007) found only one statistically significant load shift from on-peak periods as a result of the TOU price structure, but it was counterintuitive. That is, during regular weekdays all participants in the study failed to shift consumption significantly from on-peak to mid-peak or off-peak periods.

TABLE 4.2:
LOAD SHIFTING ON ALL NON-HOLIDAY WEEKDAYS FOR FULL PILOT PERIOD

	Natural Log of Peak Load Consumption in KWh	
Variable Name	Coefficient Estimate	Standard Error
TOU*Experiment(t)	0.0030	0.0766
CPP*Experiment(t)	**0.1075**	0.0715
CPR*Experiment(t)	0.0730	0.0714

Bolded values indicate statistically significant results at a 90% confidence level

Source: Wolak (2007)

Conservation Effects

The "conservation effect" is described as an overall reduction in electricity use regardless of when it was consumed. Table 4.3 shows the total reduction in electricity consumption for the participants in the pilot. The results show for TOU, CPP, and CPR pilot customers reductions in consumption of 6%, 4.7%, and 7.4% respectively[19] (Wolak 2007). On average participants reduced overall usage during the pilot by 6% or $2.75/month. This average 6% reduction only represents the conservation effect observed and does not take into account load shifting (Wolak 2007).

[19] These reductions are not found to be statistically significant at the 95% confidence level.

TABLE 4.3:
CONSERVATION EFFECT (Total Usage Reduction) FULL PILOT PERIOD

	Natural Log of Peak Load Consumption in KWh		
Treatment Group	Coefficient Estimate	Standard Error	T statistic
TOU	**-0.0598**	0.0382	-1.57
CPP	-0.0472*	0.0386	-1.22
CPR	**-0.0742**	0.0388	-1.91
* - Probability level approximately 88%.			

Bolded values indicate statistically significant results at a 90% confidence level

Source: Wolak (2007)

<u>Customer Bill Impacts</u>

Total Load Shift

The impact of load shift on consumers bills were determined by calculating each participants bills under the TOU rate structure versus the two-tier price plan. Therefore, if any bill savings occurred, these were entirely due to load shifting[20].

It was found that over the course of the pilot, on average, participants shifted load and paid approximately 3% less on the TOU pilot prices than they would have on the two-tier price plan. That is, on average pilot participants saved approximately $1.44 per month due to load shifting[21] (Strapp, King, and Talbott 2007).

[20] Conservation effects which lower consumption compared to what it would have been without the TOU prices are not considered in these results. Although it was the TOU prices which triggered the "conservation effect", the reduction in consumption would be reflected in charges on both two-tier prices and TOU prices.
[21] A reduction of approximately 24kWh/month based on the average price of $0.059/kWh

Conservation Effect

On average monthly electricity use for pilot participants was 727kWh after conserving 6%. The conservation effect, at the average price of $0.059/kWh, resulted in savings averaging approximately $2.73/month (Strapp, King, and Talbott 2007).

Overall

By combining the 3% reduction in consumption and the 6% conservation effect, pilot participants on average saved approximately 9% (or 70kWh) on their total TOU bills or $4.17/month (Strapp, King, and Talbott 2007).

Does the Smart Metering Initiative Achieve its Goals?

Despite reporting the pilot results, the OEB did not make any general conclusions or recommendations as to whether the Smart Metering Initiative should continue forward as scheduled. This section will attempt to draw some general conclusions and provide recommendations for how Ontario should proceed in light of the results discussed above. These results will be assessed on the basis of the primary goals of the Initiative[22] which are (1) to reduce consumption during peak periods, (2) to conserve electricity, and (3) to lower overall peak electricity prices. Additionally, a discussion on the actual consumer bill impacts and the cost-effectiveness of the Initiative will be presented.

[22] Only three out of the four goals will be addressed. It is felt that if the Initiative can reduce consumption during peak period and conserve electricity, then this will in turn reduce the amount of transmission congestion and thus this fourth goal is not specifically addressed in the section.

Goal 1: Load Shifting

As discussed in chapter three, one of the primary goals of the Smart Metering Initiative is to reduce consumption during peak periods. These peak periods include both regular weekday peak periods as well as "critical" peak periods.

Literature on time-varying demand response programs has found that the pricing structure is essential in its success at encouraging consumers to shift electricity consumption from peak to off-peak periods. Though there is a wide range of responsiveness to different pricing structures, in general researchers have shown that price ratios do matter, even if overall results are marginal. Moreover, researchers have shown that TOU pricing programs that offer greater financial incentives (through higher peak to off-peak price ratios) as well as shorter peak periods, produce the largest reductions in consumption (e.g. Caves, Christensen, and Harriges 1984; Faruqui and Malko 1983; Hartway, Price, and Woo 1999). For example, Faruqui and Malko (1983) found that consumers were most responsive in Arkansas, Connecticut, and Ohio with reductions of 41%, 31%, and 38% respectively. These three utilities had high peak to off-peak ratios (an average of 8.3: 1) and short on-peak periods (on average 6 hours).

