IMPACT OF ADOPTING THE TIME-OF-USE RATE PLANS ON THE ELECTRICITY COST IN THE CANADIAN RESIDENTIAL SECTOR

Ali M. Syed, *MASc* [1]
[1]Energy Management Specialist, Stantec, Saint John, New Brunswick, Canada

ABSTRACT

Time of use (TOU) electricity metering involves dividing the day, the month and the year in to slots or bands, with generally higher rates at the peak loads and low tariff rates at off-peak load periods. For this study, the statistically representative test-case Canadian house was modeled in the building energy simulation software ESP-r to estimate its sub-hourly (every fifteen minutes) electricity consumption for the appliances, lighting, domestic hot water (DHW) and space heating for an entire year. With the detailed electricity usage magnitude and sub-hourly electricity demand profile, the cost was calculated at both flat and TOU price plans for a typical weekday and weekend for the winter and non-winter seasons, respectively. Different scenarios of demand response were simulated by individually shifting the 'appliance and lighting' loads and the 'total electricity' load (including HVAC and DHW) to the off-peak hours for the typical days of both seasons. It was found that by intelligent load management, up to 28 % of electricity cost savings are possible in a typical weekday. Similarly, by shifting only appliance load to off-peak hours up to 6.3 % in daily electricity cost can be saved.

KEYWORDS

Time Of Use (TOU), DHW, HVAC, Demand Response, Electric Power, Load Profile, Energy Simulation, ESP-r

INTRODUCTION

Lights and commonly used appliances like refrigerator, microwaves, laundry, dishwashing, computers etc. represent a significant portion of the electricity usage in the Canadian residential energy end-use. Similarly, the air-conditioners are a source of electricity consumption in the summer. Many houses use electric DHW heaters and electric baseboard heaters to heat the water and maintain a comfortable inside temperatures in the winters. Generally most utility users pay a flat rate for the electric power they consume. These rates are generally the same for the entire year.

The time-of-use (TOU) electricity metering involves dividing the day, month and year in to 'tariff slots' or 'bands', with generally higher rates at the peak load periods and low tariff rates at the off-peak load periods. The idea of TOU is to get the people to reduce the electricity consumption at the peak-load time slots and shift it to the off-peak time slots. Intelligent load management or demand response can win immediate economic benefits to the consumer. The TOU package is equally beneficial for the power company. Power companies are designed to be capable of meeting the peak demands, but generally they can not store power. For all off-peak periods, the surplus capacity costs a lot of money for maintenance, without generating lot of income. So, if the peak load magnitudes can be reduced, the company can save money to build extra power plants and can offer discounted rates. To date, only Ontario Energy Board (OEB) and Nova Scotia Power (NS Power) offer the option of a TOU package to their customers in Canada. For this study a statistically representative typical single detached Canadian house was modeled for the province of Nova Scotia in the building energy simulation tool ESP-r. This test-case house model was used to assess the benefits of adopting the TOU price plan under different demand response scenarios. The scope of this study is to present the magnitude of the potential of cost savings by adopting TOU price plans. The applicability of demand shifting with respect to occupant satisfaction is not covered in the scope of the current study.

TIME OF USE PRICE PLAN OF NS POWER

Currently, NS Power offers the following rates for time of use plan (Nova Scotia Power, 2009):

WINTER (December to February)
- 7 am to 12 pm 15.320¢/kWh
- 12 pm to 4 pm 10.670¢/kWh
- 4 pm to 11 pm 15.320¢/kWh
- 11 pm to 7 am 05.335¢/kWh

NON-WINTER (March to November)
- 7 am to 11 pm 10.670¢/kWh
- 11 pm to 7 am 05.335¢/kWh

Figures 1-4 show the prices plans offered by NS Power for winter and non-winter seasons for both weekdays and weekend electricity usage.

