ONTARIO SOCIETY OF PROFESSIONAL ENGINEERS

BEHIND EVERY GREAT ENGINEER.

Retail Electricity Price Reform:

Path to Lower Energy Bills and Economy-Wide CO_2 Emission Reductions

Full Report

April 9, 2019

Executive Summary

About OSPE

The Ontario Society of Professional Engineers (OSPE) is the voice of the engineering profession in Ontario. OSPE represents the entire engineering community, including professional engineers, engineering graduates and students.

Objective:

This report identifies the need for Ontario to reform its retail electricity price plans to enable consumers to purchase surplus emission-free electrical energy at its low wholesale market energy price. A key component of this reform is to eliminate the legal requirement in the Electricity Act and its regulations to recover the fixed cost of generating electricity from the consumer's energy consumption. Fixed costs should be recovered based on the consumer's share of the fixed cost of generation which is more appropriately determined based on the consumer's peak power demand. That change will make surplus emission-free electricity cheaper than fossil fuels on an incremental kilowatt-hour (kWh) consumption basis.

OSPE has prepared this report to demonstrate to government policy makers, regulators and the public that more innovative approaches to retail price plan design can substantially reduce consumers' total energy bills and greenhouse (GHG) emissions, without imposing additional costs on the electricity system.

Context:

Ontario's electricity system has been transformed into a low emission system. All low emission electricity systems are capable of producing significant amounts of emission-free electricity that is surplus to domestic electricity needs. Ontario currently exports most of that surplus to other Canadian provinces and the United States at low wholesale market energy prices and curtails (discards) the amounts it cannot export.

Unfortunately, Ontario consumers cannot get access to that low-cost surplus electricity because Ontario's retail price plans are not designed to make surplus electricity available at its low wholesale market energy price. Ontario consumers should be able to purchase this surplus electricity at the same wholesale market energy price as utilities of other jurisdictions.

OSPE published an earlier report on energy policy titled ***"Ontario's Energy Dilemma: Reducing Emissions at an Affordable Cost"*** which was released in March 2016.[1] That report recommended that retail electricity prices should be reformed so that fossil fuels could be displaced by surplus emission-free electricity. The Ontario Energy Board (OEB) in early 2018 approved several new Time-Of-Use (TOU) price plan pilots for residential

[1] Ontario Society of Professional Engineers, *Ontario's Energy Dilemma: Reducing Emissions at an Affordable Cost* (Toronto: Ontario Society of Professional Engineers, 2018), accessed June 2, 2018. https://www.ospe.on.ca/public/documents/advocacy/2016-ontario-energy-dilemma.pdf

consumers to evaluate their effectiveness in improving electricity system operation, lowering consumers' energy bills and giving consumers more choice on how to pay for their electricity. Those TOU-style price plan pilots still have energy rates that are too high to allow consumers to economically displace their fossil fuels with surplus electricity.

Recommendations:

This report recommends that:

1. The Ministry of Energy, Northern Development and Mines should revise current legislation and regulations which prevent consumers from purchasing surplus emission-free electricity at its wholesale market energy price.

2. The Ministry of Energy, Northern Development and Mines, in collaboration with the Ontario Energy Board (OEB) and Local Distribution Companies (LDC), should deploy "smart" retail price plans on a voluntary basis that will allow Ontario consumers to purchase surplus emission-free electrical energy at its low wholesale market energy price.

This report presents three smart price plans for consideration by the Ontario government, OEB and LDCs. These smart price plans will reduce consumers' total energy costs and GHG emissions in the heating & transportation sectors.

The historical amounts of the total surplus and curtailed amounts of emission-free electricity in Ontario are summarized below in Table 1.

Table 1
Amount of Surplus Emission-Free Electricity in Ontario

Year	Curtailed Amounts TWh	Number of Homes Equivalent for Curtailed Amounts	Total Surplus TWh	Number of Homes Equivalent for Total Surplus
2014	3.6	380,000	10.0	1,040,000
2015	4.8	500,000	13.3	1,390,000
2016	7.6	840,000	15.9	1,770,000
2017	10.2	1,130,000	23.9	2,660,000

Making the surplus quantities above available to Ontario consumers at the wholesale market energy price would effectively lower the average cost of energy to consumers. However, to do so, Ontario's retail electricity rates must be redesigned to create what OSPE calls "smart" price plans.

OSPE recommends that these smart price plans be made **voluntary**. The smart price plans can capture a portion of the surplus emission-free electricity with relatively simple and low-cost heaters, switches and timers. A consumer with a fully automatic energy management system can capture a larger portion of the surplus electricity and enjoy larger energy savings albeit at an additional upfront cost for the additional control equipment.

This report analyzed several cost reduction strategies for comparison purposes among the various price plans designed for residential consumers. The analysis considered the OEB's standard Time-Of-Use (TOU) price plan, the OEB's recently approved TOU-style price plan pilots and OSPE's three proposed smart price plans. In OSPE's view, the three smart price plans are more effective at lowering consumers' annual energy bills. They can also accommodate the different metering and communication equipment capabilities of the LDCs and the different level of consumer familiarity with electricity billing parameters.

Table 2 below summarizes OSPE's estimate of the annual total energy bill savings that a typical residential consumer can expect using the OSPE Energy Plus Peak Demand Smart Price Plan with a fully automatic energy management system. These different scenarios take into consideration the current federal carbon tax and its proposed increases throughout the years[2].

Table 2
Annual Net Energy Cost Savings by Residential Fossil Fuel Consumers
(Without Creating a Higher Peak Power Demand)

	Fossil Fuel Displaced	Nat. Gas Consumer Savings $/yr	Propane Consumer Savings $/yr	Fuel Oil Consumer Savings $/yr
\$0 /tonne CO_2 Price	36%	\$64	\$395	\$721
\$20 /tonne CO_2 Price	36%	\$86	\$423	\$754
\$50 /tonne CO_2 Price	36%	\$118	\$461	\$803

OSPE estimates there will be sufficient surplus emission-free electricity in the long term (after the nuclear reactor refurbishment program is finished) to displace 36% of the fossil fuel used by 1.3 million homes. The fossil displacement only reaches 36% for each home because three conditions have to occur simultaneously in each hour:

(1) there is a need for heat;
(2) there is surplus electricity available; and
(3) there is power capacity available between the home's normal hourly electricity consumption and the home's monthly average peak power demand.

The 1.3 million represents the number of homes that can be supplied using 70% of the annual average amount of surplus emission-free electricity at the 36% fossil fuel displacement rate for each home.

Table 3 below summarizes OSPE's estimate of the greenhouse gas (GHG) emission reductions that are achievable if all the surplus emission-free electricity was used in Ontario to displace natural gas for water and space heating. Other applications such as propane and fuel oil displacement, electric car charging and industrial hydrogen production will result in larger emission reductions per unit of electricity.

[2] The Government of Canada's carbon pricing plan comes into effect in April 2019. This carbon tax is \$20 per tonne of CO_2 emissions for 2019 and will increase at a rate of \$10 per tonne per year until 2022, when the price will reach \$50 per tonne.

Table 3
Potential GHG Emission Reductions from Natural Gas Displacement
By Surplus Emission-Free Electricity

	Surplus Emission-Free Electricity Available TWh	Reduction if Natural Gas is Displaced tonnes CO_2
2020-2035 Annual Average	9.8	2,100,000
2020-2035 Total	157.0	33,400,000

OSPE's proposed rate reform will make surplus emission-free electricity affordable for fossil fuel displacement. The consumer who subscribes to the new smart price plan will have a slightly higher electricity bill but will have a much lower fossil fuel bill. Fossil fuels are imported to Ontario so the economic impact of fossil fuel displacement on the local Ontario economy will be positive. The environmental benefits are obtained at no cost to the electricity system.

As Ontario increases the emission-free generation capacity of the electricity system to supply a growing population, the surpluses will increase. The annual energy savings from fossil fuel displacement and the associated emission reductions will also be larger if smart price plans are deployed to allow consumers to take advantage of those surpluses.

Making use of surplus electricity for fossil fuel displacement is an effective way to offset annual increases in electricity bills with lower fossil fuel bills. Addressing consumers' total energy needs creates opportunities for cost and emission reductions through more effective integration of Ontario's electrical and fossil-fueled energy systems.

Ontario energy policy makers and regulators need to engage closely with engineers and other experts who design and operate our energy systems. Energy systems are among the most technically complex systems in society. A deeper understanding of the fundamental drivers of higher energy costs and emissions is essential in order to find affordable permanent solutions to reduce emissions across the entire economy. Knowing how to leverage Ontario's low emission electricity system with its high fixed costs and low variable costs is key to achieving low emissions at an affordable cost. Ontario's professional engineers look forward to working with the government to achieve its economic and environmental goals.

The report body contains a number of other conclusions and recommendations. Readers who are interested can find additional analysis detail and discussions in seven appendices.

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1. Background

The Ontario Society of Professional Engineers (OSPE) advocates for energy policy that will ensure a safe, reliable, sustainable and affordable energy supply to industry and residents. OSPE does this on behalf of its members who work in the energy sector and those who work in companies that are impacted by energy supply and prices.

Energy systems are among the largest and most technically complex systems in society. OSPE believes effective public policy dealing with energy and environmental matters must incorporate fundamental engineering and economic principles that govern energy production, distribution and consumption. OSPE attempts to make those facts known to energy policy decision makers, regulators and the public to ensure Ontario residents continue to enjoy a high standard of living with good jobs and a healthy environment.

Ontario's electricity system has recently been transformed to a very low emission system. Approximately 95% of Ontario's electricity is now emission-free. Ontario achieved this very low emission rate by:

- eliminating coal generation,
- increasing dependable hydroelectric and nuclear generating capacity to supply most of the base-load (steady round-the-clock) demand,
- adding dependable natural gas generating capacity for the additional peak-load demand during the daytime and to back up all other generating facilities.
- adding wind and solar generating capacity to further reduce emissions by displacing natural gas generation.

The very low emission rate is good for the environment and the better air quality provides health benefits and savings to the public health care system. Unfortunately, despite good intentions, the supply mix that policy makers chose to achieve a very low emission electricity system did not appropriately address three technical problems:

- Wind generation frequently competes with nuclear and hydroelectric generation at night to meet the base-load demand. Wind generation also frequently competes with solar generation during the day to meet consumers' additional peak-load demand. As a result, significant amounts of hydroelectric, nuclear, wind and solar generated electricity are now surplus to the consumer's electrical needs. Grid scale electrical storage to absorb those temporary surpluses is prohibitively expensive. Under the confines of our present retail electricity rate structure, the surplus must be exported at low wholesale market energy prices or curtailed (discarded/wasted). This low value surplus emission-free electricity could be used for fossil fuel displacement if the rate structure is redesigned.

- All emission-free generation has high fixed costs (both upfront and ongoing operating and maintenance costs) that must be paid by Ontario consumers in their retail rates even when surplus electricity is exported at low prices or curtailed. Consequently, surplus emission-free electricity contributes to higher electricity rates for consumers.

- Greenhouse gas (GHG) emissions are not reduced in Ontario when surplus electricity is exported or curtailed.

Ontario's current retail electricity price plans charge consumers too much for energy consumption during off-peak periods and too little for the use of the fixed electricity system capacity[3]. Ontario's current retail price plans have made surplus emission-free electricity too expensive to use to displace fossil fuels. As a result, Ontario consumers continue to pay for fossil fuels for their hot water, space heating and steam requirements while surplus emission-free electricity is exported at low prices or curtailed. Effectively, Ontario consumers are:

- needlessly spending money on imported fossil fuels; and
- are wasting money on the fixed costs for surplus electricity; and
- are contributing to higher than necessary GHG emissions.

This report proposes that Ontario reform its retail electricity rates so that the rates for energy consumption and the rates for peak power demand (use of installed capacity) both reflect the underlying costs. If this is done, Ontario consumers could purchase surplus emission-free electricity at close to its marginal cost of production and delivery. Consumers would then be able to economically displace fossil fuels for their thermal energy needs without reducing overall electricity system revenues.

The electricity price reforms for residential consumers that are necessary are described in this report. OSPE has not undertaken detailed analysis for non-residential consumer groups but conceptually the same principles would apply to those consumers as well.

For readers who are interested in additional details, much of the detailed supporting data, analysis and description of the wholesale markets & retail

[3] The fixed costs in the electricity system are associated with the installed capacity of the system which is needed to supply the consumer's peak power demand in watts. Energy is the amount of power multiplied by the period of time that power is flowing. Energy costs are primarily associated with fuel costs. A low emission electricity system has low fuel costs and high fixed costs. Therefore, Ontario's low emission electricity system should have low energy rates to pay for the fuel and high peak power demand rates to pay for the fixed costs. Ontario retail rates are structured in the reverse manner with high energy rates and low fixed rates.

electricity price plans are provided in seven appendices. The seven appendices are:

- Appendix A - Ontario's Wholesale Electricity Market and Retail Electricity Price Plans
- Appendix B - Ontario's OEB Approved Price Plan Pilots
- Appendix C - OSPE's Modified Low Overnight Smart Price Plan
- Appendix D - OSPE's Energy Plus Peak Demand Smart Price Plan
- Appendix E - OSPE's Energy Only Smart Price Plan
- Appendix F - Forecast of the Surplus Amount of Emission-Free Electricity
- Appendix G - Effectiveness of Various Cost Savings Strategies

2. Ontario's Energy Systems

Electricity is the sector that most Ontarians think about when they speak of energy. But Ontario has several energy sectors[4]. They include:

- The electricity sector
- The petroleum fuels sector
- The solid fuels sector
- The natural gas sector
- The hydrogen gas sector

In 2015, approximately 85% of Ontario's total energy supply was fossil fuel based. About 15% was emission-free or carbon neutral mainly for electricity production.

Only about 19% of Ontario's total energy consumption was electricity. The remaining 81% was mainly fossil fuel based, 32% was for water heating and space heating for buildings and steam production for industry and 49% was for transportation. Fossil fuels were used to provide only about 5% of the electricity supply in 2015.

Canada will not meet its long-term carbon reduction goals unless Ontario and other provinces begin to aggressively reduce carbon emissions in the heating and transportation sectors. This report identifies an opportunity to reduce emissions in those sectors using surplus emission-free electricity without imposing additional costs on the electricity system.

Ontario's electrical energy sector currently provides electricity for devices that can only run on electricity or that run more economically or conveniently on electricity.

[4] Ontario Fuels Technical Report, September 2016, prepared by Navigant Consulting Inc. for the Ontario Ministry of Energy. Accessed November 1, 2018: https://www.ontario.ca/document/fuels-technical-report

The devices include motors, lighting, electronic equipment, air conditioning and electric cars. However, there is no technical reason why electricity should not displace fossil fuels. The reason is economic. The total cost of electricity is much higher than the total cost of fossil fuels. However, the marginal cost to produce an additional unit of emission-free electrical energy is much lower than the marginal cost of fossil fuels to produce the same unit of energy. If we use idle generating capacity to make that electricity the marginal cost is very low because the fuel cost is very low in a low emission electricity system. Surplus emission-free electricity is therefore an ideal energy source to displace fossil fuels from the heating and transportation sectors.

Ontario electricity is made from various primary energy sources including nuclear, hydro (falling water), wind, solar, natural gas and bio-mass. In order for an electricity system to supply electricity reliably, it must have the ability to supply both the peak power demand and energy consumption at all times and under adverse conditions. Power by definition is the electricity flow rate at any instant of time and is measured in watts (W) or larger multiples of 1000 such as kW, MW, GW, and TW. Energy by definition is the electricity consumed over a period of time and is measured in watt-hours (Wh) or larger multiples of 1000 such as kWh, MWh, GWh, and TWh.

Electricity systems must have sufficient dependable installed capacity to supply consumers' peak power demand at any time including a reserve margin to accommodate equipment outages and unexpected load growth. Electricity systems also typically have intertie transmission connections to adjoining electricity systems. The interties are used by power system operators to assist each other during equipment outages, to help stabilize the system frequency and to import or export electricity to take advantage of more economic surplus generation in adjoining electricity systems. Ontario has 26 interties[5] to 5 adjoining electricity systems in New York, Michigan, Quebec, Manitoba and Minnesota with an effective simultaneous transfer capability of about 4,500 MW (about 20% of the electricity system's peak power demand).

Ontario's electricity market is integrated with adjoining electricity systems. That means that Ontario consumers can access even larger amounts of surplus emission-free electricity from adjoining electricity systems if Ontario reforms its retail electricity price plans.

Low emission electricity systems create significant quantities of surplus emission-free electricity because the available energy supply does not necessarily align

[5] IESO report dated Oct 14, 2014, "Review of Ontario's Interties". Accessed October 28, 2018 at: http://www.ieso.ca/sector-participants/ieso-news/2017/05/ontario-quebec-interconnection-capability---a-technical-review

perfectly with consumers' demand for electricity. This is especially true for weather dependent sources like hydroelectric, wind and solar generation.

Figures 2-1 below shows the large surpluses of emission-free electricity capacity that was available in Ontario during the night-time hours in 2016. Figure 2-2 shows the smaller surpluses during the daytime hours in 2016.

Figure 2-1
Amount of Surplus Emission-Free Electricity Capacity Available During Night-Time Hours in Ontario in 2016

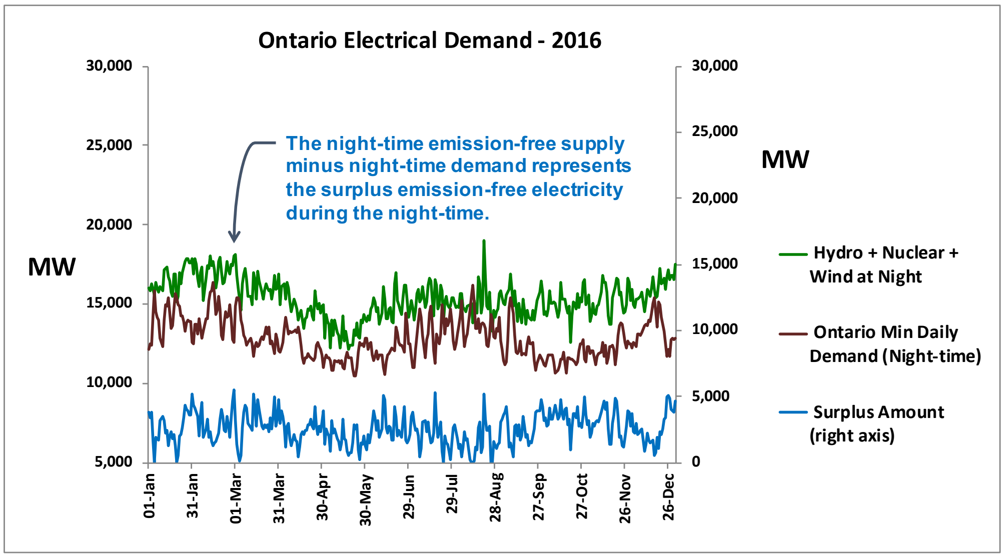
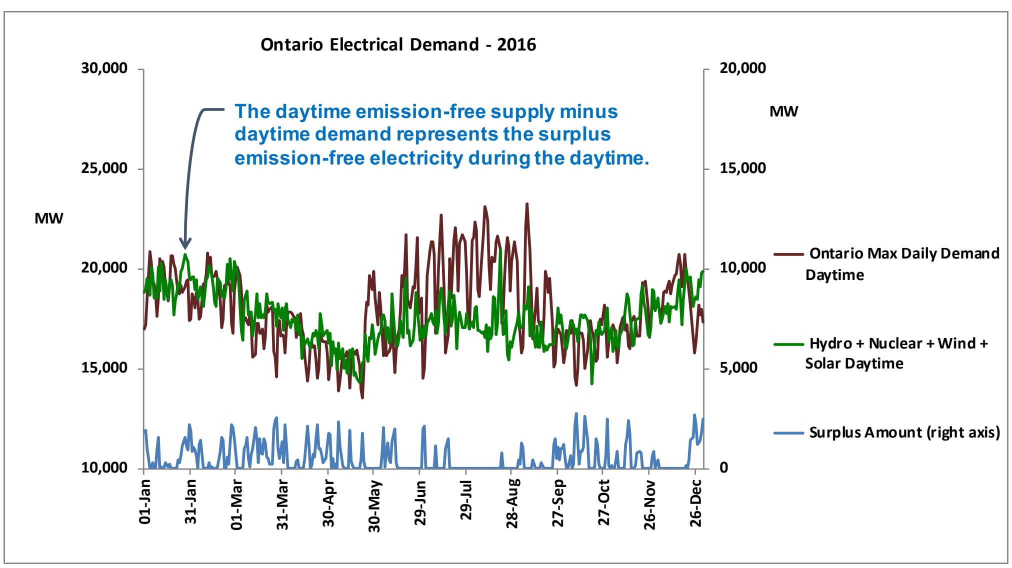


Figure 2-2
Amount of Surplus Emission-Free Electricity Available During Daytime Peak Hours in Ontario in 2016



The daytime amounts of surplus emission-free electricity are more modest. If the LDC wanted to make surplus electricity available to consumers during their on-peak dependable demand periods, the LDC would need to distinguish between surplus and dependable electricity use. Dependable electricity use during system-wide on-periods requires that the consumer pay for the required installed system capacity. However, surplus electricity use imposes no additional capacity demands on the system because the surplus can be interrupted. The consumer should not be required to pay for installed capacity use when they use surplus (interruptible) electricity. There are various ways the LDC could implement this distinction.