Critical Peak Periods

Referring to the pilot results above, results for the TOU price structure with CPP show that there was a significant reduction in critical peak period consumption for two out of the seven announced critical peak days. The two days that were found to be significant occurred during the summer months when air conditioners tend to be operating at their full capacity. As previously outlined, studies have found that electricity users are more apt to shift consumption during the summer months (when air conditioners can be adjusted) than during the winter months when electricity becomes more of a necessity[23] (e.g. Philipson and Willis 2006). Ninety three percent of the pilot participants have air conditioners therefore it is not surprising that they were able to shift consumption. Furthermore, numerous studies have shown that when consumers are able to shift demand from peak to off-peak periods, they are more apt to do so when the price differential is substantial (e.g. Caves, Christensen, and Harriges 1984; Faruqui and Malko 1983; Hartway, Price, and Woo 1999). For instance, the pilot's critical peak period price differential for CPP participants was 10: 1 during critical peak times while the price differential of the only-TOU participants remained unchanged (i.e. 3:1) during critical peak periods. This may help to explain why CPP participants decreased consumption on average during those two days by approximately 19% while only-TOU consumers did not exhibit any significant load shifting.

In Ontario it would appear that TOU pricing along with CPP will help to decrease consumption during critical peak periods as price differentials during these peak periods remain high. However, we find that these results only occur during the summer season when users are able to manage their electricity consumption more easily by reducing air conditioners, decreasing the use of lighting, etc.

Non-Holiday Weekday Peak Periods

In terms of the pilot, when critical peak days were not in effect, all participants were on the only-TOU rate structure. That is, all participants in the study were on a rate structure that had a peak to off-peak ratio of exactly 3:1. Wolak's (2007) analysis of load shifting during the pilot from peak to mid-peak and peak to off-peak periods was found to be insignificant for all participants. Namely, participants in the pilot study did not significantly shift load from on-peak

[23] In the winter months individuals who have electric heating can only curb consumption minimally, less daylight hours result in longer indoor lighting hours for most households, etc..

periods. This outcome is of particular concern. One of the goals of the Initiative is to foster a reduction in consumption during not only “critical peak periods” but all peak periods. As discussed in chapter one, the power system is strained during peak periods and one of the purposes of a demand response program such as a TOU pricing is to first and foremost reduce system strain and thus improve system efficiency and reliability during peak periods. These pilot results show clearly that the Initiative is not fostering load shift away from on-peak periods.

One of the reasons behind this lack of load shifting may be due to the small peak to off-peak price ratio. Research has shown that consumers are most responsive to TOU rates and are willing to shift load away from peak periods when price differentials are large and peak periods are short (less than 6 hours) (e.g. Braithwait, 2000; Caves and Christensen 1980; Faruqui and Malko 1983). Braithwait (2000), who did a recent analysis of responsiveness to price differentials in residential electricity users, found that peak to off-peak price ratios need to be at least 4:1 and closer to 5:1 to significantly promote load shifting between peak and off-peak periods. With Ontario’s weak 3:1 price ratio, consumers may not have shifted their electricity load as much as they may have had the price ratio been larger. To help put things into perspective, referring back the discussion on load shifting during “critical” peak periods, the same participants who were willing to shift consumption by as much as 25% when the price differential was 10:1, were not willing to significantly do so when price ratios were only 3:1.

When considering actual recent Ontario market data, one finds that the average daily HOEP price ratio between the daily maximum peak price and the daily minimum off-peak price for the last three months (May 2007 – July 2007) has been approximately 6:1 (Independent Electricity System Operator 2007). However, although this ratio is more in line with what Braithwait (2000) suggested, one would expect that it would decrease when data for an entire 12 month period is used[24]. Nevertheless, if the price ratio was indeed 6:1, Ontario would have the option of altering the ratio associated with the TOU program and thus help foster more response from consumers in terms of load shifting during peak periods.

In terms of how Ontario should move forward, pursuing TOU prices with CPP seems to foster the type of reduction in consumption for residential consumers that would help reduce the strain of the electric system during "critical" days. However, in order for residential electricity users to continue on-peak load shifting behaviour during non-critical days, the OEB will need to explore further the potential that current peak to off-peak price ratios may be too small to encourage the type of load shift required to achieve the Initiative's goals. Furthermore, Ontario HOEP data shows that a larger price differential may not even be possible for the TOU pricing program.