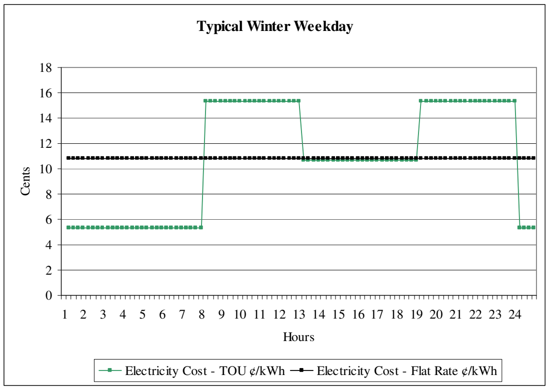

Figure 1 TOU electricity rate by NS Power in winter weekdays

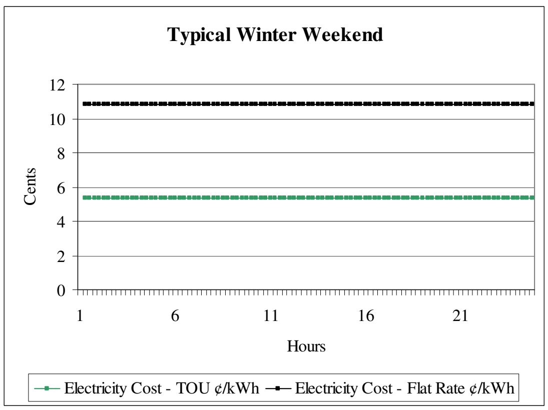

Figure 2 TOU electricity rate by NS Power in winter weekends

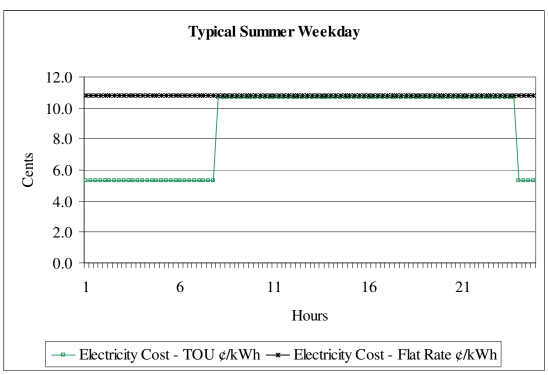

Figure 3 TOU electricity rate by NS Power in non-winter weekdays

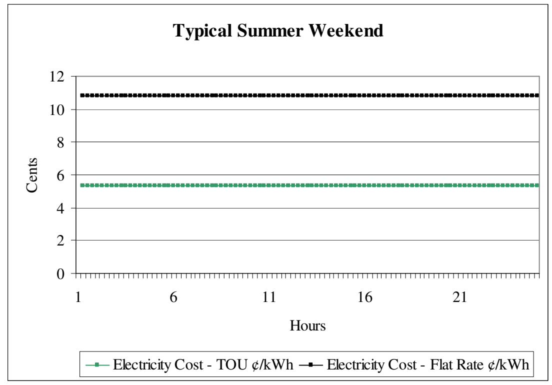

Figure 4 TOU electricity rate by NS Power in non-winter weekends

TYPICAL CANADIAN ELECTRICITY LOAD PROFILE

A load profile is a graph of variation in the electric load with the time. Load profiles vary with social-economic characteristics of the households, like household income, dwelling type and ownership, size of residence and number of children and adults (Aydinalp et al., 2000). The shape and the magnitude of the daily electricity load profiles also varies with time of the day, the time of the year, the geographical location, and the climatic conditions of the area (Paatero et al., 2006). For this study, the normalized load profile was developed based on the data from BC Hydro (one of the largest electric utilities in Canada), as identified by (Good et al., 2004) to get the shape of the profile for typical representative Canadian household in the Nova Scotia (Syed, 2007). The normalized load profile was used to generate the absolute load profile, specific to the selected house model for this study. The neural network (NN) based annual electricity consumption estimates by Aydinalp (2002) were used to obtain the mean value of kWh consumed by the selected model house for this study. These load profiles were imported in ESP-r for the house model simulation. Figure 5 shows the load profile for the selected house for a typical summer and winter days.