The total amount of surplus emission-free electricity in Ontario is becoming significant[6]. Table 2-1 below summarizes the past actual amounts of total surpluses and curtailed amounts. The difference in the two columns are the exported amounts which are larger than the curtailed amounts.

Table 2-1
Amount of Surplus Emission-Free Electricity in Ontario

Year	Curtailed Amounts TWh	Number of Homes Equivalent for Curtailed Amounts	Total Surplus TWh	Number of Homes Equivalent for Total Surplus
2014	3.6	380,000	10.0	1,040,000
2015	4.8	500,000	13.3	1,390,000
2016	7.6	840,000	15.9	1,770,000
2017	10.2	1,130,000	23.9	2,660,000

Notes for Table 6-1:
Electricity consumption per average household has dropped from 800 kWh/month in 2014 to 750 kWh/month in 2017.

Additional information on the estimated amounts of surplus emission-free electricity that will be available over the next 20 years is included in Appendix F. OSPE estimates that the total amount of surplus emission-free electricity will drop from the 23.9 TWh that was available in 2017 to about 4 TWh in 2025 during the nuclear refurbishment program. However, when the reactors return to service the long-term amount of surplus emission-free electricity is estimated to be 9.8 TWh per year. That is equivalent to the electricity consumption of over 1 million typical homes.

[6] Curtailment data accessed November 1, 2018. Data for nuclear, solar and wind was from the IESO's year-end electricity production reports at: http://www.ieso.ca/en/Corporate-IESO/Media/Year-End-Data and hydroelectric data was from OPG's annual reports at: https://www.opg.com/about/finance/pages/financial-reports.aspx

As Ontario's population and electrical demand increases in future, the electricity system will be expanded. If emission-free generation is added the amount of surplus emission-free electricity will also increase.

Energy storage systems and flexible loads can reduce or eliminate the amounts of surplus emission-free electricity either by storing the excess production or by shifting the consumer's load to a time when energy production is available. Electrical storage is currently too expensive to deploy at the large grid-scale needed for the electricity system. The exception is electric cars which have their own on-board storage. Shifting the charging time for electric cars can improve electricity system operation, reduce the installed capacity required to supply the same energy and reduce the amount of surplus electricity. Unfortunately, the amount of flexible load represented by electric cars is limited in Ontario.

Surplus emission-free electricity can displace fossil fuels for thermal energy needs like hot water, space heating and steam production without the need for a separate electrical storage system. Fossil fuels can be displaced using dual electricity-fossil fuel appliances or separate electrical appliances (eg: resistance heaters, electric water heaters, etc.). Consumers would use surplus electricity when it is available instead of fossil fuels. The fossil fuels like natural gas, propane and fuel oil would provide the heat energy dependably when the surplus electricity is not available. In this report we call this energy management approach fossil fuel displacement.

Hydrogen production using electrolyzers is a special case of fossil fuel displacement technologies. Hydrogen is currently made from natural gas and the process emits about 12 grams of carbon dioxide for each gram of hydrogen. Hydrogen can also be made from emission-free electricity. Electrolyzers use electricity to split water into hydrogen and oxygen. The clean hydrogen can be used to supply fuel cell vehicles, refineries to upgrade their petroleum fuels or can be added to the natural gas system to reduce its carbon intensity.

Electrolysis is prohibitively expensive in Ontario primarily because of the high cost of electrical energy and the additional peak power demand charges **even when that electricity is surplus and will be discarded.**

Each fossil fuel displacement technology has different capital, operating and maintenance costs. Electrolyzers are more expensive and have higher operating and maintenance costs than a baseboard heater. Consequently, to economically operate specific fossil fuel displacement technologies, a certain minimum operating load factor must be achieved to compensate the consumer for the inherent fixed costs of those technologies. Baseboard heaters with timers to control their operation are inexpensive and can operate economically at very low load factors. Electrolyzers, electrical storage and heat pumps are expensive and require higher load factors to justify their purchase.

From an energy policy perspective, we can choose to allow all technologies to compete economically for use of the surplus electricity. That decision will incentivize the development and deployment of the least expensive technologies first. Alternatively, we can favour more expensive technologies to achieve other policy goals. This report does not examine the advantages and disadvantages of various policy priorities but does identify the relative emission reduction potential of some typical fossil fuel displacement technologies that have been proposed in recent years.

Electrification of light duty vehicles has recently begun. Electric cars have been made possible by improvements in battery, electric motor and regenerative braking technologies. Reducing emissions in heavy-duty vehicles and in heating applications is more challenging and will require a different strategy because direct electrification is not yet economical.

Heavy-duty vehicles have a more severe duty cycle than cars. Current battery technologies, while improving rapidly, do not yet provide the cost/performance characteristics offered by fossil fuels. In the short term, heavy-duty vehicles will likely need to use other low emission fuels like renewable natural gas, hydrogen or synthetic liquid fuels in order to reduce their emissions.

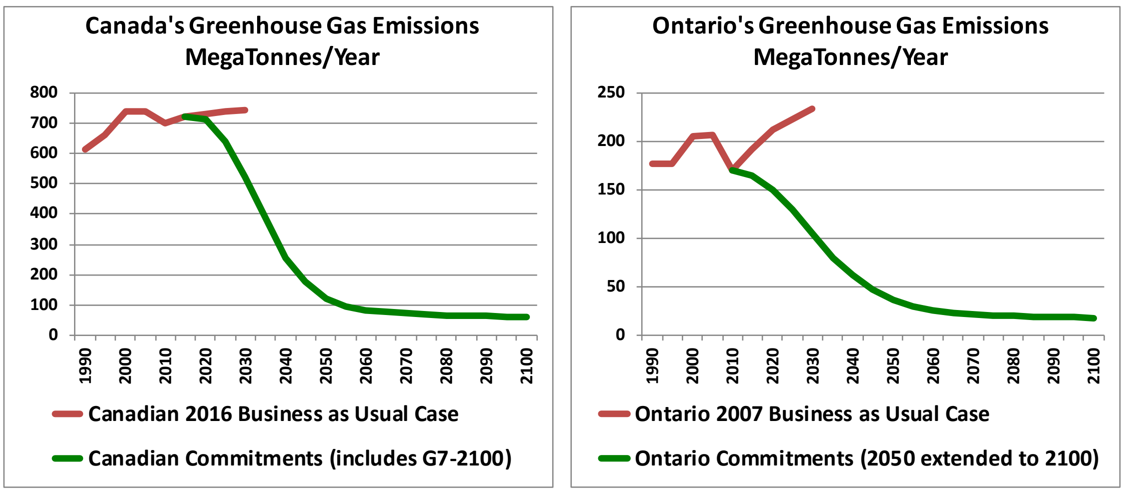
Reducing emissions in heating applications could be done economically if the marginal energy price of emission-free electricity was lower than the marginal energy price of fossil fuels at the retail level. That would allow consumers to use surplus emission-free electricity when it is available to displace some of their fossil fuel use. Fortunately, the wholesale electricity market does offer surplus emission-free electricity at a marginal price for each additional kWh of energy that is much lower than that of fossil fuels. The challenge is to adopt a retail electricity energy rate that promotes utilization of surplus emission-free electricity within Ontario.

Ontario currently exports surplus electricity at its wholesale market energy price, or discards it. That means there is no cost to the electricity system to use surplus electricity for fossil fuel displacement as long as consumers pay the wholesale market energy price (the marginal production cost) for that surplus energy.

Ontario's electricity system in 2017 produced electricity at less than 20 grams of carbon dioxide per kilowatt-hour of energy compared to about 1,000 grams of carbon dioxide per kilowatt-hour from Ontario's retired coal-fired plants. Ontario has already achieved an 80% reduction in GHG emissions in its electricity system compared to 1990 emission levels even with a larger population. This is certainly an environmental achievement worth celebrating.

Unfortunately, the efforts to reduce GHG emissions across the entire economy have not been sufficient. Despite Ontario's success in the electricity sector, Figure 2.3 below shows Canada's poor overall progress over the past 3 decades. Figure 2.3 also identifies the recent commitments Canada and Ontario have made to the international community. Canada will not meet its future commitments unless Ontario and other provinces aggressively reduce emissions in the heating and transportation sectors.

Figure 2.3 - Canada's and Ontario's GHG Emissions and Commitments[7]



Reforming our retail electricity prices is an effective way to make use of surplus emission-free electricity to displace fossil fuels and reduce envirionmental emissions. OSPE believes there is no political support for "mandatory" retail electricity price reform because mandatory reforms create both winners and losers. This happens because over the years present pricing policies have resulted in some consumers paying significantly more and some paying significantly less than the true cost of the electricity services they receive. Consumers who lose their favourable price treatment during any mandatory price reforms will likely be very vocal and put pressure on their political representatives and leaders to block those reforms.

This report therefore proposes that the new smart price plans be made "voluntary". Consumers who are prepared to purchase the required fossil fuel

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7 Government of Canada, historical and projected future GHG emissions to 2030 on a business as usual case, accessed on July 16, 2018 at: https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html and https://www.canada.ca/en/environment-climate-change/services/climate-change/publications/2016-greenhouse-gas-emissions-case.html
Government of Ontario, historical and projected future GHG emissions to 2030 on a business as usual case, accessed on March 20, 2018 at: https://www.ontario.ca/page/ontarios-climate-change-update-2014

displacement equipment and controls will subscribe to the new smart price plans. Those consumers could then take advantage of the plans to save money on their overall annual energy costs (combined electricity and fossil fuel costs). They will also reduce their environmental emissions and improve the operation of the electricity system which will benefit everyone. More details about how a smart retail electricity price plan should be designed for a very-low emission electricity system are covered later in this report.

3. Ontario's Current Electricity Retail Price Plans

The approach to electricity pricing in Ontario is based on a "user pay" model that seeks to minimize any subsidies from the taxpayer. Retail rates are established to recover the total cost of operation. The allocation of fixed and variable costs has not kept pace with the rapid transformation of Ontario's electricity system from a moderate emitting, moderate fuel cost system into a very low emitting, very low fuel cost system.

Retail price plans must recover the total costs of generation, conservation, transmission, distribution and regulatory items. However, how we recover those costs makes a great deal of difference.

Generation costs are comprised of variable costs (such as fuel costs) and fixed costs (such as financing and labour costs). The variable costs are reflected in the wholesale market energy price. The fixed costs are reflected in the global adjustment charges. The combined wholesale market energy cost and global adjustment charges are defined as "commodity" costs.

Commodity and regulatory costs are common for all LDCs. However, LDCs have different distribution costs. Transmission costs also vary by location in Ontario. The distribution and transmission costs are combined and defined as "delivery" costs.

Commodity, delivery and regulatory costs are then combined to arrive at a total retail bill before sales taxes and other rebates. Consequently, retail energy prices in Ontario vary among LDCs.

All Ontario retail consumers are assumed to require dependable (high reliability) electricity and pay the total cost for electricity when it is withdrawn from the system. However, the wholesale market offers lower reliability energy to adjoining electricity systems at the wholesale market energy price without the global adjustment charge. The lower reliability electricity is called interruptible electricity because the flow can be interrupted in order to supply dependable electricity to Ontario consumers. This lower reliability electricity, at a low energy price, is not available to retail consumers in Ontario. This report proposes to make surplus emission-free electricity available at a lower reliability level (ie: on an interruptible basis) at the wholesale market energy price just like adjoining electricity systems.

There are at least five major consumer groups that are defined by the OEB. However, to meet local requirements, the LDC can get approval from the OEB to increase the number of consumer groups. OSPE selected Milton Hydro rates to perform the analysis for this report. Milton Hydro's rates are representative of rates in most urban areas in the province. The Milton Hydro rate tables for their five major consumer groups are listed in detail in Appendix A of this report and are summarized later in this section.

LDCs that serve rural areas such as Hydro One will have retail rates that are higher than urban rates due to the lower population density and higher LDC cost to serve those rural areas. Rural residential consumers will benefit more from retail rate reform because they use higher cost propane and heating oil for their thermal energy needs.

Consumers can choose to purchase their "energy" directly from a retailer instead of the local distribution company (LDC). The global adjustment charges must still be paid to the LDC on the basis of energy consumption. LDCs do the billing for all consumers connected to the distribution system.

Ontario's Regulated Price Plans

Ontario's regulated price plans apply to two consumer groups: residential consumers and small commercial/industrial consumers under 50 kW average monthly peak power demand. Each of these groups have two price structures in their respective regulated price plan that cover the commodity costs.

The two price structures are:

- Time-Of-Use (TOU) commodity rates (included in the TOU price plan)
- Tiered commodity rates (included in the Tiered price plan)

Most residential consumers pay for their electricity based on standard province-wide Time-Of Use (TOU) commodity rates designed to be used with Ontario's smart meters. Prices per kWh vary depending on the time of day during working days. There are 3 rates defined as "on-peak", "mid-peak" and "off-peak". Holidays and weekends are treated as "off-peak" hours. These rates are then further marked up by delivery and regulatory charges.

The Tiered commodity prices are used for consumers that do not have working smart meters. The tiered price plan uses 2 different rates – a lower rate for consumption equal to or below a monthly consumption threshold value and a higher rate for consumption above the threshold value. There is a higher threshold level in the winter months to accommodate heating needs for residential consumers.

This report presents analyses for residential consumers who have working smart meters and who pay for their electricity according to the TOU price plan.

This report does not contain analysis for the small percentage of residential consumers who purchase electricity directly from retailers or who pay for their electricity according to the tiered price plan.

The residential TOU price plan includes 3 components:

- A fixed monthly charge
- An energy consumption charge (based on kWh consumed)
- A sales tax

The fixed monthly charge covers distribution costs including billing services and a small portion of the fixed regulatory costs. For Milton Hydro residential consumers, the fixed monthly rate is $25.56 per month. For residential consumers distribution costs are more closely associated with the size of the consumer's physical connection to the distribution system. That connection does not change once it is installed. Ontario's residential distribution costs are being transformed into a fixed monthly charge on consumers' bills. Most LDCs are almost finished that transition to a fixed monthly charge for distribution costs. OSPE agrees that is the correct approach for distribution costs. Distribution costs should be recovered as a fixed monthly charge also for smart price plans.

The energy consumption charge covers commodity costs, a small portion of the delivery costs and the majority of regulatory costs. The commodity cost varies with time of use but the delivery and regulatory rates that are based on energy consumption have a constant rate for all hours. The actual retail price that consumers pay at any specific hour of the day for their energy is therefore the sum of the TOU commodity energy rates plus the delivery and regulatory energy rates. For Milton Hydro, the residential delivery and regulatory energy rate is 2.21 ¢/kWh for all hours of the day.

Small commercial/industrial consumer rates are structured in a similar way to residential consumers. The commodity and regulatory costs are identical to those for residential consumers, but the delivery cost is different for both the fixed portion and the energy-based portion. Consequently, there is a separate TOU-style retail price plan for the small commercial/industrial consumer group. The OEB is presently considering a change to the distribution charges for the small commercial/industrial consumer.[8] The discussion of those changes is outside the scope of this report. However, the OEB does have an opportunity to include a more substantial retail rate reform for this group in order to provide them with access to surplus emission-free electricity at low cost for fossil fuel displacement. OSPE encourages the OEB to do so.

For larger commercial and industrial consumers Milton Hydro has three price plans. The three plans differentiate between Class A and Class B consumers. Class A consumers were originally those with an average monthly peak demand of 5 MW or larger. More recently the government allowed industrial and commercial consumers in defined sectors with an average monthly peak demand of 0.5 MW or larger to register as Class A. Class A consumers have access to the Industrial Conservation Initiative (ICI) program. Class B consumers are defined as all other consumers (not in Class A). Class A and B consumers are further subdivided by their peak demand. These three larger commercial and industrial consumer price plans include five components:

- A fixed monthly charge
- An energy consumption charge proportional to kWh consumed
- A system capacity use charge proportional to peak kW demand
- A power factor charge
- A sales tax

The power factor charge represents the cost of additional electricity system losses incurred by the electricity system outside the consumer's facility in order to supply inductive loads (eg: induction motors) and capacitive loads inside the consumer's facility. Those energy losses are not captured by the consumer's electricity meter.

Additional information on the wholesale market, retail price plans and rate tables showing the five Milton Hydro retail price plans can be found in Appendix A, of this report. Table 3-1 below summarizes the key aspects of the retail price plans for all five of Milton Hydro's major consumer groups:

Note that all weekend days and 10 annual holidays are off-peak periods. The cheap electricity on the weekends is appreciated by consumers, but that policy also eliminates the financial incentive for consumers to level their load on weekend days and holidays. Also, consumers must pay for the total annual cost to operate the electricity system. Most system costs are fixed in a low emission electricity system. Therefore, the cheap weekend rates are actually made possible by higher weekday rates.

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[8] Ontario Energy Board. Staff Report to the Board. "Rate Design for Commercial and Industrial Electricity Customers" accessed February 21, 2019. https://www.oeb.ca/sites/default/files/OEB-Staff-Report-Rate-Design-20190221.pdf

Table 3-1
Summary of Ontario Retail Electricity Rates[9]
Effective May 1, 2018 (Milton Hydro rates shown)

	Class B		Class A or B		Class A	
Electricity Charges	**Resi-dential**	**< 50 kW**	**< 1,000 kW**	**< 5,000 kW**	**>= 5,000 kW**	**Billing Units**
Fixed Monthly Charge	25.56	17.74	80.17	629.19	2,511.90	$/month
Energy: TOU On-peak	0.1541	0.1669	-	-	-	$/kWh
TOU Mid-peak	0.1161	0.1289	-	-	-	$/kWh
TOU Off-peak	0.0871	0.0999	-	-	-	$/kWh
Tier 1	0.0991	0.1119	-	-	-	$/kWh
Tier 2	0.1111	0.1239	-	-	-	$/kWh
Class A	-	-	0.0705	0.0705	0.0705	$/kWh
Class B	-	-	0.1194	0.1194	-	$/kWh
Peak Demand	-	-	9.0581	8.0355	7.9606	$/kW/mon
Sales Tax Rate	5	5	13	13	13	%

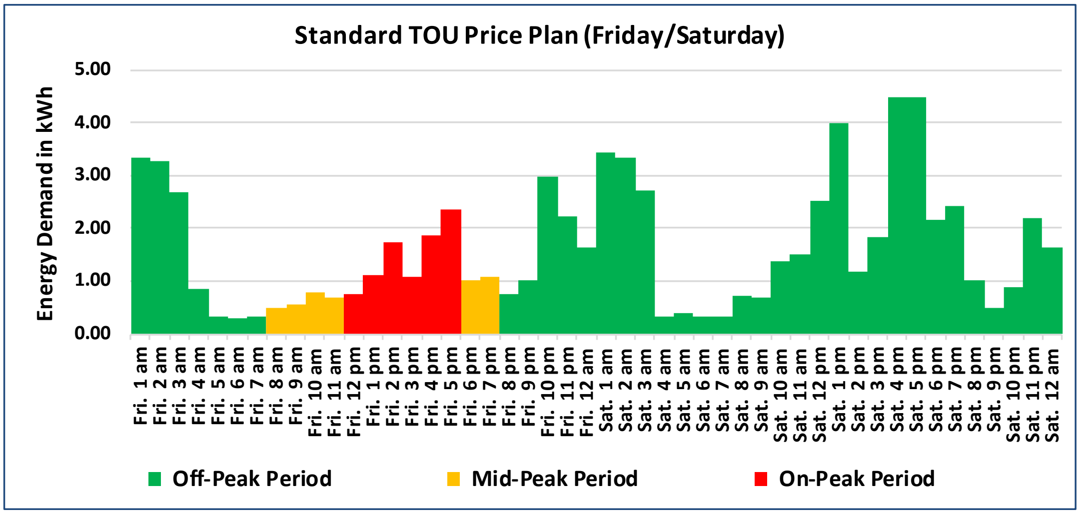
Notes for Table 3-1:

- Residential and < 50kW consumers pay either TOU or Tier consumption rates but not both. Consumers >= 50 kW pay either Class A or Class B consumption rates not both. Some Class B consumers >500 kW are permitted to subscribe to Class A rates under the Industrial Conservation Initiative (ICI) program.
- Rates above include all generation, transmission, distribution & regulatory charges.
- The Industrial Conservation Initiative (ICI) program can help lower Class A energy consumption charges theoretically down to 0.0197 $/kWh but in practice the average rate is 0.0705 $/kWh.
- The wholesale market energy price and global adjustment charge are included in the energy consumption rates ($/kWh) for all consumer groups.
- The consumer's total monthly bill is comprised of the sum of the fixed monthly charge, energy consumption charges, peak demand charge and sales tax charge.