Goal 2: Electricity Conservation

One of the other goals of the Initiative is to conserve electricity. As discussed in chapter one, although the main purpose of TOU pricing is to shift electricity load from peak to off peak periods, these types of demand response programs tend to reduce overall total consumption as well, this is known as the *conservation effect*. There are three reasons which have been identified to help explain why these small total electricity reductions occur. First, higher on-peak prices tend to reduce electricity consumption during peak hours, not all of this load reduction is shifted to other periods. Second, TOU pricing programs cause participants to become more aware of how they consume electricity which in turn results in lower electricity use. Lastly, these types of programs tend to increase the amount of information or feedback that a consumer

[24] The data used contained two out of three summer months and thus one would expect higher peak period prices during this time and consequently a larger price ratio between peak and off-peak periods.

receives about their electricity consumption which subsequently helps to lower their consumption (Wolak 2007).

The pilot results indicate that participants on average reduced their overall electricity consumption per month by 6%. These findings can be misleading, for instance, if *all* 4 million small business and residential electricity consumers in Ontario conserved 6% of their monthly electricity that would result, on average, in at most a 1.4% decrease in Ontario's average monthly demand. This is far from the 5% reduction Ontario had anticipated for 2007 and to which the Smart Meter Initiative was to be a major contributor (The Ontario Energy Board 2005). Furthermore one needs to also consider the potential that the conservation effect may have come to be, had more conservation-based programs been established. These types of programs would be of a significantly lower costs then TOU pricing programs as they do not require advanced metering and real-time communication. In addition, with the proper education, electricity consumers may be able to conserve similar amounts. Many pilot participants had expressed that cost savings were only part of the appeal of a TOU program as were helping the environment and reducing the strain on Ontario's power system (Strapp, King, and Talbott 2007). Therefore, since financial gains are not the only driving force behind electricity conservation, proper education may in fact result in a conservation effect without the high cost of a TOU pricing program.

Goal 3: Lower Overall Peak Electricity Prices

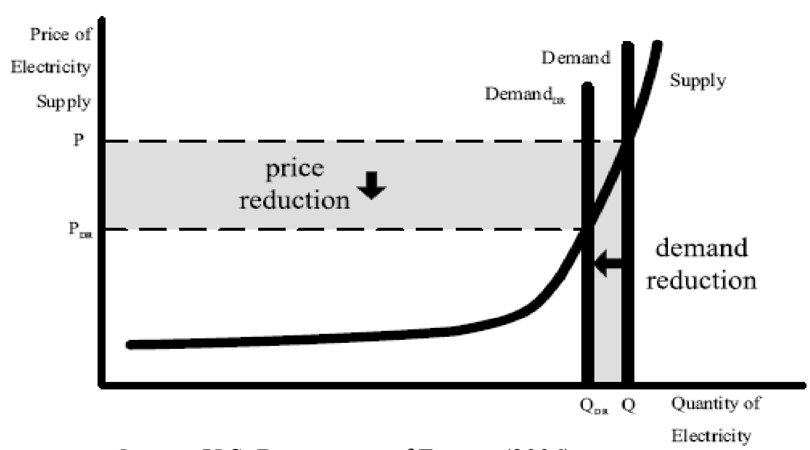
The third goal of the Smart Meter Initiative is to reduce overall electricity prices. The view that demand response programs such as TOU pricing can significantly reduce electricity prices with minor shifts in peak consumption (0% in terms of the pilot) and small overall electricity conservation (6% in terms of the pilot) is one of the reason that these types of programs are so highly regarded. However it would appear that when something sounds too good to be true, it often is.

The pilot's final report does not specifically address the affects of demand change during the pilot on overall Ontario electricity prices. It is felt that in order to fully evaluate the Initiative one must also consider how changes in demand would ultimately affect overall electricity prices.

There would appear to be flaws in the standard theory of demand response (as discussed in chapter one) - that small changes in demand could lead to substantial changes in electricity prices. This helps to explain why outcomes of many TOU pricing programs do not achieve the overall market affects regulators had hoped, at least in the long run.

Ruff (2002) presents a more realistic account of what can be expected in terms of the effects of TOU pricing programs on long run electricity prices. In the short run during peak periods, both supply and demand are highly inelastic and a sudden decrease in peak demand (as a result of TOU programs) can cause substantial immediate declines in peak prices and consequently consumers' electricity bills as shown in Figure 4.1, but these are purely a short run phenomenon.

FIGURE 4.1: ELECTRICITY PRICE/DEMAND CURVE FOR SHIFTED LOAD



Source: U.S. Department of Energy (2006)

Any reduction in prices and consequently consumer bills in excess of the small reduction in supplier costs (from not using a few peak-load plants) must be decreasing the short run rents of the large quantity of capacity (the "base load" plants) that is still needed to maintain equilibrium (Ruff 2002). Therefore, assuming that all needed generation capacity will recover its total costs over time plus a competitive profit, time-weighted average prices must return to approximately where they would have been had peak demand not decreased. In the long run, the peak price level may not be reduced significantly. As a result of lower demand during peak periods, demand-weighted average prices paid by consumers will be lower. However, these lower demand-weighted average prices will be smaller than the short run reductions in peak prices which are often given as reasons to encourage demand response programs (Ruff 2002). In terms of Ontario's market, almost all power generators are guaranteed a fixed price. Namely, if the HOEP falls due to a decrease in consumer demand, loads would have to compensate by paying more in regulatory charges. Moreover, if the HOEP were to fall, there would be an increase in electricity exports which consequently would result in an increase in the HOEP (Ruff 2002).