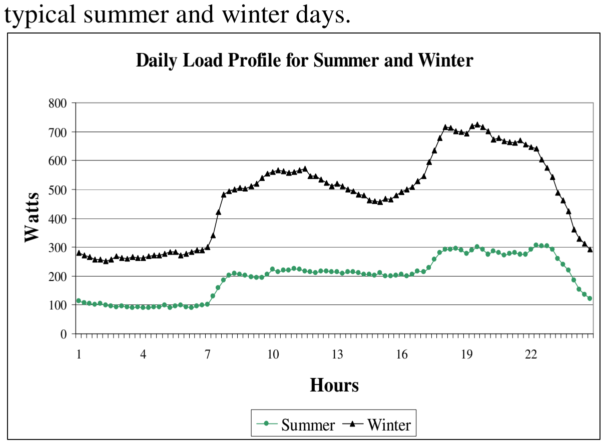

Figure 5 Load profile for a typical summer and winter day for the selected house model

DEVELOPMENT OF STATISTICALLY REPRESENTATIVE CANADIAN HOUSE MODEL IN ESP-r

The typical statistically representative house model for this study was generated using three Canadian housing stock databases, namely SHEU (Statistics Canada, 1993), EnerGuide (NRCan, 2005) and New Housing Survey (NRCan, 1997), respectively. The detailed development of the house model is presented in Syed (2007).

Some characteristics of the selected representative house used for this study are presented here:

- 2 storey house with living area of 116 m^2 (excluding basement).
- Built after 1977.
- Uses electric baseboard heaters with efficiency of 100 percent.
- DHW plant is electric, having efficiency of 82 percent.
- Construction details:
    - Main Wall RSI: 2.7 K·m²/W
    - Foundation RSI: 2.2 K·m²/W
    - Ceiling RSI: 5.6 K·m²/W
- Has a full heated basement.
- Has an unheated attic.
- It has 3 occupants.
- Infiltration: 4.6 ACH[1] @ 50Pa
- Glazed area of 6 m^2 with double glazed windows and glazed area of 2.69 m^2 with triple glazed windows.
- Temperature set points:
    - 6AM-6PM: 20 ºC
    - 9PM-10PM: 20 ºC
    - 10PM-6AM: 17 ºC
- Has an annual 'appliance and lighting' electric consumption of 9,658 kWh.

The house was modeled in the state of art building energy simulation software ESP-r. ESP-r is an energy simulation tool to model thermal, visual and acoustic performance of buildings and assessment of the energy use. The above mentioned, statistically derived information about different constructional and thermal characteristic and attributes, like floor areas, wall insulations, heating set-points, space heating equipment efficiencies, DHW systems, window types, orientation etc was used to model the house in ESP-r (Syed, 2007). Most of the required information was available in SHEU database, while remaining information was supplemented from EnerGuide and New Housing Survey. The thermostatic set-points were modeled in ESP-r. Casual gains due to the consumption of electricity were also included in the ESP-r model of the house.

[1] Air Changes per Hour

ESP-r SIMULATION RESULTS OF THE ANNUAL ELECTRICITY CONSUMPTION

Once the model was developed in ESP-r and electrical load profile properly linked to it, simulations were run to determine the total annual electricity usages for space heating, DHW heating, in addition to the appliance and lighting electric loads. The selected house was simulated for the weather file of Halifax, Nova Scotia. To get accurate results, reflecting even the minor fluctuations in the electricity consumption pattern, the simulation time step was kept 15 minutes. In this way, a total of 35,040 result points were obtained for the annual simulation, based on a simulation resolution of 4 time-steps per hours. Table 1 summarizes the simulation results for the house model.

Table 1 The annual electricity consumption of the house model for different sectors

Total Consumption Electricity (kWh/Yr)	30337
Space Heating Demand (GJ/Yr)	57.4
Demand DHW Fuel (GJ/Yr)	16.1

RESULT ANALYSIS AND DISCUSSION

The annual simulation results of electricity consumption by the 'appliance and lighting', DHW, and HVAC system were segregated in to two categories, one from December to February and the second from March to November, based on the winter and non-winter season definition of NS Power, respectively. The results of each season were further segregated in the weekdays and weekend results. Once the separate daily electricity consumption results were extracted for weekdays and weekends for both winter and non-winter seasons, the average magnitude of electricity consumption at each time step of a typical day for an entire season was sought. These averages reflect the typical daily electricity consumption for a given season. With these results available, different scenarios were run to understand the benefits of TOU price plans by varying the magnitude of load shifts or demand response, as shown in figure 6.