The residential TOU price plan is presented graphically in Figure 3.1 below to help the reader visualize how the price plan works. The Friday has all three price periods. Saturday only has the off-peak price period. A Friday and Saturday in July are illustrated so only the summer TOU schedule is visible.

[9] The rates used in this report are for Milton Ontario. Milton Hydro rates are typical of the rates paid by urban homes in Ontario. The Milton Hydro 2018 rate schedule was downloaded Aug 28, 2018 at: https://www.miltonhydro.com/MiltonHydro/media/Milton-Hydro-Documents/Rate_Schedule_for_2018__Rate_Flyer_20180501_for_Website_2.pdf

Figure 3.1
Standard TOU Price Plan for Residential Service
Milton Hydro – effective May 1, 2018
Typical Residential Demand in July (with Summer A/C Loads)



Ontario's OEB Approved Price Plan Pilots

From 2015 to January 2018 the Ontario Energy Board (OEB) approved 13 pilots from several LDCs. The OEB encouraged the province's LDCs to test other designs of price plans with a limited number of consumers to improve conservation and load leveling performance and give consumers more choice in how to pay for their electricity. Twelve of the plans were TOU-style plans. One was a fixed price plan. Appendix B of this report provides the detailed rate tables for each of the 13 pilot plans. Those tables show both the commodity rates and the additional Milton Hydro delivery and regulatory charges that are energy (kWh) based assuming that the plans had been deployed in Milton Hydro's territory. Hydro One withdrew its 5 pilot plans (4 TOU-style and 1 fixed rate) from the pilot program in June 2018. Table 3-2 below summarizes the key data in Appendix B for the 8 pilots that remain. The "Additional Delivery Rate" in the right most column represents the energy consumption-based delivery and regulatory charges that would be added to all the TOU commodity rates to arrive at the total energy rate for each additional kWh of electricity for a Milton Hydro residential consumer.

Table 3-2
Summary of Marginal Energy Rates for Ontario Rate Pilots[10]
Effective May 1, 2018 (Residential – Milton Hydro)

Name of Pilot	Highest Commodity Rate $/kWh	Lowest Commodity Rate $/kWh	Additional Delivery Rate $/kWh
Enhanced Time-of-Use	0.1750	0.0440	0.0221
Low Overnight	0.1830	0.0200	0.0221
Variable Peak Pricing with CPP	0.4960	0.0490	0.0221
Quick-Ramping CPP	0.4990	0.0550	0.0221
Seasonal Time-of-Use with CPP	0.2630	0.0530	0.0221
Seasonal Time-of-Use	0.1350	0.0540	0.0221
Super-Peak Time-of-Use	0.2520	0.0630	0.0221
Alternative Quick-Ramping CPP	0.5950	0.0600	0.0221

Notes for Table 3-2:

- Fix monthly charges and sales taxes are not shown in the table above. The residential consumer's monthly bill is comprised of the sum of the fixed monthly, energy consumption and sales tax charges.
- "Additional Delivery Rate" includes transmission, regulatory charges and a small portion of distribution costs. Most distribution costs are in the fixed monthly charge that is not shown above. "Additional Delivery Rate" must be added to the prevailing commodity rate for each pilot to arrive at the total retail energy rate used by the LDC for billing purposes.

4. Smart Retail Electricity Price Plans

OSPE's Smart Price Plans described in this report have been specifically designed to allow consumers to use surplus emission-free electricity when it is available to displace their fossil fuels. This report presents analysis of three smart price plans that OSPE has designed. The smart price plans lower consumers' annual total energy bills (electricity plus fossil fuels) and reduce GHG emissions.

OSPE considers retail price plans "smart" if they include most of the following features:

1) rates align closely with the actual electricity system costs to provide each of the electrical services consumers use.
2) rates encourage peak power demand reduction via load shifting/load levelling, conservation and energy efficiency.
3) rates encourage use of surplus emission-free electricity to displace fossil fuel use in order to lower emissions to the environment.

[10] OEB Approved Rate Plan Pilots. Accessed October 17, 2018 at: https://www.oeb.ca/sites/default/files/approved-rpp-pilot-structures-prices-20180130.pdf

4) rates encourage reduced use of electricity when the electricity system has exhausted its capacity reserves.
5) rates fairly compensate consumers who want to produce some of their own electricity without transferring their system costs to other consumers.

These features are discussed in more details below.

Aligning Retail Rates with Cost of Service

The electricity system provides consumers with both energy (kWh) and power (kW). The distribution system provides the physical connection to be able to access that energy and power. Delivery of power requires sufficient system capacity to meet each consumer's peak power demand. Price plans that differentiate among energy consumption, peak power demand and distribution system connection size will allocate costs more fairly based on the individual consumer's need for each of those three services.

Larger commercial and industrial consumers are currently billed this way, but unfortunately, their retail plans currently charge too much for energy and too little for peak power demand. Residential and small commercial/industrial consumers are billed separately for the distribution system connection size and energy consumption but not explicitly for peak power demand. Consequently, these smaller consumers are charged far too much for energy consumption in an effort to collect enough funds to also pay for the fixed cost of system capacity. As mentioned earlier in this report the OEB is currently reviewing the rate structure for the small commercial/industrial consumer group.

One of the principle reasons for the high energy rates for all consumer groups is that the global adjustment is inappropriately applied as a variable system cost based on energy consumption rather than as a fixed system cost based on peak power demand (system capacity use). The Class A large industrial consumers have access to the Industrial Conservation Initiative (ICI) program that incents them to reduce their global adjustment charge. Unfortunately, the current ICI program rules can be gamed by the consumer using behind-the-meter generation or electrical storage equipment. A Class A consumer can theoretically reduce their global adjustment payment to zero and some have done so. This allows the Class A consumer to benefit from electricity system installed capacity without paying for it. Those global adjustment costs are then unfairly transferred to Class B and other Class A consumers. The better solution is to change the legislation and regulations pertaining to the global adjustment so that the global adjustment costs are applied based on the consumer's peak power demand rather than energy consumption.

Reducing Peak Power Demand

There is very little negative environmental impact from electrical energy consumption in a low emission energy system like Ontario's. However excessive peak power demand would require more installed capacity and that imposes significant economic and environmental cost.

Consequently, low emission electricity systems should have price plans with low energy rates and high peak power demand rates to discourage wasteful use of system capacity yet still provide consumers an opportunity to benefit from low emission energy at very low prices when electricity system capacity is idle.

Displacing Fossil Fuels

As indicated earlier in this report, all very low emission electricity systems have the ability to produce low cost energy when electrical power demand is low. During low electrical load periods, consumers should be able to use surplus electrical energy to displace fossil fuels that are being used for heat, transportation and hydrogen production. However, the marginal energy price of that electricity energy has to be lower than the marginal energy price of the displaced fossil fuels.

The wholesale energy market sets prices based on the actual marginal cost of the next MWh of energy production. When emission-free generation is sufficient to meet power demands, the wholesale market energy price in Ontario falls below $14.4/MWh (1.44 ¢/kWh). Ontario's average volume weighted, wholesale market energy price for surplus emission-free energy during 2018 was 0.62 ¢/kWh. This price is about 1/3 the price of natural gas for residential consumers and is an even smaller fraction of the price of propane and heating oil.

Consumers could enjoy significant savings on their total annual energy bills if they could purchase surplus emission-free electricity at its hourly wholesale market energy price to displace their fossil fuel use. Also, those consumers would simultaneously reduce their emissions to the environment.

The larger commercial and industrial consumers above 50 kW average peak power demand have retail price plans that are based on the hourly wholesale market energy price, but unfortunately, that energy price is elevated unnecessarily by other charges that are applied through energy rates rather than through peak power demand rates.

Price plans for residential and small commercial/industrial consumers are not based on the hourly wholesale market energy price due to concerns about billing complexity for small accounts. These consumers could however be given access to a proxy like the volume weighted average market energy price over a fixed period of time. Differences with actual wholesale market prices can be reconciled at the next rate adjustment like the OEB currently does for TOU and Tiered price plans every 6 months.

Discouraging Electricity Use When Capacity Reserves are Exhausted

When the electricity system has exhausted its capacity reserves, the wholesale market energy price rises dramatically and can reach its high limit of $2,000/MWh or 200¢/kWh. Price plans that are based on the hourly wholesale market energy price will reflect those high prices when system capacity reserves are exhausted. Those very high rates should encourage consumers who can do so to reduce their electricity consumption during periods of system stress and help to avoid voltage reductions and rotating blackouts.

Class A large industrial consumers can buy energy or offer to reduce demand in the real time wholesale market auction every 5-minutes. Moderately sized commercial and industrial consumers can participate in demand reductions through aggregators. Residential and small commercial/industrial consumers are too small to participate in the real time wholesale market. As communication devices become cheaper and better internet capabilities are deployed, there may come a time in the future when residential consumers can choose to participate in the real time wholesale market either through aggregators or directly.

Consumer Self-Generation

Consumers are increasingly choosing to install their own generation on their premises. To accommodate these so-called prosumers (producers and consumers), Ontario has moved away from the earlier micro-FIT program and has adopted net metering policies. The micro-FIT program was unfairly transferring electricity system costs from prosumers to other consumers who did not generate their own electricity.

Net metering regulations require the residential prosumer to produce power primarily for themselves. Billing is on a net energy flow basis using a single meter. Credits for excess production periods, where energy is sent to the electricity system, are accumulated only for 12 months. These rules help to minimize system cost transfers that would be unfair to other consumers.

Net metering regulations do allow the LDC to charge their fixed monthly charge even in months when the prosumer exports energy into the electricity system. Unfortunately, the current residential TOU price plans do not differentiate between energy consumption and system capacity use by the prosumer. Consequently, the restriction on zero net energy flow over 12 months was included in the net-metering rules.

Price plans for prosumers should separately account for:

- distribution fixed costs,
- energy transfers into and out of the home at its wholesale market energy price, and
- system capacity use based on the monthly average peak power drawn from the electricity system by the prosumer.

The wholesale market energy price should be used to pay for energy delivered into the electricity system by prosumers. This ensures the prosumer gets a market price for all energy they contribute to the electricity system. This energy pricing approach will discourage deployment of behind-the-meter natural gas-fired generation that competes with Ontario's current generation supply mix which is 20 times lower emitting. Behind-the-meter fossil-fueled generation used only for emergency backup should not be discouraged because it provides power system resiliency. Behind-the-meter natural gas fired generation emissions are currently not tracked in the electricity system emission data. They are tracked in the overall use of natural gas by prosumers for their building requirements. This distorts Ontario's sector-by-sector emission data.

Charging the prosumer for system capacity use based on their monthly average peak power drawn from the electricity system rewards prosumers for their generation capacity when it is used to reduce the prosumer's contribution electricity system peak load. It does not reward the prosumer for generation capacity when the prosumer over-generates. The OEB may wish to evaluate whether some capacity value compensation for over-generation should be paid for zero-emission electricity.

Price plans that separate the three cost factors above are more likely to fairly compensate a prosumer for the energy they deliver to the electricity system without the need to limit the net energy production to zero over 12 months. There are economic and environmental advantages if we allow a prosumer to supply more emission-free energy for the benefit of neighbours who do not self-generate. The OSPE Energy Plus Peak Demand Smart Price Plan has been designed to differentiate among those three cost factors. The plan will be described in more detail later in this report.

Practical Considerations

When we develop smart price plans there are practical considerations for both the consumer and LDC. The closer the plan reflects the true costs of providing various electrical services, the more expensive the implementation will cost for the consumer's metering, communication and energy management equipment. Similarly, changes to the LDC billing and communication system will depend on the design of the price plans. Ultimately any extra LDC costs will be paid for by the consumer. The potential annual energy savings for the consumer from new smart price plans must be balanced against the implementation costs to make those savings available.

OSPE believes the economic and environmental benefits will justify deploying smart price plans **at least at a basic level**. The more complex implementations will require additional communication and control capabilities that will cost more initially but will achieve greater annual savings.

Technology continues to improve in cost and functionality thus making feasible tomorrow what is impractical today. As improved internet-based technologies become more functional and increasingly deployed, more opportunities for the consumer to save money and the power system to improve its economic and environmental performance will become available. Yet in order for these technologies to be commercialized, the retail price plans must be in place first. Consequently, making smart price plans available on a voluntary basis provides a mechanism to accelerate development and deployment without committing society to a specific early stage technology solution.

Surplus emission-free electricity is a byproduct of a low emission electricity system. There will be significant amounts of surplus electricity available for the foreseeable future if electricity system emissions are kept low. Consequently, it is worth the time and effort to reform our retail electricity price plans to allow consumers to take advantage of emission-free electricity surpluses.

Having the smart price plans available on a "**voluntary"** basis is important in the early stages of deployment when the equipment choices are limited and the price of that equipment is higher. Consumers who are environmentally conscious and can afford to purchase the fossil fuel displacement equipment and controls will do so first and establish a market for the devices.

This report presents analysis of three smart price plans that OSPE has designed to lower consumers' annual total energy bills (electricity plus fossil fuels) and reduce environmental emissions. These three plans are not the only way to design smart price plans. OSPE encourages the various industry stakeholders to step up and offer more innovative designs with lower implementation cost as new technology becomes available.

The three OSPE smart price plans presented in this report are:

- OSPE Modified Low Overnight Smart Price Plan
- OSPE Energy Plus Peak Demand Smart Price Plan
- OSPE Energy Only Smart Price Plan

OSPE Modified Low Overnight Smart Price Plan

The OSPE Modified Low Overnight Smart Price Plan was inspired by the Low Overnight Price Plan that Alectra Utilities included as one of their price plan pilots. This Alectra Utilities pilot enables consumers to purchase surplus electricity at night at a low price. OSPE is impressed with Alectra Utilities innovative approach to electricity pricing. Alectra Utilities is also piloting a number of new technologies and other price plans for its customers. OSPE encourages all LDCs to work with private sector energy technology companies to develop new innovative technology and associated retail price plans. The IESO's plans to make anonymized smart meter data publicly available is a welcome development that should help spur private companies to develop new technologies provided the OEB and LDC's are willing to deploy smart price plans.

The rate table for the OSPE Modified Low Overnight Smart Price Plan is summarized in Table 4-1 below.

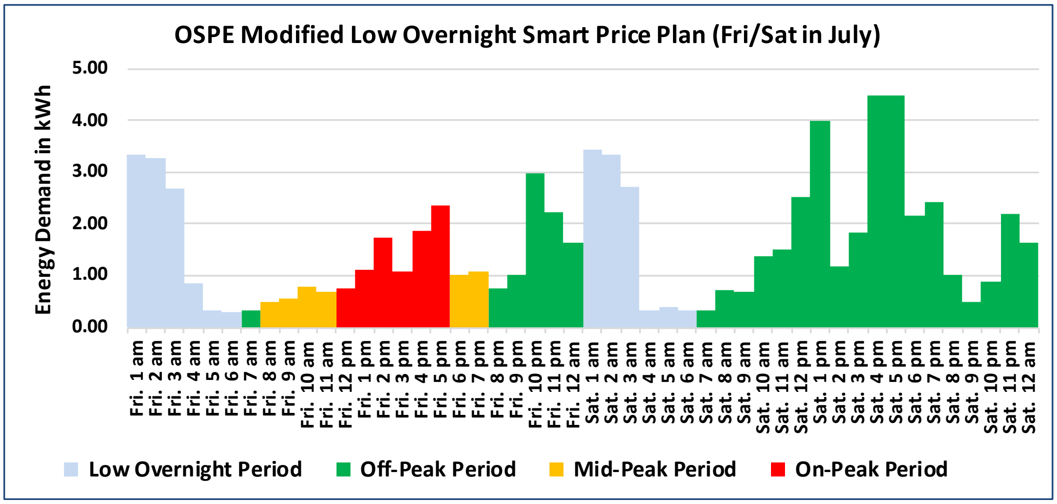
Table 4-1
Comparison of Standard TOU Price Plan with the OSPE Modified Low Overnight Smart Price Plan (Milton Hydro) May 1, 2018 Rates (All Components Included – Typical Home)

Electricity Charges	Standard TOU Price Plan	Modified Low Overnight Smart Price Plan	Billing Units
Fixed Monthly Charge	25.56	28.34	$/month
Energy: TOU On-peak Rate	0.1541	0.2064	$/kWh
TOU Mid-peak Rate	0.1161	0.1141	$/kWh
TOU Off-peak Rate	0.0871	0.0871	$/kWh
TOU Overnight Rate	-	0.0122	$/kWh
Surplus Energy Rate	-	0.0062	$/kWh
Sales Tax Rate	5	5	%
Total Bill (before taxes, load leveling and fossil fuel displacement)	**1,247**	**1,247**	**$/yr**

Note: Taxes, load shifts and electricity used for fossil fuel displacement are not included above.

The rate table for the OSPE Modified Low Overnight Smart Price Plan is diagrammatically represented in Figure 4.1 below. More details and discussion about the plan are available in Appendix C of this report.

Figure 4-1
OSPE Modified Low Overnight Smart Price Plan (Residential)



Note: Load shifts and electricity used for fossil fuel displacement are not shown above.

OSPE Energy Plus Peak Demand Smart Price Plan

The OSPE Energy Plus Peak Demand Smart Price Plan was inspired by an OSPE member, Dr. Charles Rhodes, Chief Engineer, Xylene Power Ltd. Dr. Rhodes suggested consumers could easily displace more expensive fossil fuels such as propane and fuel oil if Ontario had separate rates for energy consumption and peak power demand and if those energy rates were aligned with the wholesale market energy price. Electrical energy was available in 2018 in the wholesale market at an average volume weighted price of 2.43 ¢/kWh. That energy price is sufficiently low to displace propane and fuel oil during hours when the consumer's power demand is below the consumer's monthly average peak power demand. The fossil fuel displacement equipment required would be relatively simple – a load controller and electrical heaters that would operate preferentially before the normal fossil fueled heating devices (eg: furnace and water heater).

The rate table for the OSPE Energy Plus Peak Demand Smart Price Plan is summarized in Table 4-2 below. More details and discussion are available in Appendix D of this report.

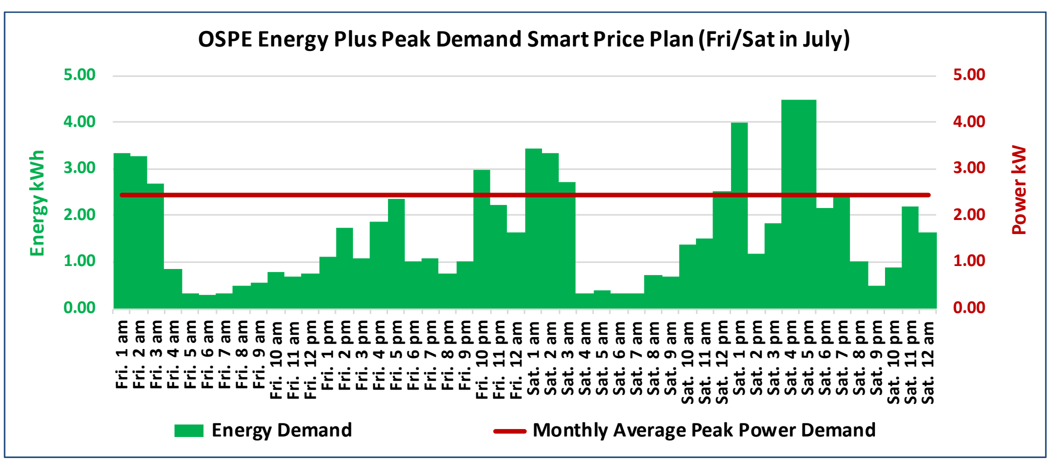
Table 4-2
Comparison of Standard TOU Price Plan with the OSPE Energy Plus Peak Demand Smart Price Plan (Milton Hydro) May 1, 2018 Rates (All Components Included – Typical Home)

Electricity Charges	Standard TOU Price Plan	Energy Plus Peak Demand Smart Price Plan	Billing Units
Fixed Monthly Charge	25.56	28.34	$/month
Energy: TOU On-peak Rate	0.1541	-	$/kWh
TOU Mid-peak Rate	0.1161	-	$/kWh
TOU Off-peak Rate	0.0871	-	$/kWh
Monthly Peak Demand Rate	-	22.78	$/kW/month
Energy Rate (all except surplus)	-	0.0243	$/kWh
Surplus Energy Rate	-	0.0062	$/kWh
Sales Tax Rate	5	5	%
Total Bill (before taxes, before load leveling and fossil fuel displacement)	**1,247**	**1,247**	**$/yr**

Note: Taxes, load shifts and electricity used for fossil fuel displacement are not included above.

The OSPE Energy Plus Peak Demand Smart Price Plan is diagrammatically represented in Figure 4.2 below. Figure 4-2 below shows the monthly average peak power demand (red line). Energy consumption in kWh per hour above that red line should be avoided in order to avoid additional peak power demand charges. The peak power demand charge is a significant portion of the total monthly bill in this plan. Lowering the monthly average peak power demand will significantly lower the monthly bill even if more energy is used that month during the low demand periods.