The deregulation of electricity markets was pursued in order to create a competitive market. In order for generation to remain a commercially viable business, large price declines due to excess generation capacity are just short-run effects that cannot be sustained in the long run while maintaining a competitive electricity market (Ruff 2002). Furthermore, most of the short run consumer gains at the expense of suppliers are achieved because producers are surprised by the decrease in peak demand and thus left with excess peak-load capacity. However, if suppliers knew, in advance, that this decrease in peak demand would occur, they would and should stop investing and maintaining peak-load plants and potentially "base-load" plants as well

(Ruff 2002). If suppliers anticipate the consumers decrease in demand, this will cause peak prices to be higher before this demand decrease, fall during it, and increase soon again after the decrease. If suppliers underestimate future peak demand reductions, they may provide too much peaking capacity. This action will drive down peak prices as demand reduction occurs. This can only temporarily reducing the level and price of peak periods and creating short run monetary benefits for consumers at the expense of producers. On the other hand, if suppliers believe that the future decreases in demand are much larger than they inevitably will be, producers may provide too little peaking capacity, causing peak prices to increase and giving suppliers a short run gain at the expense of consumers (Ruff 2002). Peak-Load pricing could help reduce the overall electricity prices, but it would only occur if the pricing program was part of a larger more intricate demand response program in which all sectors of the electricity market were targeted with appropriate demand response elements.

Actual Consumer Bill Impacts

One of the main incentives of the Smart Meter Initiative is the financial gains one can expect from the TOU pricing structure. As the pilot shows, on average consumers saved $4.17/month as a result of both their load shifting and conservation efforts. In fact, all pilot participants who were surveyed said that one of the main benefits of the TOU pricing program was that it made them more aware of how to reduce their electricity bills and gave them greater control over overall costs (Strapp, King, and Talbott 2007). Based on these responses, being financially rewarded for their efforts is an essential factor in how much they do of both. This conclusion can be drawn from the studies which show that large price differentials increase consumer responsiveness primarily due to the possibility of cost-savings.

If Ontario hopes to motivate smart meter consumers through the use of financial incentives, then the province may encounter a problem. The pilot reveals a saving for participants, on average, of approximately \$4.17/month as a result of both load shifting and conservation effort. However, pilot participants were not informed nor was it indicated on their bill that there would be a monthly charge associated with the smart metering program. In chapter three it was outlined that all consumers in Ontario on the smart metering program would be charged an amount between \$3.00-\$4.00 to cover the cost associated with implementing and maintaining the program. In reality, an average consumer would only be saving between \$0.17 - \$1.17/month on the TOU pricing plan.

The bills savings on the TOU pricing plan were already marginal compared to what some participants had expected as a result of their efforts, but once the smart metering monthly charge is incorporated, these savings diminish significantly. The concern is, if one of the motivating factors for the average Ontario electricity consumer in reducing demand is the potential for bill reductions, once consumers receive their monthly bills, they may choose to no longer load shift or conserve if doing so requires substantial effort and time. Therefore there is a very realistic possibility that any gains achieved during the pilot with respect to load shifting and conservation may never occur during actual program implementation.

By not significantly achieving all of its proposed goals; is the Initiative a program that should be pursued, especially due to its large implementation and operating costs? The following section helps to address this question with a discussion on the cost effectiveness of the smart meter program.

Is the Smart Metering Initiative Cost Effective?

Demand response programs are generally seen as cost effective when compared to the alternatives available (rolling black outs, running peak-load units) (Neumann et al. 2006). The cost effectiveness of these programs results when demand response programs are applied to all sectors of the electricity market in a well planned and coordinated manner. That is, to implement a TOU pricing program for all small electricity users in a utility is just one element of a hopefully much larger demand response program. As mentioned before, to attempt to evaluate the cost effectiveness of Ontario's entire demand response program is well beyond the scope of this paper, however, one element of it is the Smart Metering Initiative.