As can be seen in figure 6, following scenarios of demand response were analysed:

- Shifting total (HVAC and non-HVAC) electric load in a given weekday from the peak-hours to off-peak hours of the same day in the following progression:
    - 10 % to off-peak hours
    - 20 % to off-peak hours

- 30 % to off-peak hours
- 40 % to off-peak hours
- 50 % to off-peak hours
- Shifting only the 'appliance' load in a given weekday to off-peak hours of the same day in the following proportions:
    - 50 % to off-peak hours
    - 70 % to off-peak hours
- Shifting 20 % of daily 'appliance' consumption of a weekday for all weekdays in a week to the weekends.

With these scenarios the percentage savings in the electricity costs were estimated, compared to the situation if the demand response is not used at all. The results have been presented below. Table 2 shows the percent savings in daily electricity cost at different magnitudes of demand response for total electric load (HVAC and non-HVAC load) for a typical non-winter season weekday.

Table 2 Savings in electricity cost at different demand responses for total electric load for a typical non-winter weekday

Percent of load shifted to off-peak	Electricity Cost - TOU $	% Savings
0	10.8	0
10	10.2	5.5
20	9.7	9.8
30	9.3	14.2
40	8.8	18.6
50	8.3	22.9

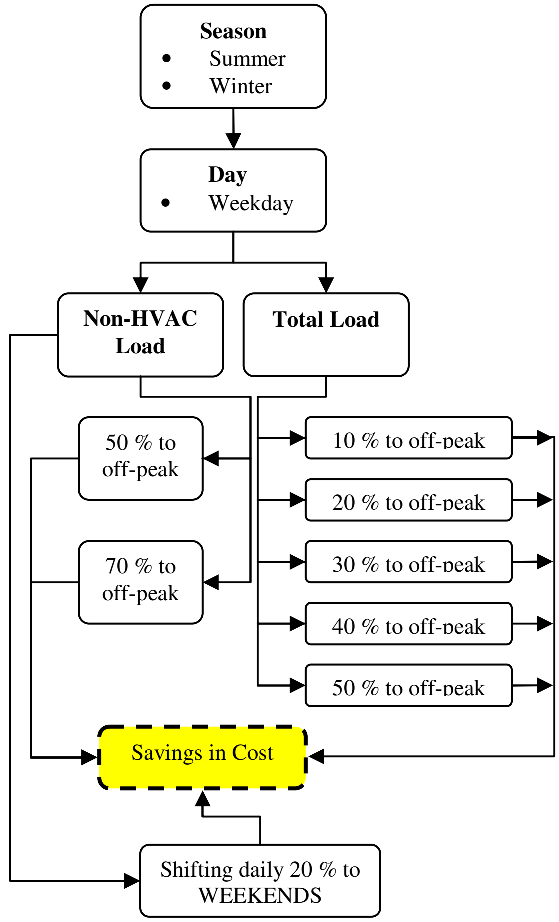

Figure 6 Flowchart showing different scenarios run with varying magnitude of demand response

Table 3 shows the percent savings in daily electricity cost at different magnitudes of demand response by shifting only the 'appliance' load in a given non-winter weekday to the off-peak hours of the same day.

Table 3 Savings in electricity cost at different demand responses for' appliance' electric load only for a typical non-winter weekday

Percent of load shifted to off-peak	Electricity Cost - TOU $	% Savings
0	10.8	0
50	10.2	5.7
70	10.0	7.5

Table 4 shows the percent savings in daily electricity cost at different magnitudes of demand response for total electric load (HVAC and non-HVAC load) for a typical winter season weekday.

Table 4 Savings in electricity cost at different demand responses for total electric load for a typical winter weekday

Percent of load shifted to off-peak	Electricity Cost - TOU $	% Savings
0	12.2	0
10	11.4	6.7
20	10.7	11.9
30	10.1	17.2
40	9.5	22.5
50	8.8	27.7

Table 5 shows the percent savings in daily electricity cost at different magnitudes of demand response by shifting only the 'appliance' load in a given winter weekday to the off-peak hours of the same day.