Figure 4-2
OSPE Energy Plus Peak Demand Smart Price Plan (Residential)



Note: Load shifts and electricity used for fossil fuel displacement are not shown above.

To access surplus emission-free electricity at its lower price at any time of day, a communication capability between the LDC and consumer's load controller would be required. The consumer's load controller would use the surplus emission-free electricity only when it was available. The LDC would assign the lower price of 0.62 ¢/kWh to that additional surplus emission-free electricity consumption when the monthly bill is prepared.

OSPE Energy Only Smart Price Plan

The OSPE Energy Only Smart Price Plan was inspired by Ontario's 2010 Long Term Energy Plan (LTEP). The Ontario government at the time planned to purchase about 10,000 MW of renewable energy projects. OSPE's analysis in 2011 showed that if the government proceeded with those contracts a significant amount of the new emission-free electricity would have to be curtailed (discarded) to maintain electricity system reliability. OSPE's analysis was published in March 2012.[11]

The OSPE Energy Only Smart Price Plan is based on energy (kWh) consumption billing because that is what residential consumers are familiar with. The rate table for the OSPE Energy Only Smart Price Plan is summarized in Table 4-3 below.

Table 4-3
Standard TOU Price Plan versus
OSPE Energy Only Smart Price Plan (Milton Hydro)
May 1, 2018 Rates (All Components Included – Typical Home)

Summary	Standard TOU Price Plan	Energy Only Smart Price Plan	Billing Units
Fixed Monthly Charge	25.56	28.34	$/month
Energy: TOU On-peak Rate	0.1541	-	$/kWh
TOU Mid-peak Rate	0.1161	-	$/kWh
TOU Off-peak Rate	0.0871	-	$/kWh
Energy: Peak-load Rate	-	0.2120	$/kWh
Intermediate Load Rate	-	0.1422	$/kWh
Base-load Rate		0.0724	$/kWh
Surplus Energy Rate		0.0062	$/kWh
Sales Tax Rate	5	5	%
Total Bill (before taxes, before load leveling and fossil fuel displacement)	**1,247**	**1,247**	**$/yr**

Note: Taxes, load shifts, and electricity used for fossil fuel displacement are not included above.

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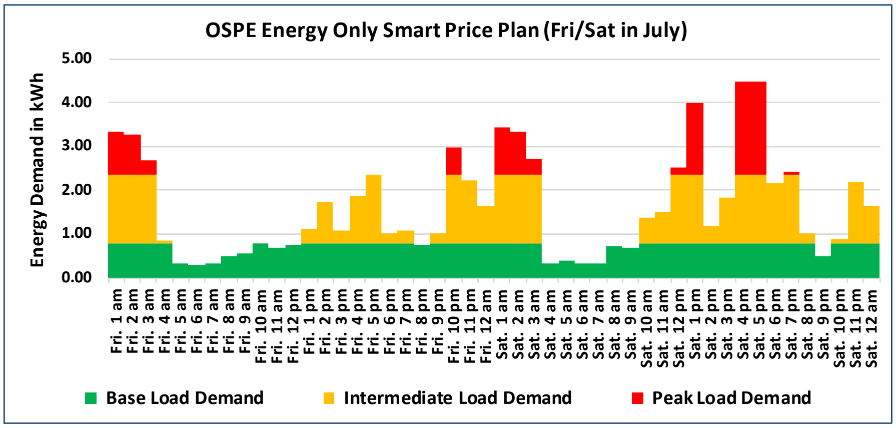
[11] Ontario Society of Professional Engineers, *Wind and the Electrical Grid – Mitigating the Rise in Electricity Rates and Greenhouse Gas Emissions*, (March, 2012). Accessed Jan. 29, 2019. https://www.ospe.on.ca/public/documents/advocacy/2012-wind-electrical-grid.pdf

The OSPE Energy Only Smart Price Plan is diagrammatically represented in Figure 4-3 below. More details and discussion are available in Appendix E of this report.

Figure 4-3 -OSPE Energy Only Price Plan (Residential)



Note: Load shifts and electricity used for fossil fuel displacement are not shown above.

In order to access surplus emission-free electricity at lower cost this plan will require a communication capability between the LDC and the consumer's load controller to identify when the surplus exists. The LDC would later assign the lower price of 0.62 ¢/kWh to that additional surplus emission-free electricity consumption when the monthly bill is prepared.

The annual electricity bill amount for the standard TOU price plan and each of the three smart plans in Table 4-1, 4-2 and 4-3 are the same. The tables demonstrate that the three OSPE smart price plans are designed to be revenue neutral to the LDC if the consumer makes no changes to their energy use. Revenue neutrality is currently a requirement by the OEB for approval of any new price plans. However, once consumers begin to shift their loads and displace their fossil fuels, the smart price plans will provide significant savings in consumers' annual energy bills (electricity plus fossil fuels). The savings are summarized later in this report.

5. Using Surplus Electricity to Displace Fossil Fuels

Surplus emission-free electricity could be used by residential consumers to displace the fossil fuels they use for water and space heating at very low electricity prices. To do that consumers need either dual electricity-fossil fuel heating devices or a separate set of electrical devices and a means to switch between the two energy sources. Any electrical heating solution should be assessed beforehand and installed by qualified personnel to ensure both electrical and fire safety.

When surplus emission-free electricity is available, the residential consumer would use electricity rather than fossil fuels for the required thermal energy. The consumer uses less fossil fuel and produces less emissions for the same total thermal energy consumption. Surplus emission-free electricity is considered "interruptible" because the supply cannot be guaranteed and can be interrupted at any time. Interruptible electricity imposes no additional installed capacity demands on the overall electricity system. The fossil fuels rather than the electricity provide consumers the dependability for the thermal loads. This means the electricity can be legitimately purchased at only its marginal cost of production of the energy without any fixed capacity charges. Surplus emission-free electricity has a very low marginal price in the wholesale energy market. In 2018, the average volume weighted price was 0.62 ¢/kWh (or 0.0062 $/kWh). Residential consumers emit less carbon dioxide (CO_2) when surplus emission-free electricity is used to displace fossil fuels. The emission savings when we displace fossil fueled heating equipment operating at 85% lifetime efficiency with emission-free electricity and resistance heaters are:

- 213 grams carbon dioxide per kWh for reduced natural gas use
- 253 grams carbon dioxide per kWh for reduced propane use
- 293 grams carbon dioxide per kWh for reduced fuel oil use

Industrial hydrogen suppliers can also use surplus emission-free electricity in electrolysers to make hydrogen for oil refineries rather than making hydrogen from natural gas using the steam methane reforming (SMR) process. The SMR process emits about 12 grams of carbon dioxide into the atmosphere for each gram of hydrogen that is produced.

The resulting reduction in atmospheric carbon dioxide emissions depends on how the hydrogen is used. Due to the differences in conversion efficiencies of different end uses for hydrogen, the reduction in atmospheric emissions are:

- Displacing gasoline in fuel cell cars: 350 grams CO_2 /kWh of electricity
- Displacing SMR hydrogen at refineries: 210 grams CO_2 /kWh of electricity
- Displacing natural gas in pipelines: 110 grams CO_2 /kWh of electricity

However, to make all of these options economically viable, the marginal price of each additional unit of emission-free electrical energy (kWh) at the retail level must be less than the marginal price of the same amount of useful energy from fossil fuels at the retail level.

In this report, we have assumed that electrical resistance heating equipment will be used for fossil fuel displacement. Heat pumps can boost the energy output of electrical heating equipment over a one-year period by 2 to 4 times depending on the type of heat pump and local weather conditions. However, the report does not present analysis for electrical heat pumps because they are significantly more expensive than resistance heating equipment.

The price of fossil fuels for heating purposes will depend on what fossil fuel the consumer is using. Most residential consumers use one of three types of fossil fuels for water heating and space heating: natural gas in urban homes and fuel oil and propane in rural homes. Some homes use electric or bio-mass heating systems. This report does not analyze electric or bio-mass heating fuels.

Urban residential consumers pay a combination of fixed monthly charges and volume rates for their natural gas. Natural gas distribution system costs and billing services are charged as a fixed monthly charge in a similar way to electricity. Natural gas volume rates are used to recover the cost of natural gas, carbon taxes and transmission costs.

Because reducing GHG emissions is currently a global priority, GHG emission reduction can be facilitated if more of the natural gas energy system costs are recovered in the volume rate instead of the fixed monthly charge. That would raise the marginal cost of natural gas energy and make it more economical to displace natural gas with surplus emission-free electricity. However, natural gas retail price reform is outside the scope of this report.

Ontario commissioned a comprehensive Fuels Technical Report in 2016[12] for long term energy planning. This OSPE report used the 2018 price per gigajoule in the Fuels Technical Report for propane and heating oil. However, this OSPE report used the 2018 Union Gas marginal price in Milton, Ontario so we could better compare that price with electricity prices in Milton, Ontario.

The rates were adjusted to reflect an average lifetime fuel efficiency of 85% for heating equipment based on the higher heating value of fossil fuels. The results of the conversion are reflected in Table 5-1 below.

Table 5-1
Marginal 2018 Retail Price of an Additional kWh of Fossil Fuels

$0 per Tonne CO_2 Price

Fuel Type	Units	Residential	Commercial	Industrial
Fuel Oil	¢/kWh	13.9	12.3	8.0
Propane	¢/kWh	7.9	5.7	7.8
Natural Gas	¢/kWh	1.8	1.8	1.7

[12] Ontario Fuels Technical Report, September 2016, prepared by Navigant Consulting Inc. for the Ontario Ministry of Energy. Accessed November 1, 2018. https://www.ontario.ca/document/fuels-technical-report

Table 5-1 (continued)

\$20 per Tonne CO_2 Price

Fuel Type	Units	Residential	Commercial	Industrial
Fuel Oil	¢/kWh	14.5	12.9	8.6
Propane	¢/kWh	8.4	6.2	8.3
Natural Gas	¢/kWh	2.2	2.2	2.1

\$50 per Tonne CO_2 Price

Fuel Type	Units	Residential	Commercial	Industrial
Fuel Oil	¢/kWh	15.4	13.8	9.5
Propane	¢/kWh	9.1	7.0	9.1
Natural Gas	¢/kWh	2.8	2.8	2.8

Notes for Table 5-1:

- Prices are based on the 2018 year forecast in the Ontario Fuels Technical Report except for residential natural gas price which is the actual 2018 Union Gas marginal price in Milton, Ontario. Prices have been adjusted up to reflect a lifetime higher heating value combustion efficiency of 85%. The propane price for industrial consumers is based on a blend of propane and natural gas liquids from the Ontario Fuels Technical Report. A pure industrial propane price was not available.
- Marginal costs represent the cost of the next kWh of energy and excludes fixed monthly costs.
- All prices including the carbon price are expressed in Canadian dollars.

Table 5-2
Marginal Price of an Additional kWh of Surplus Emission-Free Electricity For Different Consumer Groups

Description	Billing Units	Resi-dential	< 50 kW	< 1,000 kW	< 5,000 kW	>= 5,000 kW
Present Retail Price Plans (min)	¢/kWh	8.71	9.99	7.05	7.05	7.05
Present Retail Price Plans (max)	¢/kWh	15.41	16.69	11.94	11.94	7.05
Wholesale market energy price – 2018 (volume weighted price)	¢/kWh	0.62	0.62	0.62	0.62	0.62

Notes for Table 5-2:

- Marginal prices represent the next kWh of energy and excludes fixed monthly charges and peak kW demand charges for larger industrial and commercial consumers.
- Retail Price Plan prices are based on Milton Hydro rates effective April 1, 2018. Milton Hydro rates are similar to rates in most communities in the Greater Toronto Area. The residential and <50 kW columns represent prices for consumers on TOU price plans.

- The wholesale market energy price shown is the volume weighted wholesale market energy price when surplus emission-free electricity was available.

The present marginal prices for each additional kWh of surplus emission-free electrical energy are summarized in Table 5-2 above for each of the five major consumer groups. The retail price of surplus emission-free electricity, even during off-peak periods, is much higher than the actual marginal cost of that electricity for all consumer groups.

By comparing Table 5-1 with Table 5-2 above, we can see that the present retail price of surplus emission-free electricity for residential consumers is:

- Much more expensive than natural gas in all time periods even with a carbon price of $50 per tonne CO_2
- More expensive than propane during on-peak periods and similar to propane during off-peak periods even at $50 per tonne CO_2
- More expensive than fuel oil during on-peak periods but cheaper than fuel oil only during off-peak periods

Effectively, Ontario's current retail electricity pricing approach is creating a significant disincentive for its use and harming the Ontario economy and environment by incenting consumption of higher cost and higher emitting energy alternatives for consumers' heating needs. Canada's plans to price CO_2 emissions at $50 per tonne by 2022 will not be sufficient to motivate consumers to use emission-free electricity instead of fossil fuels.

Ontario's retail electricity price plans with their excessively high energy rates for electricity are making the federal carbon price ineffective with little prospect of causing consumers to switch to surplus emission-free electricity for some of their heating needs.

It is worth noting that the wholesale market operates on an auction basis with a common clearing price for electricity. This means that as consumers begin to use surplus electricity for fossil fuel displacement, the wholesale market energy price will rise. When the surplus has been fully used the price will reach 1.44 ¢/kWh based the present production taxes on hydroelectric generation. The supply and demand will stabilize at a lower price if not all of the surplus is used. That stable price and the amount of fossil fuel displacement that will occur will depend on several factors:

- The marginal production cost of generators
- The cost of fossil fuel displacement equipment
- The volume price of fossil fuels being displaced
- The number of consumers participating in fossil fuel displacement

What this means is that not all the surplus emission-free electricity will be used for fossil fuel displacement in Ontario. However, we should be able to eventually capture at least 70%. Residential consumers will use it for water heating, space heating and electric car charging and industry will also use it for steam production and hydrogen production provided the retail energy rate is aligned with the wholesale market energy price for each kWh of energy.

The remaining unused amounts of the surplus will continue to be exported and contribute to emission reduction in other jurisdictions. Very little, if any, is expected to be curtailed (wasted). Adjoining jurisdictions currently purchase more than half of our total surplus emission-free electricity. Hydro Quebec uses our surpluses to refill their storage reservoirs and New York and Michigan use it to displace higher fuel cost fossil fired plants. Unfortunately, Ontario consumers are paying for the fixed cost of the capacity to produce that exported energy. OSPE believes Ontario consumers who pay for those fixed costs should have access to that surplus at the same terms and conditions as adjoining electricity systems. That will only happen if Ontario reforms its retail electricity price plans.

6. Analysis and Results

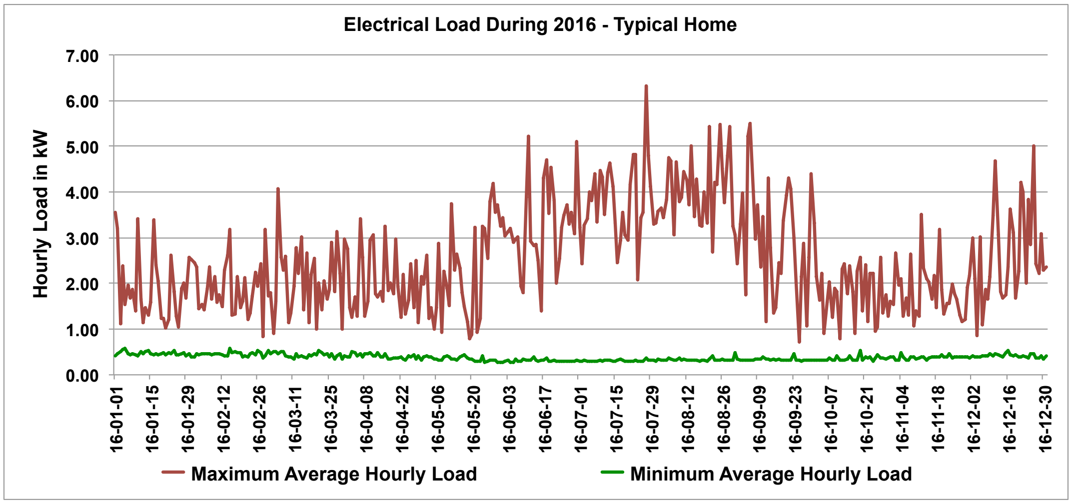
In order to perform the energy savings analysis OSPE required the following data:

- Hourly consumption of electricity for a typical residential consumer.
- Hourly consumption of fossil fuels for a typical residential consumer for the same year as the hourly electrical data.
- The amount of surplus emission-free electricity forecasted to be available between 2020 and 2035.
- The rates for the standard residential TOU price plan and the TOU-style price plan pilots approved for testing by the OEB in January 2018.
- The rates for each of the three OSPE smart price plans.
- The Fair Hydro Plan impact on current rates in order to ensure the new smart price plan rates would be revenue neutral on an annual basis with the existing standard TOU price plan for the typical residential consumer.

The OEB provides annual consumption data for a typical residential home but not hourly consumption data. The hourly electrical load profile of the home that OSPE used for the analysis in this report is shown below in Figure 6-1. The home's energy-related design details are described in Appendix A in this report. The 2017 Long Term Energy Plan (LTEP) identified the 2016 typical residential electricity consumption as 750 kWh/month or 9,000 kWh/year. In this analysis the actual home we used has a 2016 annual electricity consumption of 8,845 kWh. This is within 1.8% of the LTEP data.

Figure 6-1

Typical Daily Residential Load over a 1-Year Period[13]



OSPE analyzed the hourly cost of electrical service for the consumption shown in Figure 6-1 using the Fair Hydro Plan rates effective May 1, 2018 and also for rates published by the OEB without the Fair Hydro Plan[14]. This was done to see the size of the annual deferred amounts that will come due when the Fair Hydro Plan expires at the end of 2021. The results are summarized in Table 6-1 below and provide an annual electricity cost baseline for subsequent cost analysis.

Table 6-1

Cost of Electrical Service for 2018 for a Typical Urban Ontario Home (does not include taxes or government subsidies)

Residential Plan	Annual Cost	All-in Cost per kWh
TOU Price plan with Fair Hydro Plan	$1,247	14.1 ¢
TOU Price plan without Fair Hydro Plan	$1,650	18.7 ¢

13 The homeowner's hourly consumption data for 2016 was downloaded from the IESO smart meter data repository and included in this report with permission from the homeowner.
14 OEB regulated price plan rates without the Fair Hydro Plan. Accessed October 27, 2018 at: https://www.oeb.ca/sites/default/files/RPP-Supply-Cost-Report-20180501-20190430-correction.pdf

Notes for Table 6-2: The all-in-cost per kWh for electricity includes all charges including the fixed monthly charge divided by the total energy consumption in kWh. These are not the marginal costs for each additional kWh.

When the Fair Hydro Plan was introduced, it was supposed to lower electricity bills by 17% and the provincial 8% sales tax was removed for a total of 25% annual bill reduction. Annual increases under the Fair Hydro Plan are limited to the consumer price index which was approximately 2% in 2017 and 2018. However, comparing the annual costs in Table 6-1 indicates the annual bill reduction from the Fair Hydro Plan has grown in 2018 to over 24% not including the sales tax reduction.

OSPE believes the larger discount is the result of at least two factors:

- larger electricity system cost transfers to residential consumers caused by the Industrial Conservation Initiative program,
- larger amounts of curtailment of surplus emission-free electricity than were forecasted in the 2017 LTEP, and

The Industrial Conservation Initiative program has been much more successful than planned and is transferring additional costs from Class A to Class B consumers. Residential consumers are part of the Class B group. Also, the surplus emission-free electricity curtailments in 2017 were larger than forecasted.

This suggests the deferral account is accumulating losses faster than forecasted in the 2017 LTEP. That means the electricity rate increase will be larger than 8% in 2022 and 33% by 2026 forecasted in the 2017 LTEP.

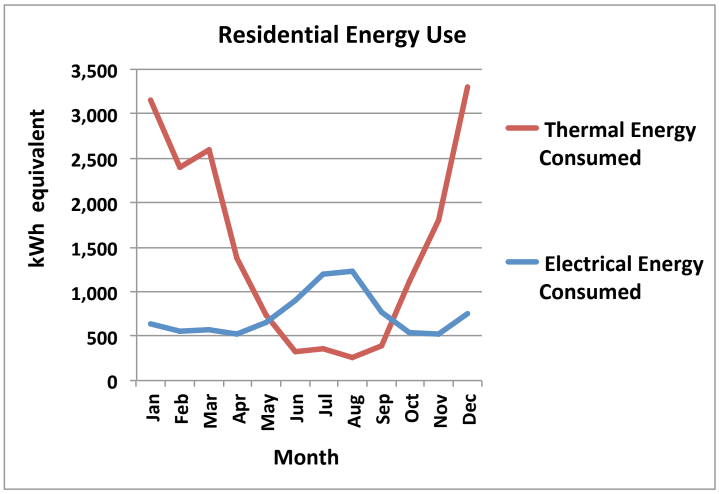
Fortunately, the Ontario government has indicated in a March 21, 2019 press release that it plans to introduce changes to the present Fair Hydro Plan Act.