The total electricity demand in Ontario over the last 6 months (January 1, 2007 to June 30, 2007) was approximately 76,327 GWh[25], which is approximately 12,700 GWh per month. During this same period, the monthly average weighted price per MWh was approximately $48.00. The pilot revealed that participants conserved, on average, 6% of their electricity consumption or approximately 46kWh per month. The pilot results did not specify when this conservation effect occurred, thus for simplicity it is assumed these conservation efforts occurred during all three periods (on-peak, mid-peak, and off-peak). The Independent Electricity Operator System (IESO) estimated that at the end of 2005 there were approximately 4 million residential users and small businesses in Ontario who demanded electricity on a monthly basis. If *all* 4 million small electricity users conserved the 6% a month (or 46kWh), this conservation effort would equal a total of 184, 000 MWh conserved in one month or approximately 1.4% of Ontario's total monthly demand. One might think that this would lead to an impressive $8.83 million savings a month, but in fact part of this savings is reduced rents to government-owned

[25] All electricity market figures were taken from Independent Electricity Operator System (IESO) website at www.ieso.ca.

generators as discussed above. The real cost of the Initiative is $1 billion plus $50 million per year, but the real gain is not $8.83 million a month, but rather the difference between the value that loads place on peak period consumption foregone and the marginal cost of peak generation. Therefore one may find that the Initiative is in fact not cost effective if this difference does not exceed the cost.

Conclusion

Based on the pilot results, it would appear that the peak-load pricing program scheduled for Ontario is not adequately meeting its intended goals. The pilot reveals that consumers in Ontario are likely to shift their electricity load between periods, but that these load shifts are not occurring when they are most needed. Shifting from the on-peak only occurred during critical peak periods when price differentials were significantly high. The concern with these results is that Ontario clearly stated that one of its goals was to shift load from on-peak periods regardless of whether a critical event was announced or not. The pilot results indicate that although on-peak load shifts occur during critical peak times, they do not occur during regular weekday peak periods and therefore implementing the smart meter program as currently designed may not achieve the desired effect in terms of load shifting

Furthermore, Ontario had hoped that the Initiative would assist the province in reducing overall electricity usage. Based on the pilot results it would appear that the Initiative could help achieve this goal, though the amount of decreased residential demand is modest. Realistically, residential users only contribute 0.5% to demand savings; a very small percentage of the 5% that Ontario hopes to save by the end of 2007. Moreover, it is also unclear as to when this conservation is occurring. One would suspect that an Initiative of this sort would try to promote conservation during on-peak periods since these are the times when electricity prices are high and system vulnerability occurs. This would be important information to acquire in order to understand whether the Initiative is truly effective at, not only reducing overall electricity demand in Ontario, but conserving electricity in times where the system is in most jeopardy. The smart meter program does help in terms of electricity conservation, but there are other programs which are also available to assist in this area and which are much less costly to implement.

Clearly everyone involved would like to see a decrease in electricity prices; the issue is that economic principle shows that lowering electricity prices at the expense of power producers will only occur in the short run. In the long-run, small price reductions could occur as supply curves shift due to demand decreases, but these will not occur through one demand response program such a TOU pricing. In order to achieve lower overall electricity prices, a more intricate cost-effective demand response program needs to be implemented which includes not only small users and price-based programs, but also incentive-based programs, changes to dispatch/pricing processes, a movement away from day-ahead markets to real-time markets, etc. (Ruff 2002). The smart metering program will not be able to fulfill its goals independently and to think that is setting producers, consumers, and policymakers up for disappointment.

After the Pilot: How Ontario Should Proceed

The pilot results indicate that the smart meter program is not meeting the goals as intended and unless altered, may not be cost effective when implemented on a mandatory basis. But Ontario does have a choice. There are other options available which can achieve Ontario's electricity management goals, while being cost effective and conducive to mandatory implementation. Nevertheless, Ontario may decide to continue forward with the proposed

Initiative, in which case re-evaluating its peak to off-peak price ratio may aid in assuring its success as a mandatory Ontario program.