Table 5 Savings in electricity cost at different demand responses for' appliance' electric load only for a typical winter weekday

Percent of load shifted to off-peak	Electricity Cost - TOU $	% Savings
0	12.2	0
50	11.4	6.3
70	11.2	8.2

From tables 2-5, it can be seen that there is a huge potential for cost reduction by changing the load usage pattern to shift a portion of load to the non-peak hours. These results are obtained by shifting the daily load to the off peak hours of the same day. The example can be to do laundry, cooking, shower, washing etc. in the off-peak hours. The typical comparison of this demand response with the conventional flat rate price plan is presented in figure 7. Figure 7 shows the typical electricity draw in Wh for the selected house. With the proposed remand response, it can be seen that a portion of load in the peak hours can be shifted to the off peak hours. In this way, though the total daily electricity draw of the house remains the same, the load can be effectively shifted to the off-peak hours, resulting in a direct reduction in the cost.

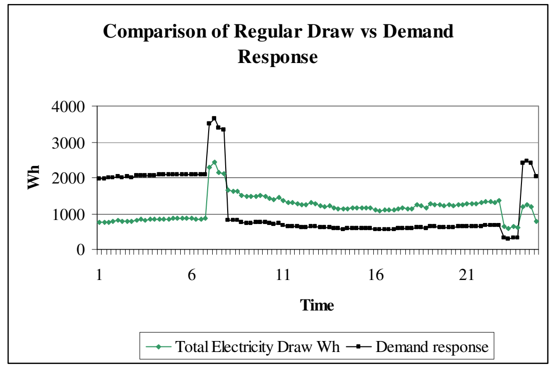

Figure 7 Comparison of regular electricity draw with the demand response to shift load to off-peak hours

CONCLUSION

From the results, it can be concluded that with intelligent load management and adopting the TOU rate plans, the electricity cost can be reduced by huge amounts without undue discomfort to the end-user. It can be seen that in non-winter season by shifting load to off peak hours, up to 23 percent can be saved in the cost. By shifting appliance load to off-peak hours, up to 7.5% can be reduced in the cost. For winter season up to 27.7 percent can be saved in the cost by shifting load to off-peak hours. By shifting appliance load to off-peak hours in winter season, up to 8.2% can be reduced in the cost.

These economic benefits of TOU plans are realized with the existing house insulation values and heating system control strategy. Adopting the energy conservation measures along with the efficient demand response, like occupancy and day-light sensors, low flow faucets and shower-heads and improved house insulations etc. can further increase the potential of cost savings for the electricity in domestic sectors.

ACKNOWLEDGEMENTS

The author wants to thank Dr. Ismet Ugursal, Chairman, Department of Mechanical Engineering, Dalhousie University, Halifax for technical assistance. The author acknowledges the financial support for this work provided by the Canadian Mortgage and Housing Corporation (CMHC) and Natural Resources Canada (NRCan).

REFERENCES

Aydinalp M. 2002, A new approach for modeling of residential energy consumption, PhD Thesis, department of Mechanical Engineering, Dalhousie University, Halifax, Canada

Aydinalp, M., Ugursal, V. I. and Fung, A., Modeling of the appliance, lighting, and space-cooling energy consumption in the residential sector using neural networks, Applied Energy, Volume 71, Issue 2, 2000

Good, J., Fung A., Zhang, Haixiong, Development of occupant driven load profiles for building simulation, Report submitted to CETC Buildings Group, NRCan, Ottawa, March 2004

Nova Scotia Power, Domestic Service Time of Day Tariff (online), Accessed in 2009

Available: http://www.nspower.ca/about_nspi/rates_regs/regulatory_initiatives/definitions/DomesticServiceTime.shtml

NRCan 1997, New Housing Survey, Natural Resources of Canada, Ottawa

NRCan 2005, Service Organizations' User Guide Electronic File Transfer for EnerGuide for Houses, Natural Resources of Canada

Paatero, Jukka V. and Lund , Peter D., A model for generating household electricity load profiles, Int. J. Energy Res.; 30: 273-290, 2006

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

Syed Ali M., 2007, Analysis of renewable energy potential in the residential sector through high resolution building energy simulation, MASc Thesis, department of Mechanical Engineering, Dalhousie University, Halifax, Canada