Large rate increases will suppress electrical demand as consumers purchase higher efficiency appliances, convert their electrical cooking appliances to natural gas or install solar panels to avoid the higher electricity bills. The lower electrical demand will result in larger amounts of surplus emission-free electricity.

The hourly consumption of fossil fuels for a typical residential consumer is not available. However, OSPE did have the monthly natural gas consumption data for the same home and same year as the hourly electrical data. OSPE used the monthly data and allocated it equally across the whole month on an hourly basis. This is not strictly correct because weather varies daily but at least the monthly average consumption will be correct. The natural gas energy content was adjusted to reflect the 85% lifetime combustion efficiency of heating equipment relative to the higher heating value of the fuel. That adjustment provided the required thermal energy demand each hour for that consumer.

Figure 6-2 below shows the electrical and thermal energy consumption for a typical Ontario residence.

Figure 6-2
Residential Electrical and Thermal Energy consumption



With its very low emission electricity system, Ontario could meet the economy-wide international emission goals simply by electrifying all fossil fuel applications. While that is mathematically possible, it is not economically practical. The total cost of electricity production is 3 to 5 times more expensive on a delivered thermal energy basis than fossil fuels. However, as indicated earlier in this report all low emission electricity systems can produce significant amounts of surplus emission-free electricity at very low marginal cost.
To evaluate the effectiveness of the various price plans to reduce the typical consumer's energy bills, OSPE analyzed 4 different cost reduction strategies separately:

- Manual load shifting from on-peak to off-peak hours (eg: electric vehicle charging and delaying use of appliances to off-peak periods)
- Energy conservation (reduced consumption by any means)
- Automatic load flattening using electrical storage
- Fossil fuel displacement using surplus electricity for hot water and space heating.

The results of the analysis is presented in more detail in Appendix G of this report. Summaries of the results are provided below.

Savings with a Manual Load Shifting Strategy

When energy consumption is shifted from on-peak to off-peak periods, the consumer saves the higher rate but must pay for the energy at the lower rate. The consumer saves only the difference in rates multiplied by the consumption in kWh. Table 6-2 below summarizes the savings that are possible for each price plan for each kWh that is shifted. There are no savings with most TOU-style price plans if the load shift occurs on weekends or holidays because energy consumption during all weekend and holiday hours is charged at the same off-peak rates. The two exceptions are the Low Overnight price plan pilot and the OSPE Modified Low Overnight Smart Price Plan because they both have lower rates between midnight and 6 am also on weekends and holidays.

Table 6-2
Bill Savings for Every kWh of Manual Load Shifting

Description of Retail Price Plan	On-Peak to Off-Peak Shift MAX. Savings (¢/kWh)	Mid-Peak to Off-Peak Shift MAX. Savings (¢/kWh)
Standard Residential TOU Price Plan	6.70	2.90
OEB Approved Pilots:		
Enhanced Time-of-Use	13.10	8.80
Low Overnight	16.30	7.20
Variable Peak Pricing with CPP	44.70	-
Quick-Ramping CPP	44.40	3.90
Seasonal Time-of-Use with CPP	21.00	-
Seasonal Time-of-Use	8.10	-
Super-Peak Time-of-Use	18.90	-
Alternative Quick-Ramping CPP	53.50	3.40
OSPE Smart Price Plans:		
Modified Low Overnight	19.42	10.19
Energy Plus Peak Demand	74.84 (1)	-
Energy Only	13.96	6.98

Notes for Table 6-2:

(1) The OSPE Energy Plus Peak Demand smart price plan provides a $22.78/kW/month bill reduction for each kW reduction in the monthly average peak power demands. If the demand is shifted away from the daily peak demand for the whole hour, every day, for the whole month the equivalent savings would be 74.84 ¢/kWh. However, if the peak demand reduction occurs for the whole hour but only on one day of the month the equivalent savings would be 2.46 ¢/kWh. This plan rewards the consumer more for lowering all the daily peaks each month because that has the greatest value for the electricity system.

Most consumers find that load shifting produces modest bill reductions because it is difficult to find large loads that operate for many hours that can be manually shifted to lower rate periods on a consistent basis. See Appendix G for additional discussion.

Savings with an Energy Conservation (Load Reduction) Strategy

When energy consumption is eliminated, the consumer saves the rate that is applicable multiplied by the consumption in kWh.

Table 6-3 below summarizes the maximum and minimum savings that can be realized with each price plan for every kWh reduction in demand. The maximum rates for all TOU rate type plans are not applied on weekends and holidays because all hours on those days are off-peak periods. Plans with relatively high Critical Peak Pricing (CPP) rates only have a limited number of hours when those higher CPP rates apply.

Table 6-3
Bill Savings for Every kWh of Reduced Consumption

Description of Retail Price Plan	Max. Savings ¢/kWh	Min. Savings ¢/kWh
Standard Residential TOU Price Plan	15.41	8.71
OEB Approved Pilots:		
Enhanced Time-of-Use	19.81	6.61
Low Overnight	20.51	4.21
Variable Peak Pricing with CPP	51.81	7.11
Quick-Ramping CPP	52.11	7.11
Seasonal Time-of-Use with CPP	28.51	7.51
Seasonal Time-of-Use	15.71	7.61
Super-Peak Time-of-Use"	27.41	8.51
Alternative Quick-Ramping CPP	61.71	8.21
OSPE Smart Price Plans:		
Modified Low Overnight	20.64	1.22
Energy Plus Peak Demand	77.27 (1)	2.43
Energy Only	21.20	7.24

Notes for Table 6-3:

(1) The OSPE Energy Plus Peak Demand smart price plan provides a $22.78/kW/month bill reduction for each kW reduction in the monthly average peak power demand and 2.43 ¢/kWh in energy savings. If the energy reduction lowers the daily peak power demand for the whole hour, every day, for the whole month the savings would be worth 77.27 ¢/kWh. However, if the energy reduction lowers the daily peak power demand for only one day of

the month the savings would be worth only 4.89 ¢/kWh. If the energy reduction does not lower the daily peak power demand the savings would be worth only 2.43 ¢/kWh.

Most consumers find that conservation and energy efficiency produce modest bill reductions because many of the loads that can be reduced by conservation or by purchasing more efficient appliances do not operate for enough hours to produce a significant bill reduction. The exception are a few appliances that have high loads and operate for long periods of time like an air conditioner and electrical heating appliances. Unfortunately, due to their high cost, the opportunity to replace these high load appliances with more efficient models are limited to approximately once every 15 to 20 years. See Appendix G for additional discussion.

Savings with an Automatic Load Flattening Strategy Using Electrical Storage

The electricity system can supply a flat load demand at relatively low cost. However, to achieve a flat load profile consistently from day-to-day, a consumer will need an energy management system that includes both an automatic load controller and electrical storage equipment.

Inflexible loads can only be shifted to off-load periods by charging an electrical storage system off-peak and then drawing that electricity out of the storage system when that electricity is needed during the on-peak period. The total amount of energy consumed from the electricity system will be higher by the amount of losses incurred in charging and discharging the storage system. OSPE's analysis has assumed a 5% charging loss and a 5% discharging loss in the storage system. OSPE also assumes the load flattening will occur on a daily basis only and not on a weekly or seasonal basis. This assumption lowers the cost of storage but leaves some seasonal load variations that the electricity system must accommodate.

OSPE analyzed 2 load shifting options. The first option flattens the load over the whole 24-hour period. That leads to the lowest energy production costs for the electricity system. The second option transfers all load out of the on-peak and mid-peak periods and creates a higher flat off-peak load. This maximizes the bill savings. This second option is included to show the maximum annual savings that are possible with each price plan. The original load profile and the 2 new load profiles after the load is shifted are shown in Figure G-2 and Figure G-3 in Appendix G.

To achieve the flat 24-hour load profile, a 28 kWh electrical storage system is required for the sample consumer OSPE selected for the analysis. That storage is approximately equivalent to two Tesla PowerWall storage systems. The 2018 commercial price for a fully installed residential storage system with two

PowerWalls including chargers, inverters and control system integrated with the home's electricity system is approximately $25,000 Canadian. The price above assumes that the two PowerWalls are close to the main electrical panel and that existing electrical circuits are up to code. This cost does not include an optional solar installation or integration with an existing solar installation.[15]

To maximize energy bill savings, we could shift all electrical load out of the on-peak and mid-peak periods and into the off-peak periods using additional amounts of electrical storage. This is not a practical load profile because it would stress the electricity system if enough consumers implemented it. However, to achieve a flat load profile only during off-peak periods, a 42 kWh electrical storage system is required. That is equivalent to approximately three Tesla PowerWall storage systems with an installed price of about $35,000 Canadian.

Table 6-4 below summarizes the annual electricity costs for each of the price plans OSPE has analyzed both before and after the automatic load shift. See Appendix G for additional discussion.

Table 6-4

Annual Electricity Costs Using
Automatic Load Shifting/Levelling Using Electrical Storage

Description of Retail Price Plan	Before Load Shift (Annual $)	24-Hour Flat Load (Annual $)	Flat Off-Peak Load Only (Annual $)
Standard Residential TOU Price Plan	1,247	1,243	1,105
OEB Approved Pilots:			
Enhanced Time-of-Use	1,270	1,242	913
Low Overnight	1,265	1,218	938
Variable Peak Pricing with CPP	1,194	1,190	959
Quick-Ramping CPP	1,255	1,236	1,023
Seasonal Time-of-Use with CPP	1,239	1,257	1,128
Seasonal Time-of-Use	1,217	1,234	1,127
Super-Peak Time-of-Use"	1,285	1,270	1,087
Alternative Quick-Ramping CPP	1,222	1,206	1,014
OSPE Smart Price Plans:			
Modified Low Overnight	1,247	1,184	859
Energy Plus Peak Demand	1,247	995	N/A
Energy Only	1,247	912	N/A

Notes: (1) The 5 Hydro One price plan pilots have been withdrawn and are not listed above.

[15] Estimated price for an installed Tesla PowerWall residential energy storage system. Accessed on October 28, 2018 at: http://mpowersolutions.ca/faq

(2) N/A means "not analyzed" because these smart plans were designed to improve overall electricity system performance and not to deliberately stress the system.

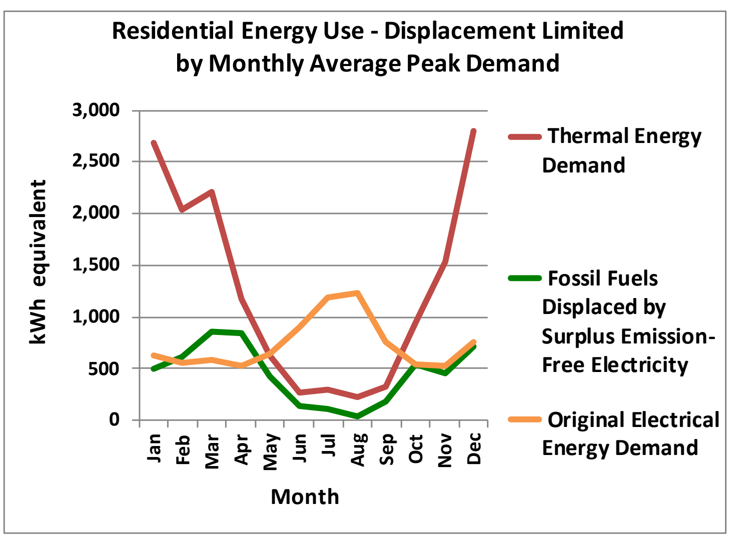
Table 6-4 above shows that smart price plans produce larger annual bill savings. None of the plans save enough money to justify a $25,000 investment in electrical storage equipment needed to flatten the entire day's load demand. However, if storage was provided and justified for other reasons such as emergency backup power, then some modest amount of load shifting could be economically performed to reduce the on-peak loads and achieve some savings.

Savings with a Fossil Fuel Displacement Strategy

To analyze the savings a consumer can expect, OSPE modelled the OSPE Energy Plus Peak Demand Smart Price Plan with an energy management system.

The first situation we modeled limits the fossil fuel displacement so that the consumer's monthly average peak power demand is not exceeded. The maximum amount of surplus emission-free electricity used for fossil fuel displacement when it is available is the lesser of the difference between the prevailing dependable electrical load and the monthly average peak power demand or the actual required thermal load, whichever is less. The green line in Figure 6-3 shows the amount of thermal energy that can be supplied by surplus emission-free electricity.

Figure 6-3
Thermal Energy that Can Be Supplied by Surplus Emission-Free Electricity (Limited by the Monthly Average Peak Power Demand)



Note: Fossil fuel displacement is limited to the hours when surplus electricity is available from the electricity system and the consumer's monthly average of the daily peak demand.

Table 6-5 below shows the maximum annual energy cost savings that the consumer would have enjoyed in 2018 using surplus emission-free electricity at its volume weighted average wholesale energy price of 0.62 ¢/kWh. Table 6-5 applies early in the deployment of smart price plans when there is more surplus electricity than demand for it. Once the fossil fuel displacement market has matured, the surplus quantities will have to be shared and the weighted average wholesale market price for the surplus will be higher. Therefore, the savings will be smaller than those shown in Table 6-5. Additional discussion is in Appendix G of this report.

Table 6-5
Annual Net Cost Savings by Typical Residential Fossil Fuel Consumer Using a Fossil Fuel Displacement Cost Reduction Strategy (Limited by the Monthly Average Peak Power Demand)

	Power Limit kW	Fossil Fuel Displacement	Nat. Gas Savings	Propane Savings $/yr	Fuel Oil Savings $/yr
$0/t CO_2 Price	**2.53**	**36%**	**$64**	**$395**	**$721**
$20/t CO_2 Price	**2.53**	**36%**	**$86**	**$423**	**$754**
$50/t CO_2 Price	**2.53**	**36%**	**$118**	**$461**	**$803**

Notes:

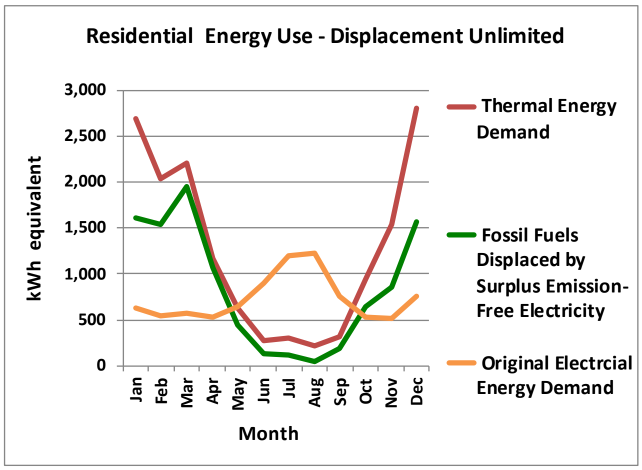
1. In addition to the savings above the consumer also saves 8% provincial sales tax on any fossil fuels that are displaced by electricity.

Table 6-5 above shows that the greatest savings will accrue to consumers that use the most expensive fossil fuels. Those are the consumers that will likely volunteer first for the new smart price plans. Propane and heating oil are used primarily in rural Ontario. Urban consumers in Ontario typically use natural gas for water heating and space heating. Consumers with electric cars will also be early subscribers because they will enjoy a larger savings compared to the standard TOU price plan if they charge their cars during periods when surplus emission-free electricity is available.

Electric car owners in Milton Ontario will save an additional $239 per year with the OSPE Energy Plus Peak Demand Smart Price Plan compared to the standard TOU price plan. The analysis assumed the owner can charge their car with an equal amount of surplus emission-free electricity at 0.62 ¢/kWh and off-peak dependable electricity at 2.43 ¢/kWh rather than the TOU off-peak rate of 8.71 ¢/kWh. The average car was assumed to travel 16,000 km per year and use about 0.25 kWh/km.

The second situation OSPE analyzed allowed unlimited amounts of surplus emission-free electricity to be used for fossil fuel displacement. Unlimited access can be permitted in the early deployment years because there are not likely to be sufficient consumers subscribing to the plan to cause loading problems on the local distribution circuit. Figure 6-4 below shows the larger amount of thermal energy that can be supplied.

Figure 6-4
Thermal Energy that Can Be Supplied by Surplus Emission-Free Electricity (Not Limited by the Monthly Average Peak Power Demand)



Note: Fossil fuel displacement is limited to the hours when surplus electricity is available from the electricity system.

Table 6-6 below shows the maximum annual energy cost savings that the consumer would have enjoyed in 2018 using surplus emission-free electricity at its volume weighted average wholesale energy price of 0.62 ¢/kWh. Table 6-6 applies early in the deployment of smart price plans when there is more surplus electricity than demand for it. Once the fossil fuel displacement market has matured the surplus quantities will have to be shared and the savings will be smaller than those shown in Table 6-6 below. Additional discussion is in Appendix G of this report.

We do not want to use surplus electricity produced from natural gas-fired generation to supply resistance heaters, otherwise emissions will double to meet our heating needs. Fossil fueled power plants are only about 30 to 50% efficient whereas new gas-fired furnaces, boilers and water heaters are typically at least 85% efficient over their lifetime.

Homes with ground sourced heat pumps (GSHPs) are 4 times more energy efficient than resistance heaters over the period of 1 year so they can achieve emission reductions even if they use electricity from natural gas fired generation. OSPE has not analyzed the use of GSHPs because of their high upfront cost.

Table 6-6
Annual Net Cost Savings by Typical Residential Fossil Fuel Consumer Using a Fossil Fuel Displacement Cost Reduction Strategy Not Limited by the Monthly Average Peak Power Demand

Month	Power Limit kW	Fossil Fuel Displacement	Nat. Gas Savings $/yr	Propane Savings $/yr	Fuel Oil Savings $/yr
$0/t CO_2 Price	Unlimited	67%	$120	$741	$1,351
$20/t CO_2 Price	Unlimited	67%	$161	$792	$1,412
$50/t CO_2 Price	Unlimited	67%	$222	$863	$1,504

Notes:
1. In addition to the savings above the consumer also saves 8% provincial sales tax on any fossil fuels that are displaced by electricity.

Fortunately, it is easy to detect when natural gas-fired plants are being used to meet electrical demand. Fossil fueled generating plants have a higher marginal cost of production than emission-free generating plants. When fossil fueled plants are operating to meet the demand, they set a higher clearing price on the wholesale market, of typically above 20 $/MWh (2 ¢/kWh).

Emission Reduction Potential

Table 6-7 below summarizes OSPE's estimate of the maximum carbon dioxide emission reduction that can be achieved using the available surplus emission-free electricity to displace natural gas. The quantities of surplus emission-free electricity can vary due to economic conditions, generation technology choices by planners, effectiveness of conservation programs and weather conditions.

Table 6-7
Maximum Amount of Emission Reductions from Using Surplus Emission-Free Electricity Directly for Fossil Fuel Displacement (Assumes All Surpluses are Used for Water and Space Heating)

	Surplus Emission-Free Electricity in TWh (1)	Reduction for Natural Gas only Mt CO_2
16-yr Annual Average	9.8	2,100,000
16-year Total	157.0	33,400,000

Notes for Table 6-7:
1. Includes both curtailed and exported quantities of surplus emission-free electricity.

2. Other uses such as propane and fuel oil heating, electric car charging and hydrogen production provide greater emission reductions on a per kWh basis.
3. Forecast assumes no new emission-free generation is added from 2020 - 2035.

The number of residential consumers that can be supplied by the long term forecasted supply of 9.8 TWh/yr of surplus emission-free electricity, assuming 70% of the surplus is used, are:

- 1,300,000 homes with 36% fossil fuel displacement (limited access)
- 700,000 homes with 67% fossil fuel displacement (unlimited access)

Unlimited access to surplus emission-free electricity would create individual consumer load peaks during off-peak periods. This may eventually create some local distribution bus congestion when many subscribers to the smart price plan are located on the same distribution system circuit.

If Ontario increases the emission-free generation capacity of the electricity system to supply a growing population the surplus amounts will increase. The annual energy savings from fossil fuel displacement and the associated emission reductions will also be larger if smart price plans are deployed to allow consumers to take advantage of those surpluses.

7. Implementation Considerations

Deploying new smart price plans involves a number of implementation choices that have to be evaluated and selected. Those choices impact both the consumer and LDC, so some compromises may have to be made to keep costs affordable for the consumer who eventually also pays the LDC costs. It may also mean that a phased approach may be more appropriate to give both the LDCs and consumers time to adapt to the new communication technology and control devices that are rapidly becoming available. The simplest and least costly smart price plan implementation could be deployed first. A more functionally rich and more complex smart plan implementation could be deployed later. For example, the LDC could begin deploying smart price plans with no communication capability, later add one-way communication capability to the consumer's devices and eventually adopt two-way communication capability between the LDC and the consumer's control equipment to provide direct control of the consumer's flexible loads (such as fossil fuel displacement) consistent with electricity system conditions. The control and communication equipment required to operationalize smart price plans should be open to competitive forces among private sector technology developers in order to accelerate technology development and help reduce costs.

OSPE believes there is very little political support for mandatory retail price reform as a result of complaints of higher bills from consumers after the mandatory deployment of smart meters and TOU rates some years ago.