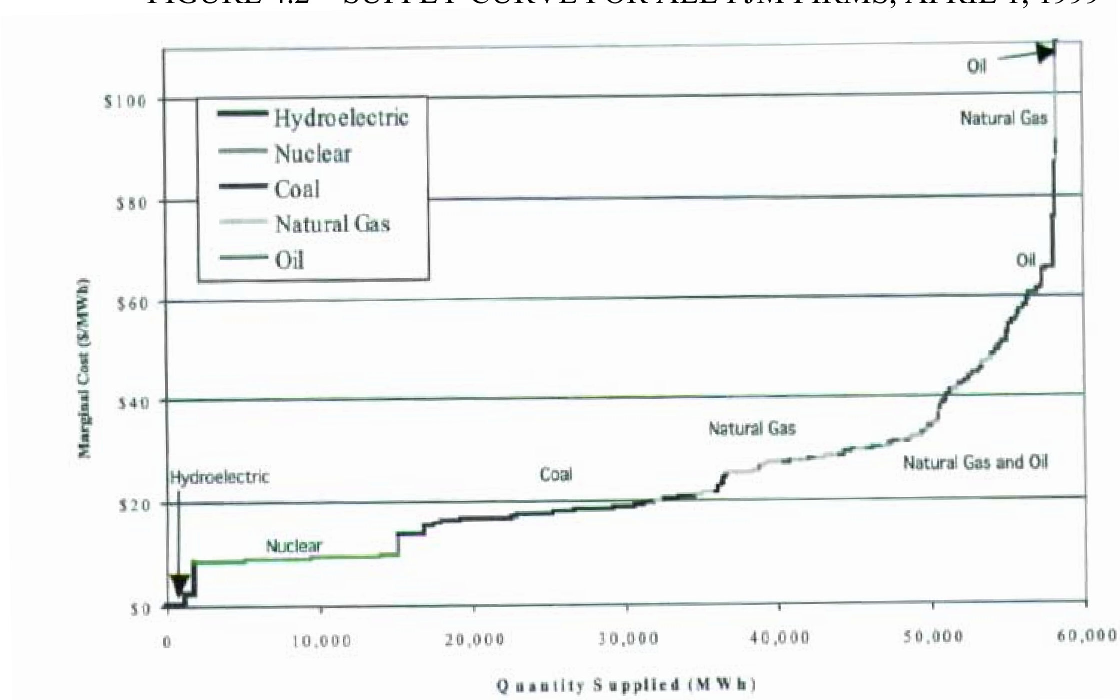
The pilot revealed what is already known about the price responsiveness of large loads, in order to get a response, a big price difference must be present. If Ontario chooses to move forward with the smart meter program, higher price differentials could assist in ensuring that consumers are aware and responding to market signals. However, this may not be possible given the HOEP price ratio findings presented earlier. Some researchers have suggested that using interactive and automatic load reduction tools such as Smart thermostats[26] can significantly reduce overall electricity usage and help with peak load shifting above and beyond both classic TOU programs and CPP programs (e.g. Neumann et al. 2006; Parmesano 2007). Braithwait (2000) found that interactive communication equipment resulted in peak load shift of 26% in the summer months and reductions approaching 50% during some critical peak periods. However, there have been mixed results associated with interactive communication and automatic load control equipment in residential users. Results obtained from the California Statewide Pricing Pilot found overall conservation and peak load shift (with the use of automatic load control) results analogous to those of the Ontario pilot where this type of equipment was not used (Charles River Associates 2005). Furthermore, Matsukawa (2004) found this type of equipment did not have a significant effect on conservation or peak load shift in a study conducted in Japan and whatever effect did occur did not offset the high cost of this type of equipment. Others have suggested that educational programs surrounding electricity conservation and appliance labeling may help in promoting load shift and conservation (e.g. Parmesano 2007), however others have shown that information alone is not able to promote large energy conservation effects (Geller

[26] Smart thermostats can adjust the temperature settings on air conditioners and heating units as well as indicate peak periods via digital display.

1981). Similar results occurred during the pilot. Participants were educated through both written and oral means, and this line of action proved to be less effective than price differentials (Strapp, King, and Talbott 2007). What we find is that although other programs or equipment may aid consumers slightly in terms of conservation and load shifting, a large price differential between peak and off-peak periods is necessary to observe significant results in TOU pricing programs. Unfortunately, Ontario may not be able to provide these large price ratios to its small-users.

Holland and Mansur (2006) suggest another option which saves substantially on costs (since regular meters can be used) and still captures the benefits of time-of-use pricing. They recommend a monthly rate program as opposed to a time-of-use or real-time pricing plan. They conducted a study over a two year period (Spring 1998 to Spring 2000) with one of the large electricity markets in the United States, PJM. PJM has a similar supply curve (figure 4.2) to the one presented in chapter one for Ontario.

FIGURE 4.2 – SUPPLY CURVE FOR ALL PJM FIRMS, APRIL 1, 1999



Source: Holland and Mansur (2006)

They found that approximately 30% of efficiency gains could be captured by varying flat rates monthly instead of annually, while only 15% of these gains were captured using TOU pricing. That is, monthly flat rate adjustment has many of the same effects as real-time pricing plans, captures more of the deadweight loss than TOU rates, and does not require new metering technology (Holland and Mansur 2006). This type of program may be exactly what Ontario needs, especially in terms of small-users. It would allow Ontario to achieve, according to Holland and Mansur (2006), the electricity management goals it wanted to through the smart meter program, while avoiding the large costs of the Smart Meter Initiative. While not only saving in costs, a program of this type would also give Ontario the opportunity to assess how small electricity users in Ontario react to varying prices and would provide a baseline from which to assess the viability of more costly but also more effective time-varying programs such as real-time pricing.