Residential consumers with high load factors (flat load every day) typically pay more than their fair share of electricity system costs with the present residential TOU price plan. Consumers with low load factors (highly variable loads especially during on-peak periods) typically pay less than their fair share of electricity system costs. Therefore, mandatory retail rate reforms that bring prices and costs more into alignment will create winners and losers.

OSPE believes that deployment of new smart price plans should be voluntary. Consumers who own their own home and are financially able to purchase the required additional equipment can subscribe to the new smart price plans that are offered by their LDC. The consumers will also need some assurance that the new smart price plans will not be cancelled before they have recovered the cost of the equipment they purchased. OSPE suggests a 10-year period would be appropriate for residential consumers because their payback period will typically range from 2 to 5 years depending on the degree of automation the consumer chooses. The consumer should be able to cancel their subscription to the smart plan at any time without penalty but the LDC should not be able to cancel the consumer's subscription to the smart price plan until the 10-year period has expired.

Typical residential consumers are not sufficiently versed in energy and economic analysis to develop their own business case to select the appropriate energy management system, fossil fuel displacement equipment and electrical and thermal storage equipment. Residential consumers will need some help to make an informed decision for their specific circumstances. The Ministry of Energy, Northern Development and Mines, or an engineering consultant it hires, in consultation with various LDCs, are in the best position to provide consumers information on the true marginal cost of various energy sources, the best value among the various system design options and which suppliers are available to supply, install and maintain the equipment.

The smart price plans can be tested through a limited pilot to iron out any implementation issues and to develop an effective deployment plan. An information package for residential consumers also needs to be developed to solicit subscribers to the smart price plans and to keep consumers updated on their energy consumption and cost data after they are subscribers. The party responsible to pay for the cost of equipment during the pilot phase needs to be determined. If there is any possibility the pilot and deployment will be cancelled, then the equipment should be provided to the consumer at no charge during the pilot. That may limit the choice of features in the smart price plans and the number of volunteer consumers to keep pilot costs manageable.

During the early years of the smart price plan deployment, there will be more surplus electricity available than consumption by subscribers. Providing consumers unlimited access to the surplus emission-free electricity would be better for consumers and the environment. However, when subscribers become numerous and begin to impact distribution circuit loading, access to surplus electricity can be capped or limited by the LDC. This can be done by modifying the smart price plan rules or by adding appropriate control signals and communication links to the consumers' control equipment.

When consumers switch to the new smart price plan, some will experience a rise and others a fall in their usual monthly bill if they don't make any changes to their load profiles. The size of the bill change will depend on the consumer's load profile relative to the typical consumer that the smart price plan was developed for. This difference in bill amount can be ignored but that will encourage individuals who are currently paying more than their fair share for electrical services to preferentially subscribe to the smart price plan. These consumers actually deserve a lower bill for having a load profile that can be supplied at lower cost. However, if OEB rules do not allow a step change in the bill an alternative approach is to calculate the difference between the standard TOU price plan and the smart price plan for that specific consumer using the prior year's load profile. An offsetting monthly charge can be included in the consumer's bill when the subscription starts and then phased out over a period of time, say 5 years. This alternative approach will incentivize consumers to subscribe to the smart price if they are serious about displacing some of their fossil fuel use or charging their electric cars during hours when there is surplus emission-free electricity.

OSPE has proposed three smart plans in this report. Each has different implementation impacts.

The OSPE Modified Low Overnight Smart Price Plan is the easiest and cheapest for the LDCs and consumers to implement because it is similar to the existing TOU price plans and its basic implementation does not require communication capability. This plan is also easy for residential consumers to understand because they only need to know energy consumption units (kWh) and the time of day. Fossil fuel displacement can be accomplished with thermostat-controlled heaters and timers. The cost per home should not exceed $1,000 for space heating but the savings will be more modest than the amounts shown in Table 6-5 or Table 6-6 by about half. The price plan does not need the residential consumer to know about power demand units (kW). However, to capture the maximum amount of low-cost surplus emission-free electricity any time during the day, the consumer will need a more complex implementation with an energy management system and communication capability with the LDC.

The OSPE Energy Plus Peak Demand Smart Price Plan provides the greatest savings for the residential consumer if all its features are made available. This plan has the strongest price signals to help improve overall electricity system performance, however, it is more difficult for consumers because they need to understand both energy and power parameters. If the LDC does not have communication capability, the plan still provides consumers with cost effective displacement of propane and fuel oil with electricity during low demand hours. The consumer needs to purchase an automatic energy management system to maximize savings and to avoid inadvertently creating a higher monthly average peak power demand. Inadvertently creating a higher peak power demand will increase the consumer's monthly bill with this plan.

The OSPE Energy Only Smart Price Plan allows the consumer to be billed in energy only units. However, to use the plan to maximize fossil fuel displacement, the consumer will need to purchase an energy management system with communication capability with the LDC. The LDC will also have to modify its billing algorithms with this plan because it does not operate on either time-of-use or peak power demand like other retail plans the LDC is currently familiar with. The plan operates on hourly energy consumption thresholds. The thresholds are established based on the consumption of a typical Ontario residential consumer.

8. Conclusions

Ontario's retail electricity market presently does not differentiate between high reliability (dependable) electricity and low reliability (interruptible) electricity. The fixed cost of generation and transmission capacity must be paid for by Ontario consumers who need dependable electricity for their important electricity loads. Electricity which can be interrupted by the LDC is less reliable and has less value. That is why exported electricity, which can be interrupted, is sold at the wholesale market energy price without the fixed cost of generation included (ie: no global adjustment charge). Surplus emission-free electricity can be interrupted so it should also be available to Ontario consumers in their retail price plans at the wholesale market energy price.

High reliability electricity is far more valuable to the consumer than low reliability electricity and yet the retail consumer must pay the same price for both. The current Ontario approach to retail electricity pricing encourages consumers to use fossil fuels instead of lower cost surplus emission-free electricity and results in higher overall annual energy bills for Ontario consumers and higher emissions.

This major misalignment between the wholesale and retail electricity markets should be corrected.

Ontario's current retail electricity price plans have made surplus emission-free electricity too expensive to displace fossil fuels for heating requirements. That leads to excessive curtailment (waste) of emission-free electricity and unnecessary GHG emissions. Reforming retail electricity rates is necessary to enable Ontario consumers to purchase surplus emission-free electricity at its marginal cost of production for the purpose of economically displacing fossil fuels for their heating requirements.

Canada plans to price carbon dioxide emissions at $50 per tonne by 2022. That price will not be sufficient to motivate consumers to use clean electricity instead of fossil fuels for their heating needs. Ontario's current retail price plans are making the federal carbon price ineffective with little prospect of incentivizing consumers to use surplus emission-free electricity for their heating needs. The situation for residential and small commercial/industrial consumers will become even worse when the Fair Hydro Plan expires at the end of 2021 and electricity rates rise significantly. The Ontario government announced March 21, 2019 that it intended to make changes to Fair Hydro Plan Act.[16] OSPE looks forward to changes that will make surplus emission-free electricity a viable energy alternative to fossil fuels.

The on-peak price periods in Ontario's standard TOU price plan encouraged consumers to shift their discretionary loads to after 7 pm. The addition of solar generation in the distribution system now suppresses overall electricity system demand during the on-peak TOU period on sunny days but not the 7 pm to 10 pm period. The overall electricity system peak period now often falls in the TOU price plan off-peak period from 7 pm to 10 pm. This results in a need for additional generation capacity to meet the 7 pm to 10 pm demand. The cost of that additional capacity for the electricity system is high and will cause electricity rates to rise further. This misalignment of the TOU on-peak rate period with the electricity system on-peak period needs to be corrected.

All price plans will save consumers money when they use less electricity especially during on-peak periods either through conservation or by shifting loads to lower priced periods. However, none of the existing price plans save consumers enough money to justify the purchase of electrical storage and energy management equipment to perform the load shifts automatically and consistently. The bill savings using manual load shifts is modest.

Electrifying all applications that use fossil fuels is not currently a practical approach to reduce emissions because the total cost of electricity is much higher than the total cost of fossil fuels. However, surplus electricity produced by emission-free electricity systems has a very low marginal cost of production. That cost is lower than the marginal cost of fossil fuels. Therefore, displacement of

[16] Ontario government announcement on changes to the Fair Hydro Plan Act, accessed March 24, 2019 at: https://news.ontario.ca/mndmf/en/2019/03/keeping-electricity-affordable-and-improving-transparency.html

fossil fuels by surplus emission-free electricity is a viable low-cost strategy to reduce economy-wide emissions.

The smart retail electricity price plans will significantly reduce a consumer's total annual energy cost (electricity plus fossil fuels) and also reduce carbon dioxide emissions through reduced fossil fuel use. The smart price plans will also further reduce the energy cost to charge an electric vehicle at night to as low as 0.62 ¢/kWh from the present 8.71 ¢/kWh. That will help offset the lost $14,000 purchase incentive for electric vehicles that was recently cancelled by the Ontario government in 2018 and will improve the smaller federal subsidy of up to $5,000 per electric and hydrogen fuel cell vehicle proposed in the March 2019 federal budget.[17]

The new smart electricity price plans should be deployed using a voluntary program. Consumers who can benefit most from the new smart price plans will subscribe first and become early adopters. They will establish a market for the fossil fuel displacement equipment. That should help reduce equipment costs over time and make it possible for more consumers to subscribe.

Smart price plans improve the business case for investments in solar and wind generation because the plans reduce the amount of curtailment (waste) that those sources are subjected to in a low emission electricity system. Smart price plans allow the output from solar and wind generation to be used for hydrogen production and fossil fuel displacement when electricity demand is lower than the available generation output.

OSPE's proposed rate reform will make surplus emission-free electricity affordable for fossil fuel displacement. The consumer who subscribes to the new smart price plan will have a slightly higher electricity bill but will have a much lower fossil fuel bill. Fossil fuels are imported to Ontario so the economic impact on the local Ontario economy will be positive. The environmental benefits are obtained at no cost to the electricity system.

As Ontario increases the emission-free generation capacity of the electricity system to supply a growing population the surpluses will increase. The annual energy savings from fossil fuel displacement and the associated emission reductions will also become larger in future if smart price plans are deployed to allow consumers to take advantage of those surpluses.

Addressing the consumer's total energy needs creates opportunities for cost and emission reductions through more effective integration of our electrical and fossil-fueled energy systems.

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[17] Canadian government subsidies for electric cars, accessed March 24, 2019 at: https://www.budget.gc.ca/2019/docs/nrc/infrastructure-infrastructures-electricity-electricite-en.html

The current monthly electricity bill is not transparent to consumers. For example, there are both fixed monthly charges and variable energy-based charges in both the Delivery item and Regulatory item on the bill. The fixed and variable components are not explicitly identified in the monthly Delivery and Regulatory bill items. This confuses the consumer as to what fraction of the Delivery and Regulatory charges vary with energy consumption. It also gives the consumer the false impression that the TOU rates are the actual marginal cost of electrical energy in those TOU rate periods. To make matters worse for consumers, neither the LDCs nor their fossil fuel suppliers provide the marginal cost of energy in a commonly understood energy unit across all fuel types. The consumer has no easy way to compare prices of different energy sources on both a marginal cost and total cost basis. Most rural consumers in Ontario are not aware that off-peak electricity is cheaper than heating oil in many locations in Ontario on a marginal cost basis. Ontario energy consumers need more transparent comparative energy pricing information.

The Industrial Conservation Initiative program is too generous and contributing to unfair cost transfers from Class A to Class B consumers.

9. Recommendations

The Ministry of Energy, Northern Development and Mines should revise existing legislation and regulations and the Ontario Energy Board should revise Distribution Codes that prevent consumers from purchasing surplus emission-free electricity at its wholesale market energy price. The global adjustment charges and other delivery and regulatory charges that are presently applied in accordance with energy consumption need to be reconsidered and preferably applied based on the consumer's average peak power demand. If rates primarily based on energy consumption are retained, the LCDs should be required by the OEB to provide consumers an energy rate consistent with the marginal cost of electricity production when surplus emission-free electricity is available in the electricity system. The volume weighted average wholesale market energy price during hours when surplus emission-free electricity is available is an appropriate proxy.

The Ministry of Energy, Northern Development and Mines should require the Ontario Energy Board and Local Distribution Companies to deploy smart price plans on a voluntary basis. The smart price plans should:

- encourage consumers to make productive use of surplus emission-free electricity for fossil fuel displacement, electric car battery charging, hydrogen production and other applications that lower consumers' annual energy bills and reduce emissions to the environment.

- encourage consumers to embrace energy efficiency and conservation that help to reduce the fixed cost of the electricity system.
- encourage consumers to level their daily load profile to reduce the need for peak generation capacity.
- fairly compensate consumers who have behind-the-meter low emission generation for their production without transferring system costs created by that generation to other consumers.
- Discourage consumers from installing fossil fuel-fired generation behind-the-meter that competes with Ontario's low emission electricity system. Behind-the-meter fossil-fueled generation used only for emergency backup should not be discouraged because it provides power system resiliency.

Regulations and codes that apply to retail price plans should require that retail electricity prices be aligned with the actual costs incurred in providing various electricity services, namely:

- fixed costs that are independent of either energy consumption or peak power demand should be recovered based on fixed monthly rates.
- costs associated with peak power demand should be recovered based on peak power demand rates or an equivalent proxy.
- costs associated with energy consumption should be recovered based on wholesale market energy prices.
- any subsidies or surcharges should be separately identified so that the actual cost of each type of electricity service remains transparent to consumers.
- Rates should be reviewed periodically but no more frequently than once per 6-month period.

The Ministry of Energy, Northern Development and Mines, the Ontario Energy Board and Local Distribution Companies should collaborate to deploy smart price plans as soon as practical. The deployment approach should make some of the benefits of smart price plans available to the largest number of consumers. The three OSPE smart price plans described in this report are examples that hopefully will stimulate additional innovation and result in smart price plans that are tailored to the specific metering and internet communication capability of each Local Distribution Company. The control and communication equipment required to operationalize smart price plans should be open to competitive forces among private sector technology developers in order to accelerate technology development and help reduce costs.

The Ontario Energy Board and Local Distribution Companies should develop the appropriate parameters for each smart price plan for each consumer group after a more detailed analysis than was performed for this report.

LDCs who wish to pilot the smart price plans before full deployment should focus on encouraging consumers that use propane and heating oil and who own electric cars to participate first. Those applications will produce larger annual energy bill savings and emission reductions.

Below are a number of recommendations that relate to the deployment of the new smart price plans both at the pilot stage and when the plans become permanent:

- The new price plans should be **voluntary,** and the consumer should be able to exit at any time without penalty.
- Consumers should be able to rely on the new smart price plans for at least 10 years to recover their investment in the energy management system (load controllers, communication equipment, fossil fuel displacement equipment and energy storage equipment) needed to take maximum advantage of the plans.
- The Ministry of Energy, Northern Development and Mines should arrange for an engineering consulting firm to:
    - develop specifications for various options to take advantage of surplus emission-free electricity
    - arrange for a testing laboratory to certify energy management systems offered by suppliers to assure consumers that the supplier's equipment meets the specifications.
- The Ministry of Energy, Northern Development and Mines (or a designated LDC that is conducting a pilot) should provide consumers with an information brochure. The brochure should include various equipment options, typical installed prices and the typical annual energy cost savings (electricity plus fossil fuels) they can expect. The savings should be based on the IESO forecasted quantities of surplus electricity and the LDC forecasted number of subscribers of smart price plans. The brochure should include the names and contact information of private sector companies that supply equipment, installation and maintenance services that meet the specifications developed by the engineering consultant.
- The Ministry of Energy, Northern Development and Mines should provide periodic revisions to the information brochure to coincide with the periodic OEB rate reviews.
- The LDC should include a monthly information package with the smart price plan subscriber's monthly bill comparing the subscriber's monthly electricity cost results with that of the standard TOU price plan. This comparison report should be provided during the pilot phase (if a pilot is conducted) and for the first 2 years after deployment of the smart price plan.
- The Ministry responsibilities in the bullets above may be delegated to the OEB or IESO on behalf of the Ministry.

The Ministry of Energy, Northern Development and Mines should make available to residential and small commercial/industrial consumers the comparative costs in the same energy units of all fuels on both a total cost and marginal cost basis.

The Local Distribution Companies should provide alternative communication capability to consumers in areas where smart meters are not able to communicate with the Local Distribution Company computers. To effectively use smart price plans the meters must be read monthly. Local Distribution Companies should try to make smart price plans available to all consumers who want to subscribe to the smart price plans by employing other means of communicating with the smart meters. Other smart meter reading options should be considered including monthly meter reader visits, public internet-based communications, cellular phone communication or landline telephone dial-up communication services.

The Ministry of Energy, Northern Development and Mines, and the Ontario Energy Board should incentivize Local Distribution Companies to introduce improved communication and load management capability into their service areas so that their consumers can take advantage of new technologies to lower their overall annual energy costs, improve electricity system operation and contribute to lower greenhouse gas emissions.

The Ontario Energy Board should consider sponsoring the development of a basic communication capability between the Local Distribution Companies and their consumers' load control equipment for Local Distribution Companies that do not have the financial resources to develop their own communication solutions. Use of international standards should be encouraged.

The Ontario Energy Board should realign TOU on-peak rate periods for existing TOU price plans with the actual electricity system on-peak periods. The on-peak periods should be reviewed periodically as consumer load profiles change but no more frequently than once per 6-month period.

The Ministry of Energy, Northern Development and Mines, and the Ontario Energy Board should review and revise the Fair Hydro Plan Act before the Fair Hydro Plan (FHP) rate discount expires at the end of 2021 and take action to help consumers mitigate the anticipated large annual increases in electricity bills.

The Ministry of Energy, Northern Development and Mines should re-examine the design of the Industrial Conservation Initiative (ICI) program. The ICI program needs to be redesigned to eliminate unfair cost transfers from Class A to Class B consumers. Legislation and regulations will need to be revised to implement this recommendation.

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11. Definitions

Advanced Metering Infrastructure – digital smart meter infrastructure that allows two way communication between the LDC and the consumer's premises so that information needed for both billing and energy management can be exchange. The amount of information that can be transmitted by Advanced Metering Infrastructure can vary widely among manufacturers.

Base-Load Demand – is the electrical power the consumer requires continuously at the same rate every hour of the day. The term is used in the context of a load profile. Base-load demand is the portion of the power demand that is the steady round-the-clock power demand.

Capacity (Load) Factor – the actual energy produced (consumed) in a given period of time divided by the energy that could be produced (consumed) if the full nameplate rating of the generator (load device) was operated continuously for the same period of time.

Critical Peak Pricing – the very high rate charged during very high system demand periods to encourage consumers to reduce their load before operating reserves are exhausted and forced load interruptions must be implemented. Not all TOU-style price plans include the Critical Peak Pricing feature.

Demand – the power flowing in a circuit to supply the consumer's electrical appliances. Demand is also often referred to as Load Demand. The load demand is often categorized into two types: Base-Load Demand and Peak Load Demand.

Emission-Free Electricity – electricity that originates from generation with negligible atmospheric emissions during plant operation.

Energy – energy is defined as power multiplied by time and represents the actual amount of electricity consumed over a specific period of time. It is measured in kilowatt-hours (kWh) for residential consumers.

Load Demand – the same as Demand.

Mid-Peak Demand – is the total power flowing in a circuit during the mid-peak time period as defined by regulations related to time-of-use electrical meters.

Off-Peak Demand – is the total power flowing in a circuit during the off-peak time period as defined by regulations related to time-of-use electrical meters.

On-Peak Demand – is the total power flowing in a circuit during the on-peak time period as defined by regulations related to time-of-use electrical meters. An individual consumers' peak demand may or may not fall within the on-peak demand period as defined by regulations nor coincide with the system-wide peak demand. The on-peak demand period may or may not contain the system-wide peak demand on any specific day due to variations in weather conditions.

Overnight Off-Peak Demand - is the total power flowing in a circuit during the overnight off-peak time period as defined by regulations related to time-of-use electrical meters. Currently defined as 00:00 to 06:00 am.

Peak Demand – is the highest power demand during any specified time period, usually a day, month, season or year.

Peak-Load Demand - is the additional electrical power demand above the base-load demand required by the consumer. The term is used in the context of a load profile. Peak-load demand only exists for a portion of the day.

Power – is the rate of energy flow. It is measured in kilowatts (kW) for residential consumers.

Surplus Emission-Free Electricity –electricity that produced from emission-free sources and is also surplus to Ontario's domestic electrical load requirements.

Total Power Demand – The total power demand is equal to the total power flowing in the circuit at any instant of time. The total power demand is also equal to the base-load demand plus the peak-load demand.

12. Index of Abbreviations

A/C	Air Conditioning or Air Conditioner depending on context
AMI	Advanced Metering Infrastructure
CPP	Critical Peak Pricing
CO_2	Carbon Dioxide
EST	Eastern Standard Time
FHP	Fair Hydro Plan
FIT	Feed In Tariff program
GHG	Greenhouse Gas
GJ	Gigajoule (1 billion joules)
GST	Goods and Services Tax (federal sales tax)
GW	Gigawatt (power flow quantity of 1 billion watts)
GWh	Gigawatt-hour (energy quantity of 1 billion watts for 1 hour)
HST	Harmonized Sales Tax (combined provincial and federal sales tax)
ICI	Industrial Conservation Initiative
IESO	Independent Electricity System Operator
kW	kilowatt (1000 watts)
kWh	kilowatt-hour (energy quantity of 1000 watts for 1 hour)
LDC	Local Distribution Company (local electricity distributor)
LED	Light Emitting Diode (high efficiency lighting technology)
LTEP	Ontario Long Term Energy Plan
MW	Megawatt (power flow quantity of 1 million watts)
MWh	Megawatt-hour (energy quantity of 1 million watts for 1 hour)
MSP	Ontario Market Surveillance Panel
OEB	Ontario Energy Board
OPG	Ontario Power Generation Inc.
OSPE	Ontario Society of Professional Engineers
PST	Provincial Sales Tax
RPP	Regulated Price Plan
SBG	Surplus Baseload Generation
SMR	Steam Methane Reforming (of hydrogen)
TOU	Time-of-Use electricity price plan
TW	Terawatt (power flow quantity of 1 trillion watts)
TWh	Terawatt-hour (energy quantity of 1 trillion watts for 1 hour)
W	Watt (a unit of electrical power)

13. Acknowledgements

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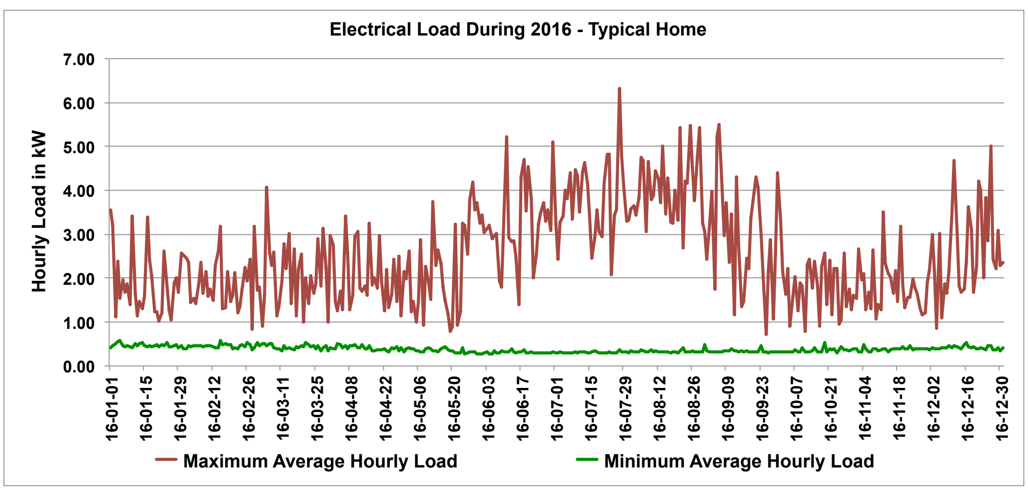
Appendix A - Ontario's Wholesale Electricity Markets and Retail Electricity Price Plans

In this analysis the Ontario Society of Professional Engineers (OSPE)[18] used an actual home with a 2016 annual electricity consumption of 8.84 MWh. This is within 1.2% of the 2015 Independent Electricity System Operator (IESO) data and within 1.8% of Ontario's 2017 Long Term Energy Plan (LTEP) data for a typical residential home.

The home was a 2,100 square foot bungalow, constructed in 1995 with natural gas water heater, natural gas forced air furnace and electricity for all other appliances including air conditioning. The home had energy upgrades including a programmable thermostat, vinyl double glazed windows and insulated steel doors with double glazed windows, R50 in the attic, R26 in the basement walls, light emitting diode (LED) lighting and a temperature-controlled attic exhaust fan. The analysis in this report uses the 2016 hourly electricity consumption data for that home as the typical residential load profile. The data was downloaded from the IESO smart-meter repository with permission from the homeowner. The hourly electricity consumption data is shown in Figure A-1 below:

Figure A-1
Typical Daily Residential Load over a 1-Year Period[19]



The retail price of electricity contains many components. Below is a list of the components in electricity rates:

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18 A complete list of abbreviations is listed in the body of the report in Volume 1.
19 The homeowner's hourly consumption data for 2016 was downloaded from the IESO smart meter data repository and included in this report with permission from the homeowner.

Components	**Description**
1 - Wholesale market energy price	Energy portion of generation costs (also includes a small portion of fixed costs by low cost producers).
2 - Global adjustment	Fixed cost portion of generation costs + conservation program costs.
3 - Delivery	Transmission and distribution costs.
4 - Regulatory	Various smaller costs not included above.
5 - Taxes	Federal and provincial sales taxes (as applicable).
6 – Retail contract price	Replaces the wholesale market energy price for consumers who do not buy electricity from their Local Distribution Company (LDC).

The Ontario Energy Board (OEB) commodity price which is reported on the OEB website for the Time-Of-Use (TOU) and Tiered regulated price plans only includes the wholesale market energy price and the global adjustment. OEB regulated price plans only apply to consumers that buy electricity from LDCs. The vast majority of residential and small commercial/industrial consumers buy electricity from LDCs. TOU price plans apply varying rates based on which hours and days the electricity is used. Ontario's has one TOU price plan for residential consumers and one for small commercial/industrial consumers under 50 kW average peak power demand. The TOU plan defines on-peak, off-peak and mid-peak rates. Normal workdays have all three periods. Summer and winter have different on-peak and mid-peak periods. Workday evenings are designated off-peak periods. All weekend and holiday hours are designated off-peak periods.

The OEB Tiered regulated price plan is used for residential and small commercial/industrial consumers who do not have working smart meters. The Tiered price plans charge for electricity based on total monthly use with one rate for a basic amount of energy and a higher rate for additional amounts of energy. The basic amount is larger in the winter for residential consumers.

Residential consumers who buy their electricity from their LDC are charged items 1 through 5 on their bill. Residential consumers who buy their electricity from a retailer are charged items 2 through 6 because item 6 replaces item 1.

Wholesale Market Energy Price

Descriptions of how the wholesale market operates and establishes the wholesale market energy price can be found on the IESO's website. The wholesale market energy price at any time represents the incremental or marginal cost of producing the next MWh of electrical energy. The wholesale market energy price reflects the marginal cost of energy for the producer that sets the market clearing price. The wholesale market auction's main function is to ensure the lowest marginal cost producers are selected to provide electricity first. Energy is not accepted from producers with higher marginal costs than the clearing price and those producers are forced to shut down their facilities.

The marginal cost of production of the major generation technologies and loads Ontario uses to balance supply and demand is listed below:

- Large industrial load reduction (varies up to +200 ¢/kWh)
- Voluntary demand response participants (varies from +10 to +200 ¢/kWh)
- Natural gas-fired (varies by plant type and above 2 ¢/kWh).
- Flexible hydroelectric capacity (0.08 to 1.44 ¢/kWh). This represents a production tax imposed by the provincial government that varies with the output of the facility. The rates are:
    - 0.08 ¢/kWh for the first 50 GWh/yr
    - 0.16 ¢/kWh for the additional production up to 400 GWh/yr
    - 0.22 ¢/kWh for the additional production up to 700 GWh/yr
    - 1.44 ¢/kWh for production above 700 GWh/yr
- Solar (-0.3 ¢/kWh)
- 90% of wind nameplate capacity (-0.3 ¢/kWh)
- Flexible nuclear capacity at Bruce Power (-0.5 ¢/kWh).
- Last 10% of wind nameplate capacity (-1.5 ¢/kWh)
- Inflexible nuclear and hydroelectric capacity (-200 ¢/kWh)

Inflexible nuclear and hydroelectric generation are allowed to bid a very low marginal cost into the market auction so that they are not forced to shut down frequently. These facilities cannot be shut down frequently due to equipment and environmental protection reasons.

The last 10% of wind nameplate capacity is allowed to bid a lower marginal cost into the market auction so that these facilities can minimize winter freezing conditions on their mechanical power train equipment.

When the electricity system demand rises the market clearing price rises. The market clearing price begins at -200 ¢/kWh at zero system load demand and rises up to 1.44 ¢/kWh when the load demand uses up all the emission-free generation capacity (ie: hydroelectric, nuclear, wind and solar). If demand rises further the natural gas generators start up and set the clearing price. When there is insufficient generation, consumers who have subscribed to the voluntary demand response program will have their loads curtailed. If generation capacity and voluntary demand response is not sufficient to meet the rising dependable load demand, then large industrial plants that participate in the market auction are paid to shut down their loads at prices up to 200 ¢/kWh. If the supply deficiency continues to deteriorate, voltage reductions and eventually rotating blackouts are implemented by system operators to prevent a widespread power system collapse.

Generation is scheduled based on forecasts 1 day ahead to allow natural gas generation sufficient time to warm up and connect to the electricity system if they are needed the following day. If operating conditions change unexpectedly due to a sudden load increase or a sudden loss of generation, the natural gas plants may not be able to respond to the sudden increase in load demand. In those situations, the system operator will call for industrial load reductions and the clearing price will spike up dramatically until the natural gas plants are able to respond and supply additional output. That is why we see large spikes up in the market clearing price even when the overall electricity system load is not particularly high.

The wholesale market energy price is paid by the IESO to all generators that have bid less than or equal to the wholesale market energy price and inject energy into the electricity system. This means that generators that have lower marginal production costs for energy than the wholesale market energy price receive a portion of their fixed costs from the wholesale market energy price payments. The remaining fixed costs (the contracted price minus the wholesale market energy price) are paid to all generators from the global adjustment account. The global adjustment payment ensures there is sufficient cash flow to service the generators' debt and operating fixed costs irrespective of the electrical energy the generator produces. The generator's variable costs for energy production are paid only when the generator injects energy into the electricity system.

Wholesale market energy prices are the same across Ontario but that may change later after the IESO completes its market renewal reforms. How those reforms impact individual LDC's and their consumers is not certain yet. Currently the LDC's pay the IESO and the OEB allows the LDC to have a variance account that keeps it whole with respect to what individual consumers pay them based on TOU or Tiered price plans. The variance account is used to adjust Delivery charges at the next rate approval by the OEB.

Table A-1
Volume Weighted Average Hourly Ontario Energy Price

Year	All Hours (¢/kWh)	Only Hours With Surplus Emission-Free Electricity (¢/kWh)	Only Overnight Hours 00:00 to 06:00 (¢/kWh)
2015	2.36	0.59	1.23
2016	1.66	0.44	0.63
2017	1.58	0.40	0.48
2018	2.43	0.62	1.22

For the purposes of this report OSPE has analyzed the Hourly Ontario Energy Price (HOEP) as reported by the IESO at its website.[20] The volume weighted average HOEP (wholesale market energy price) is summarized in Table A-1 above.

Global Adjustment

The global adjustment (GA) is a mechanism to ensure generators get paid their contracted price for the electricity they produce for any take-or-pay volumes regardless of the wholesale market energy price. Generators that have very low marginal energy production costs are market price takers. They accept the 5-minute wholesale market clearing price that is set by higher cost plants. Most plants including plants that are held off-line in reserve get most of their revenue from the global adjustment account. This financial arrangement means that the global adjustment is affected by the wholesale market energy price. The two are inversely co-related. When the wholesale market energy price drops in a particular month, the GA rises and vice versa.[21]

For residential and small commercial/industrial consumers that buy electricity from their LDC the two changes cancel each other out. However, consumers that buy electricity from a retailer at a fixed energy price end up paying more for their electricity when the wholesale market energy price falls and less when the wholesale market energy price rises. This is a counter intuitive result but it occurs because of the inverse relationship mentioned above.

The global adjustment account also includes other charges such as the cost of the province's electricity conservation programs currently estimated at about $400 million dollars a year.

In a low emission electrical system, fuel costs are very low, so most of the costs of electricity are due to the fixed cost of installed capacity for generation and transmission. That cost is best recovered from consumers based on that consumer's proportionate use of the electricity system capacity. A consumer's instantaneous peak power demand is not a good measure of an individual consumer's proportionate use of overall system capacity. When there are many consumers drawing power from the electricity system, their individual peaks do not occur at the same instant in time. That means the electricity system sees the average of the consumer's power demand over the particular time interval of

[20] IESO power data is available at its website, accessed Jan 13, 2019, at: http://www.ieso.ca/Power-Data/Data-Directory

[21] This inverse relationship between wholesale market energy cost and global adjustment effectively means that the total commodity price paid by the consumer per kWh of energy is fairly stable. This pricing stability should be expected given that fixed costs represent the majority of costs of operating the generation and transmission system.

interest. The consumer's average hourly peak power demand is a better measure of the consumer's proportionate use of the electricity system capacity in any given hour. For monthly billing, the consumer's monthly average peak power demand is a more appropriate measure of the consumer's proportionate use of the electricity system capacity.

The global adjustment is charged to all consumers to ensure all contractual costs to produce electricity are recovered from consumers each month. The global adjustment is not allocated equally to all consumers. Some consumers such as the large industrial Class A group can avoid some (or even all) of the global adjustment charges by subscribing to the Industrial Conservation Initiative (ICI) program and by demonstrating that they reduced their peak load during the electricity system's 5 highest power demand hours in the previous year. The ICI program is too generous and is causing significant unjustified cost transfers from Class A to Class B consumers. The problem is described in more detail in the Ontario Market Surveillance Panel (MSP) Report issued on December 18, 2018.[22] The ICI program urgently needs to be revised because it is causing four serious economic and environmental problems:

- It is transferring significant electricity system costs unfairly from Class A consumers (large industrials) to Class B consumers (everyone else).
- It is causing the Fair Hydro Plan (FHP) deferral account for residential and small commercial/industrial consumers to accumulate losses faster than forecasted. Those additional costs will cause electricity rates to rise faster than forecasted beyond 2021 when the FHP expires.
- It is incentivizing uneconomic amounts of behind-the-meter generation and electrical storage by Class A consumers. Most industrial behind-the-meter generation is natural gas-fired and emits nearly 20 times more carbon dioxide emissions per kWh of energy produced than Ontario's electricity system. Behind-the-meter fossil-fueled generation used only for emergency backup should not be discouraged because it provides power system resiliency.

The Global Adjustment charges are applied the same for LDCs in Ontario and their residential consumers.

Delivery

Delivery is comprised of transmission and distribution charges.

All consumers pay for transmission costs. Small consumers pay based on monthly energy consumption in kWh, larger consumers pay based on monthly

[22] Report on the ICI program effectiveness, accessed Dec 29, 2018 at: https://www.oeb.ca/sites/default/files/msp-ICI-report-20181218.pdf

peak power demand in kW. There are several transmission systems in the province. The transmission charges vary in different regions in the province in proportion to how that region uses each of the different transmission systems. The Ontario Energy Board (OEB) approves the appropriate transmission charges for each region.

Consumers serviced by the distribution system of their LDC also pay distribution costs. In the past, distribution charges for residential consumers were a combination of a modest fixed monthly charge and a significant energy charge based on consumption in kWh. In July 2015 the OEB approved a 4-year transition beginning in 2016 to a fixed monthly charge for residential consumers[23]. Most LDCs are well on their way to converting to a fixed monthly charge for residential consumers. Larger consumers still pay a combination of fixed monthly charges and either an energy charge or peak power demand charge for their distribution costs.

The OEB approves the rates that each LDC can charge their customers for each rate group. This report uses the OEB approved Milton Hydro rates for analysis purposes.

All LDC's have at least five major rate classes. The list below is for Milton Hydro.

- Residential Service
- General Service < 50 kW average monthly peak power demand (these are primarily small commercial/industrial consumers.
- General Service >=50 kW and <1,000 kW average monthly peak power demand
- General Service >=1,000 kW and <5,000 kW average monthly peak power demand
- Large Use Service >=5,000 kW average monthly peak power demand (these are large industrial consumers).

LDC's have other special rate classifications including classifications for various unmetered loads. The LDCs can get OEB approval for additional sub-divisions of those major classes to accommodate local conditions.

Regulatory

All consumers pay regulatory charges such as wholesale market service charges, rural and remote rate protection charges, administration charges and some

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[23] OEB approved a change to fixed monthly rates for residential consumers beginning in 2016. Downloaded Sep 3, 2018 at: https://www.oeb.ca/industry/policy-initiatives-and-consultations/rate-design-electricity-distributors-formerly-revenue

additional cost recovery charges. All consumers are billed regulatory charges by energy consumption. Regulatory charges are the same for all LDCs in Ontario.

Taxes

Energy is normally subject to a 13% harmonized sales tax (HST). However, in 2017 the Ontario government decided to rebate the 8% provincial sales tax (PST) portion of the HST to residential and small commercial/industrial consumers for their electricity purchases. For those consumers the effective tax is now 5% representing the federal goods and services tax (GST). Sales taxes are included in consumers' electricity bill from their LDC. Some business consumers receive a sales tax input credit so the PST sales tax rebate did not change their net sales tax costs.

However, the provincial sales tax was not removed from fossil fuels purchases. Residential consumers can avoid the 8% PST on their energy consumption when they use electricity to displace fossil fuels. In addition, electricity used to charge electric cars, does not include the road tax that is applied to gasoline and diesel sales.

Retailer Energy Price

Retailers are permitted to enter into contracts with producers for electricity. The retailers are permitted to sell that energy on a longer term, fixed price basis to consumers who choose to buy electricity from the retailer instead of the LDC. Therefore, consumers who buy electricity from a retailer pay the retailer's fixed contract price for energy rather than the TOU or Tiered commodity prices for residential and small commercial/industrial consumers or the Hourly Ontario Energy Price (HOEP) for other larger industrial and commercial consumers. Electricity billing is done by the LDC, even for consumers that purchase energy from a retailer. Most consumers in Ontario purchase energy from their LDC. This report does not include analysis for consumers who purchase energy from a retailer.

Ontario's Retail Electricity Price Plans

Tables A1.1 to A1.5 below summarize the retail electricity rates applicable to each of the 5 major consumer groups within the 2 classes. Charges for poor power factor are also applicable to the 3 larger consumer groups but are not included in the tables in this report. Poor power factor creates system thermal losses outside the consumer's premises that are not captured by the consumer's kW and kWh meters. The poor power factor charge is intended to recover the cost of those losses. All rates are subject to regular review by the OEB (typically semi-annually or annually).

Table A1.1
Retail Price plans – Milton Hydro – effective May 1, 2018
Components in Rates for Residential Service[24]

Bill Component	**Rate**	**Unit**
Commodity (TOU or Tiered not both)		
- TOU Energy Rates		
▪ On-peak	0.132	$/kWh
▪ Mid-peak	0.094	$/kWh
▪ Off-peak	0.065	$/kWh
- Tiered Energy Rates		
▪ Tier 1	0.077	$/kWh
▪ Tier 2	0.089	$/kWh
- Wholesale Market Rates		
▪ Energy	Included	$/kWh
▪ Global Adjustment	Included	$/kWh
Delivery		
- Fixed Charge	25.31	$/month
- Energy Charge	0.0182	$/kWh
Regulatory		
- Fixed Charge	0.25	$/month
- Energy Charge	0.0039	$/kWh
Tax	5	%

Consolidated Retail Rates for Residential Service
(combines related bill components)

Summary		**Rate**	**Unit**
Fixed Charge		25.56	$/month
Energy Charge:	On-peak	0.1541	$/kWh
	Mid-peak	0.1161	$/kWh
	Off-peak	0.0871	$/kWh
	Tier 1	0.0991	$/kWh
	Tier 2	0.1111	$/kWh
Tax		5	%

Notes for Table A1.1:

1. Most residential consumers are on TOU rates. A few are on Tiered rates.
2. The rates above include the Fair Hydro Plan Act bill reductions from 2017 to 2021.
3. On-peak is 11 am to 5 pm weekdays from May 1 to Oct 31.
4. Mid-peak is 7 am to 11 am and 5 pm to 7 pm weekdays from May 1 to Oct 31.
5. On-peak is 7 am to 11 am and 5 pm to 7 pm weekdays from Nov 1 to Apr 30.
6. Mid-peak is 11 am to 5 pm weekdays from Nov 1 to Apr 30.
7. Off-peak is 7 pm to 7 am weekdays, all hours on weekends and holidays.
8. Tier 1 is up to 600 kWh/mon. May 1 to Oct 31, Tier 2 is above 600 kWh/mon.
9. Tier 1 is up to 1,000 kWh/mon. Nov 1 to Apr 30, Tier 2 is above 1,000 kWh/mon.