Concluding Comments

This paper was not meant to argue whether time-varying pricing works, many countries have been able to apply it successfully and it is grounded in solid economic theory. The issue is whether Ontario's Smart Metering Initiative can be successful at achieving the full benefits realized through time-varying prices. As discussed throughout this paper, there are many variables which affect the success of peak-load pricing programs such as customer price responsiveness, operational variables, and mandatory versus voluntary implementation. The pilot results show that there may be more cost effective and suitable programs for Ontario residents which will ultimately lead to Ontario's electricity management goals such as the monthly time varying pricing program. We live in a complex and uncertain world and despite our best efforts to analyze, critique, and conclude accurately whether such a demand response action will be successful is unknown. It is felt that Ontario should reconsider the mandatory implementation of a smart meter program to all small business and residential users in Ontario by 2010. There are less costly options which are apt to achieve better results, provide valuable information for advancement, and will likely be more accepted by Ontario's small electricity users.

References

Acton, J. P. et al. 1980. *British Industrial Response to the Peak-Load Pricing of Electricity.* Vol. R-2508-DOE/DWP. Santa Monica, CA: RAND.

Aigner, Dennis J. 1981.The Welfare Econometrics of Peak-Load Pricing for Electricity. *Journal of Econometrics* 26, no. 1:1-15.

Aigner, Dennis J., and Joseph G. Hirschberg. 1985. Commercial-Industrial Customer Response to Time-of-Use Electricity Prices: Some Experimental Results. *RAND Journal of Economics* 16, no. 3:341-355.

Aigner, Dennis J., and Khalifa Ghali. 1989. Self-Selection in the Residential Electricity Time-of-Use Pricing Experiments. *Journal of Applied Econometrics* 4, 131-144.

Aigner, Dennis J., and Edward E. Leamer. 1984. Estimation of Time-Of-Use Pricing Response in the Absence of Experimental Data: An Application of the Methodology of Data Transferability. *Journal of Econometrics* 24, 205-227.

Aigner, D. J., J. Newman, and A. Tishler. 1994. The Response of Small and Medium-Size Business Customers to Time-Of-use Electricity Rates in Israel. *Journal of Applied Econometrics* 9, no. 3:283-304.

Atkinson, Scott E. 1979. Responsiveness to Time-of-Day Electricity Pricing: First Empirical Results. *Journal of Econometrics* 9, 79-95.

Baladi, S. M., Joseph A. Herriges, and Thomas J. Sweeney. 1998. Residential response to voluntary time-of-use electricity rates. *Resource and Energy Economics* 20, 225-244.

Boisvert et al., 2007. Customer Response to RTP in Competitive Markets: A Study of Niagara Mohawk's Standard Offer Tariff. *The Energy Journal* 28, no.1:53-74.

Braithwait, S. 2000. Residential TOU Price Response in the Presence of Interactive Communication Equipment. In *Pricing in Competitive Electricity Markets*, ed. Ahmed Faruqui and Kelly Eakin, 359-373. USA: Klumer.

Campbell, N., McFetridge, D., and Rusnov, T. 2007. *Monitoring Report on the IESO-Administered Electricity Markets: November 2006-April 2007*. Toronto, ON: Ontario Energy Board.

Caves, Douglas W., and Laurits R. Christensen. 1980. Econometric Analysis of Residential Time-Of-Use Electricity Pricing Experiments. *Journal of Econometrics* 14, 287-306.

Caves, Douglas W., Laurits R. Christensen, and Joseph A. Herriges. 1984. Consistency of Residential Customer Response in Time-Of-use Electricity Pricing Experiments. *Journal of Econometrics* 26, no. 1:179-203.

Charles River Associates. 2005. *Impact Evaluation of the California Statewide Pricing Pilot: Final Report. Oakland*, California: Charles River Associates.

Duncan, Dwight Minister of Energy. 2005. *Eligibility of Smart Meter Pricing plan.*

Eaton, Curtis B., Eaton, Diane F., and Allen, Douglas, W. 2004. *Microeconomics: Theory with Applications.* 6th ed. United States of America: Prentice Hall.

Faruqui, Ahmad, and Robert J. Malko. 1983. The Residential Demand for Electricity by Time-Of-Use: A Survey of Twelve Experiments with Peak Load Pricing. *Energy* 8, no. 10:781-795.

Filippini, Massimo. 1995. Swiss Residential Demand for Electricity by Time-of-Use. *Resource and Energy Economics* 17, no. 3:281-290.

Geller, Scott E. 1981. Evaluating Energy Conservation Programs: Is Verbal Report Enough? *The Journal of Consumer Research* 8, no.3:331-335.

Hartman, Raymond S. 1988. Self-Selection Bias in the Evolution of Voluntary Conservation Programs. *The Review of Economics and Statistics* 70, 448-458.

Hartway, Rob, Snuller Price, and C.K. Woo. 1999. Smart meter, customer choice and profitable time-of-use rate option. *Energy* 24, 893-903.

Hendricks, Wallace, and Koenker, Roger. 1979. *Demand for electricity by time-of-day: An evaluation of experimental results.* Paper presented at the Rutgers conference on the demand for and pricing of public utility services, Rutgers University.

Henley, Andrew, and John Peirson. 1994. Time-of-Use Electricity Pricing: Evidence from a British Experiment. *Economics Letters* 45, no. 3:421-426.

Hill, Daniel H., et al. 1979. *Evaluation of the FEA's load management and rate design demonstration projects.* Vol. EA-1152. Palo Alto, CA: Electric Power Research Institute.

Hill, Lawrence J. 1991. Residential time-of-use pricing as a load management strategy: Effectiveness and Applicability. *Utilities Policy,* 308-318.

Holland, Stephen P., and Erin T. Mansur. 2006. The Short-Run Effects of Time-Varying Prices in Competitive Electricity Markets. *The Energy Journal* 27 no. 4:127-155.

Independent Electricity System Operator. 2007. Monthly Market Reports: December 2006 to June 2007. http://www.ieso.ca/imoweb/marketdata/marketSummary.asp (accessed August, 2000).

King, Chris. 2005. *Market Research Results - California Statewide Pricing Pilot.* Report presented to the Ontario Power Authority. Redwood City, CA: eMeter.

Kohler, Daniel F., and Bridger M. Mitchell. 1984. Response to Residential Time-Of-Use Electricity Rates: How Transferable Are the Findings? *Journal of Econometrics* 26, 141-177.

Lafferty, Ronald, et al. 2001. *Demand Responsiveness in Electricity Markets*. Report for the Office of Markets, Tariffs, and Rates.

Matsukawa, Isamu. 2001. Household Response to Optional Peak-Load Pricing of Electricity. *Journal of Regulatory Economics* 20, no. 3:249-267.

Matsukawa, Isamu. 2004. The Effects of Information on Residential Demand for Electricity. *The Energy Journal* 25, no. 1:1-17.

Miedema et al. 1981. *Time-of-use electricity price effects: Final Report.* Report prepared for the U.S. Department of Energy. NC: Research Triangle Park.

Mountain, Dean C., and Evelyn L. Lawson. 1995. Some Initial Evidence of Canadian Responsiveness to Time-of-Use Electricity Rates: Detailed Daily and Monthly Analysis. *Resource and Energy Economics* 17, no. 2:189-212.

Natural Resources Canada. 2006. *Canada's Energy Outlook: The Reference Case 2006*. Ottawa, ON: Natural Resources Canada.

Neumann, Scott., et al. 2006. How to Get More Response from Demand Response. *Electricity Journal* 19, 24-31.

Ontario Energy Board. 2005. *Smart Meter Implementation Plan: Report of the Board to the Minister.* Toronto, ON: The Ontario Energy Board.

Ontario Energy Board. 2004. *Demand-Side Management and Demand Response in the Ontario Electricity Sector*. Report of the Board to the Minister of Energy. Toronto, ON: The Ontario Energy Board

Park, Rolla E., and Jan P. Acton. 1984. Large business customer response to time-of-day electricity rates. *Journal of Econometrics* 26, 229-252.

Parmesano, H. 2007. Rate Design is the No. 1 Energy Efficiency Tool. *The Electricity Journal* 20, no.6:18-25.

Philipson, L., and Willis, H. L. 2006. *Understanding electric utilities and de-regulation.* Florida: CRC Press.

Reiss, Peter C. and Matthew W. White. 2002. *Household Electricity Demand, Revisited*. for the Edison Electric Institute.

Rothwell, Geoffrey, and Gomez, Tomas. 2003. *Electricity Economics: Regulation and Deregulation.* Canada: Wiley Interscience.

Ruff, Larry E. 2002. *Economic Principles of Demand Response in Electricity*. Report prepared for the Edison Electric Institute.

Statistics Canada. 2005. Survey of Household spending, household equipment at December 31, by province, territory, and selected metropolitan areas, annual, Table 203-0020. CANSIM.

Strapp, James., King, Chris, and Talbott, Sharon. 2007. *Ontario Energy Board Smart Price Pilot: Final Report*. Report to the Ontario Energy Board.

U.S. Department of Energy. 1978. *Analytical master plan for the analysis of data from the electric utility rate demonstration projects.* NC: Research Triangle Institute.

U.S. Department of Energy. 2006. *Benefits of Demand Response in Electricity Markets and Recommendations for Achieving Them*. Report to the United States Congress. Washington, DC: U.S. Department of Energy.

Viscusi, W. K., Vernon, John M., and Harrington, Joseph E. Jr. 2000. *Economics of Regulation and Antitrust.* 3rd ed. Cambridge, MA: The MIT Press.

Viscusi, W. K., Vernon, John M., and Harrington, Joseph E. Jr. 2005. *Economics of Regulation and Antitrust.* 4th ed. Cambridge, MA: The MIT Press.

Wolak, Frank. 2007. *Load Impact and Conservation Effect Analytical Model: Ontario Smart Price Pilot*. Report to the Ontario Energy Board.