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[24] Milton Hydro rate information was accessed Dec 29, 2018 and can be found at: https://www.miltonhydro.com/MiltonHydro/media/Milton-Hydro-Documents/Rate_Schedule_for_2018__Rate_Flyer_20180501_for_Website_2.pdf

Table A1.2
Retail Price plans – Milton Hydro – effective May 1, 2018
Components in Rates for General Service <50 kW

Bill Component	Rate	Unit
Commodity (TOU or Tiered not both)		
- TOU Energy Rates		
▪ On-peak	0.132	$/kWh
▪ Mid-peak	0.094	$/kWh
▪ Off-peak	0.065	$/kWh
- Tiered Energy Rates		
▪ Tier 1	0.077	$/kWh
▪ Tier 2	0.089	$/kWh
- Wholesale Market Rates		
▪ Energy	Included	$/kWh
▪ Global Adjustment	Included	$/kWh
Delivery		
- Fixed Charge	17.49	$/month
- Energy Charge	0.031	$/kWh
Regulatory		
- Fixed Charge	0.25	$/month
- Energy Charge	0.0039	$/kWh
Tax	5	%

Consolidated Retail Rates for General Service <50kW
(combines related bill components)

Summary		Rate	Unit
Fixed Charge		17.74	$/month
Energy Charge:	On-peak	0.1669	$/kWh
	Mid-peak	0.1289	$/kWh
	Off-peak	0.0999	$/kWh
	Tier 1	0.1119	$/kWh
	Tier 2	0.1239	$/kWh
Tax		5	%

Notes

1. Most small commercial/industrial consumers are on TOU rates.
2. The rates above include the Fair Hydro Plan Act bill reductions from 2017 to 2021.
3. On-peak is 11 am to 5 pm weekdays from May 1 to Oct 31.
4. Mid-peak is 7 am to 11 am and 5 pm to 7 pm weekdays from May 1 to Oct 31.
5. On-peak is 7 am to 11 am and 5 pm to 7 pm weekdays from Nov 1 to Apr 30.
6. Mid-peak is 11 am to 5 pm weekdays from Nov 1 to Apr 30.
7. Off-peak is 7 pm to 7 am weekdays, all hours on weekends and holidays.
8. Tier 1 is up to 750 kWh/month, Tier 2 is over 750 kWh/month.

Table A1.3
Retail Price plans – Milton Hydro – effective May 1, 2018
Components in Rates for General Service <1,000 kW

Bill Component	**Rate**	**Unit**
Commodity (Class A or B GA but not both)		
- Wholesale Market Rates		
▪ Energy	0.0158 (1)	$/kWh
▪ Global Adjustment - Class B	0.0997	$/kWh
▪ Global Adjustment - Class A	0.0508	$/kWh
Delivery		
- Fixed Charge	75.92	$/month
- Energy Charge	0.0	$/kWh
- Peak Demand Charge	9.0581	$/kW
Regulatory		
- Fixed Charge	0.25	$/month
- Energy Charge	0.0039	$/kWh
Tax	13	%

Consolidated Retail Rates for General Service <1,000kW
(combines related bill components)

Summary	**Rate**	**Unit**
Fixed Charge	76.17	$/month
Energy Charge - Class A	0.0705	$/kWh
Energy Charge - Class B	0.1194	$/kWh
Peak Demand Charge	9.0581	$/kW
Tax	13	%

Notes

1. Wholesale market energy price varies constantly, table uses 2017 average weighted wholesale market energy price of 0.0158 $/kWh.
2. Class A are large industrial loads above 5 MW average monthly peak load, or medium industrials above 1 MW average monthly peak load who have opted into the Industrial Conservation Initiative (ICI), or designated industrial loads above 500 kW average monthly peak load who have opted into the Industrial Conservation Initiative (ICI).
3. Class B loads are all loads that are not Class A.
4. Class A loads can reduce their GA charges by reducing their total load during the 5 highest power demand periods to qualify for reduced global adjustment charges in the following year. Theoretically the GA charge could be zero if the consumer has zero load during the 5 highest power demand periods. In practice that is difficult to achieve for most businesses. The table above includes the average GA paid by the Class A loads in 2017 as reported by the IESO in its Q4 2017 Electricity Energy Report.

Table A1.4
Retail Price plans – Milton Hydro – effective May 1, 2018
Components in Rates for General Service <5,000 kW

Bill Component	Rate	Unit
Commodity (Class A or B GA but not both)		
- Wholesale Market Rates		
▪ Energy	0.0158 (1)	$/kWh
▪ Global Adjustment - Class B	0.0997	$/kWh
▪ Global Adjustment - Class A	0.0508	$/kWh
Delivery		
- Fixed Charge	628.94	$/month
- Energy Charge	0.0	$/kWh
- Peak Demand Charge	8.0355	$/kW
Regulatory		
- Fixed Charge	0.25	$/month
- Energy Charge	0.0039	$/kWh
Tax	13	%

Consolidated Retail Rates for General Service <5,000kW
(combines related bill components)

Summary	Rate	Unit
Fixed Charge	629.19	$/month
Energy Charge - Class A	0.0705	$/kWh
Energy Charge - Class B	0.1194	$/kWh
Peak Demand Charge	8.0355	$/kW
Tax	13	%

Notes

1. Wholesale market energy price varies constantly, table uses 2017 average weighted wholesale market energy price of 0.0158 $/kWh.
2. Class A are large industrial loads above 5 MW average monthly peak load, or medium industrials above 1 MW average monthly peak load who have opted into the Industrial Conservation Initiative (ICI), or designated industrial loads above 500 kW average monthly peak load who have opted into the Industrial Conservation Initiative (ICI).
3. Class B loads are all loads that are not Class A.
4. Class A loads can reduce their GA changes by reducing their loads during the 5 highest power demand periods (measured in the previous year). Theoretically the GA charge could be zero if the consumer has zero load during the 5 highest power demand periods. In practice that is difficult to achieve for most businesses. The table above includes the average GA paid by the Class A loads in 2017 as reported by the IESO in its Ontario Energy Report Q4 2017 electricity.

Table A1.5
Retail Price plans – Milton Hydro – effective May 1, 2018
Components in Rates for Large User >=5000 kW

Bill Component	Rate	Unit
Commodity (Class A)		
- Wholesale Market Rates		
▪ Energy	0.0158 (1)	$/kWh
▪ Global Adjustment - Class A	0.0508 (4)	$/kWh
Delivery		
- Fixed Charge	2,511.65	$/month
- Energy Charge	0.0	$/kWh
- Peak Demand Charge	7.9606 (4)	$/kW
Regulatory		
- Fixed Charge	0.25	$/month
- Energy Charge	0.0039	$/kWh
Tax	13	%

Consolidated Retail Rates for Large User >=5,000kW
(combines related bill components)

Summary	Rate	Unit
Fixed Charge	2,511.90	$/month
Energy Charge	0.0705 (4)	$/kWh
Peak Demand Charge	7.9606 (4)	$/kW
Tax	13	%

Notes

1. Wholesale market energy price varies constantly, table uses 2017 average weighted wholesale market energy price of 0.0158 $/kWh.
2. Class A are large industrial loads above 5 MW average monthly peak load, or medium industrials above 1 MW average monthly peak load who have opted into the Industrial Conservation Initiative (ICI), or designated industrial loads above 500 kW average monthly peak load who have opted into the Industrial Conservation Initiative (ICI).
3. Class A loads can reduce their GA changes by reducing their loads during the 5 highest power demand periods (measured in the previous year). Theoretically the GA charge could be zero if the consumer has zero load during the 5 highest power demand periods. In practice that is difficult to achieve for most businesses. The table above includes the average GA paid by the Class A loads in 2017 as reported by the IESO in its Ontario Energy Report Q4 2017 electricity.
4. Consumers who subscribe to the ICI program can have their global adjustment calculated based on their peak power demand (MW) relative to the electricity system peak power demand during the 5 highest power demand hours. This effectively lowers the marginal cost of energy outside those peak hours to $0.0197 per kWh.

Appendix B - Ontario's OEB Approved Price Plan Pilots

In January of 2018 the OEB approved 13 residential retail electricity price plan "pilots" for residential consumers that will be tested with a limited number of Regulated Price Plan consumers for a limited time by various LDCs.

Alectra Utilities, London Hydro, Oshawa PUC Networks Inc., Hydro One and a group of LDCs operating under the name ConsumerFirst submitted plans to participate in the pilot program and received OEB approval to proceed. However, Hydro One subsequently withdrew its five price plan pilots from the program. The Hydro One price plan pilots are summarized in this appendix as Tables B9 through B13 inclusive. Because they were withdrawn the Hydro One pilot plans have not been analyzed in this report.

Alectra Utilities (formerly PowerSteam Inc. in York Region) has tested a price plan pilot since 2015 called Advantage Power Pricing (APP). The pilot has been renamed and is now identified to consumers as the "APP-Dynamic" price plan and is described in Table B3 - "Variable Peak Pricing with CPP" price plan. Critical Peak Pricing (CPP) is a higher rate that is applied during high power demand periods when the electricity system is under stress.

One of the authors of this report has been a subscriber of the earlier Alectra Utilities APP pilot and the more recent APP-Dynamic pilot and found these pilots much easier and more convenient to use than the standard TOU Price Plan offered across Ontario. The higher cost periods are at the same hours all year round from 3 pm to 9 pm and therefore easier to remember. However, the savings from load shifting are modest because of the difficulty in manually reducing load without the benefit of an automatic load controller and energy storage equipment. That equipment is currently too expensive to purchase based on the maximum savings offered by the APP-Dynamic Price Plan.

The detailed descriptions of the pilots are available from the OEB website[25].
A summary of the 13 plans is presented below. The first 8 plans (Tables B1 to B8) have been analyzed in detail in this report. Tables B1 to B13 only show the incremental price for each additional kWh of electricity. The fixed monthly charges are not shown in the tables. All pilot plan rates are subject to regular review by the OEB (typically semi-annually).

[25] OEB Approved RPP Pilot Structures and Pricing, accessed Dec 29, 2018: https://www.oeb.ca/sites/default/files/approved-rpp-pilot-structures-prices-20180423.pdf and https://www.oeb.ca/industry/policy-initiatives-and-consultations/rpp-roadmap

Table B1
"Enhanced Time-of-Use" Price Plan (Alectra Utilities, CustomerFirst)

Period	Summer May - Oct	Winter Nov - Apr	C-Price ¢/kWh	R-Price ¢/kWh
Off-Peak	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All day	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All day	4.4	6.61
Mid-Peak	Weekday: 7am - 11am Weekday: 5pm – 7pm	Weekday: 11am – 5pm	13.2	15.41
On-Peak	Weekday: 11am – 5pm	Weekday: 7am - 11am Weekday: 5pm – 7pm	17.5	19.71

Notes:
- C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
- Weekend includes 10 statutory holidays.
- Rates effective May 1, 2018.

Table B2
"Low Overnight" Price Plan (Alectra Utilities)

Period	Summer May - Oct	Winter Nov - Apr	C-Price ¢/kWh	R-Price ¢/kWh
Overnight Off-Peak	12am - 6am	12am - 6am	2.0	4.21
Off-Peak	Weekday: 6am - 7am Weekday: 7pm – 12am Weekend: 6am – 12am	Weekday: 6am - 7am Weekday: 7pm – 12am Weekend: 6am – 12am	6.5	8.71
Mid-Peak	Weekday: 7am - 11am Weekday: 5pm – 7pm	Weekday: 11am – 5pm	9.2	11.41
On-Peak	Weekday: 11am – 5pm	Weekday: 7am - 11am Weekday: 5pm – 7pm	18.3	20.51

Notes:
- C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
- Weekend includes 10 statutory holidays. Rates effective May 1, 2018.

Table B3
"Variable Peak Pricing with CPP" Price Plan (Alectra Utilities)

Period	Hours	C-Price ¢/kWh	R-Price ¢/kWh
Off-Peak	Weekday: 12am – 3pm Weekday: 9pm – 12am Weekend: All day	4.9	7.11
Low On-Peak	50% of Weekdays: 3pm - 9pm	9.9	12.11
Medium On-Peak	30% of Weekdays: 3pm - 9pm	19.8	22.01
High On-Peak	20% of Weekdays: 3pm - 9pm	39.7	41.91
Critical Peak Price (CPP)	Top 6 peak days each summer and winter. Each 4 hours in duration	49.6	51.81

Notes: C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
Weekend includes 10 statutory holidays.
12 CPP events per year each four hours in duration. Rates effective May 1, 2018.

Table B4
"Quick-Ramping CPP" Price Plan (London Hydro)

Period	Summer May - Oct	Winter Nov - Apr	C-Price ¢/kWh	R-Price ¢/kWh
Off-Peak	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	5.5	7.71
Mid-Peak	Weekday: 7am - 11am Weekday: 5pm – 7pm	Weekday: 11am – 5pm	9.4	11.61
On-Peak	Weekday: 11am – 5pm	Weekday: 7am - 11am Weekday: 5pm – 7pm	13.2	15.41
Quick-Ramping CPP	8 peak days Jul & Aug 4 peak days Jun & Sep 2 consecutive hours from 4pm – 8pm	8 peak days Jan & Feb 4 peak days Dec & Mar 2 consecutive hours from 4pm – 8pm	49.9	52.11

Notes: C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
Weekend includes 10 statutory holidays. Rates effective January 30, 2018.
Load controllers required to automatically reduce load during CPP events.
48 Quick-Ramping CPP events per year each 2 hours in duration.

Table B5
"Seasonal Time-of-Use with CPP" Price Plan (Oshawa PUC Networks)

Period	**Summer Jun - Aug**	**Winter Dec - Feb**	**Shoulder Sep-Nov Mar-May**	**C-Price ¢/kWh**	**R-Price ¢/kWh**
Off-Peak	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	N/A	5.3	7.51
On-Peak	Weekday: 7am - 7pm	Weekday: 7am – 7pm	N/A	13.2	15.41
Shoulder	N/A	N/A	All Hours	7.9	10.11
CPP	4 peak days Jul & Aug 2 peak days Jun from 4pm - 8pm Each 4 hours in duration	4 peak days Jan & Feb 2 peak days Dec from 4pm – 8pm Each 4 hours in duration	N/A	26.3	28.51

Notes:
- C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
- Weekend includes 10 statutory holidays.
- 20 CPP events per year each four hours in duration.
- Rates effective May 1, 2018

Table B6
"Seasonal Time-of-Use" Price Plan (CustomerFirst)

Period	**Summer Jun - Aug**	**Winter Dec - Feb**	**Shoulder Sep-Nov Mar-May**	**C-Price ¢/kWh**	**R-Price ¢/kWh**
Off-Peak	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	N/A	5.4	7.61
On-Peak	Weekday: 7am - 7pm	Weekday: 7am – 7pm	N/A	13.5	15.71
Shoulder	N/A	N/A	All Hours	8.1	10.31

Notes:
- C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
- Weekend includes 10 statutory holidays.
- Rates effective May 1, 2018

Table B7
"Super-Peak Time-of-Use" Price Plan (Oshawa PUC Networks)

Period	**Summer** **Jun - Aug**	**Winter** **Sep - May**	**C-Price** **¢/kWh**	**R-Price** **¢/kWh**
Off-Peak	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	6.3	8.51
On-Peak	Weekday: 7am - 1pm	Weekday: 7am – 7pm	9.5	11.71
Super-Peak	Weekday: 1pm – 7pm	N/A	25.2	27.41

Notes: C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
Weekend includes 10 statutory holidays. Rates effective May 1, 2018

Table B8
"Alternative Quick-Ramping CPP" Price Plan (London Hydro)

Period	**Summer** **May - Oct**	**Winter** **Nov - Apr**	**C-Price** **¢/kWh**	**R-Price** **¢/kWh**
Off-Peak	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	6.0	8.21
Mid-Peak	Weekday: 7am – 11am Weekday: 5pm – 7pm	Weekday: 11am – 5pm	9.4	11.61
On-Peak	Weekday: 11am – 5pm	Weekday: 7am – 11am Weekday: 5pm – 7pm	13.2	15.41
Quick-Ramping CPP	6 peak days Jul & Aug 3 peak days Jun & Sep Each one hour in duration Between 4 pm and 8 pm	6 peak days Jan & Feb 3 peak days Dec & Mar Each one hour in duration Between 4 pm and 8 pm	59.5	61.71

Notes: C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
Weekend includes 10 statutory holidays. Rates effective May 1, 2018
36 Quick Ramping CPP events each one hour in duration.

[Hydro One Pilot Plans B9 and B10 were withdrawn on June 22, 2018][26]

Table B9
"Time-of-Use Enhanced 3-Part Rate" Plan (Hydro One)

Period	**Summer** **May - Oct**	**Winter** **Nov - Apr**	**C-Price** **¢/kWh**	**R-Price** **¢/kWh**
Off-Peak	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	Weekday: 12am - 7am Weekday: 7pm – 12am Weekend: All Day	0.6	2.81
Mid-Peak	Weekday: 7am – 11am Weekday: 5pm – 7pm	Weekday: 11am – 5pm	12.4	14.61
On-Peak	Weekday: 11am – 5pm	Weekday: 7am – 11am Weekday: 5pm – 7pm	33.2	35.41

Notes:
- C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
- Weekend includes 10 statutory holidays.
- Rate protection available for $8 per month. Rates effective May 1, 2018.
- This pilot plan has a full retail price rate that is low enough during off-peak periods to economically displace propane and fuel oil but is not low enough to displace natural gas.
- Winter heating power demand is much higher than summer cooling power demand in Ontario. Distribution system equipment loading needs to be considered if no limit is placed on consumers' electric heating power demand.

Table B10
"Time-of-Use 2-Part Rate" Price Plan (Hydro One)

Period	**Summer** **May - Oct**	**Winter** **Nov - Apr**	**C-Price** **¢/kWh**	**R-Price** **¢/kWh**
Off-Peak	Weekday: 12am – 1pm Weekday: 6pm – 12am Weekend: All Day	Weekday: 12am – 4pm Weekday: 8pm – 12am Weekend: All Day	4.9	7.11
On-Peak	Weekday: 1pm – 6pm	Weekday: 4pm – 8pm	28.0	30.21

Notes:
- C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
- Weekend includes 10 statutory holidays.
- Rate protection available at $3 per month. Rates effective May 1, 2018

[26] Jun 22, 2018 letter withdrawing all Hydro One RPP pilot plans, accessed Dec 29, 2018. http://www.rds.oeb.ca/HPECMWebDrawer/Record/612521/File/document

[Hydro One Pilot Plan B11 was withdrawn on June 22, 2018][27]

Table B11
"Variable Peak Pricing" Price Plan (Hydro One)

Period	**Summer May - Sep**	**Winter Oct - Apr**	**C-Price ¢/kWh**	**R-Price ¢/kWh**
Off-Peak	Weekday: 12am – 1pm Weekday: 5pm – 12am Weekend: All Day (except Super-Critical and Critical days)	Weekday: 12 m – 5pm Weekday: 7pm – 12am Weekend: All Day	6.4	8.61
Super Critical On–Peak	10 peak days from 1 pm – 5 pm	N/A	54.8	57.01
Critical On–Peak	25 non-super critical from 1pm – 5pm	N/A	33.7	35.91
Non-Critical On–Peak	Non-Super Critical & Non-Critical Weekday from 1pm – 5pm	Weekday 5pm – 7pm	23.6	25.81

Notes:

- C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
- Weekend includes 10 statutory holidays.
- Rate protection available at $3 per month
- Rates effective May 1, 2018

[27] Jun 22, 2018 letter withdrawing all Hydro One RPP pilot plans, accessed Dec 29, 2018. http://www.rds.oeb.ca/HPECMWebDrawer/Record/612521/File/document

[Hydro One Pilot Plans B12 and B13 were withdrawn on June 22, 2018][28]

Table B12
"Real Time Price Rate Treatment" Price Plan (Hydro One)

Period	Summer May - Sep	Winter Oct - Apr	C-Price ¢/kWh	R-Price ¢/kWh
Low Price Days	138 days with lowest demand (90% of days)	N/A	Hourly price between 6.9 and 11.5	Hourly price between 9.11 and 13.71
High Price Days	15 days with highest demand (10% of days)	N/A	Hourly price between 1.3 and 85.0	Hourly price between 3.51 and 87.21
All Days	N/A	All hours	8.0	10.21

Notes:

- C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
- Weekend includes 10 statutory holidays.
- Rate protection available at $3 per month
- Rates effective May 1, 2018

Table B13
"Flat Prices" Price Plan (Hydro One)

Period	C-Price ¢/kWh	R-Price ¢/kWh
All days, All hours	9.8	12.01

Notes:

- C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
- Rates effective May 1, 2018

[28] Jun 22, 2018 letter withdrawing all Hydro One RPP pilot plans, accessed Dec 29, 2018. http://www.rds.oeb.ca/HPECMWebDrawer/Record/612521/File/document

Appendix C - OSPE's Modified Low Overnight Smart Price Plan

The OSPE Modified Low Overnight Smart Price Plan was designed for residential consumers. Making major structural changes to the existing consumer price plans can add costs for LDCs and confusing for consumers especially those who are not technically minded. OSPE reviewed the TOU-style plans approved by the OEB to determine if they could be used with minor modifications to capture most of the features of smart price plans described in the body of this report in Section 4 (Volume 1).

OSPE identified one OEB approved price plan pilot from Alectra Utilities called the "Low Overnight Price Plan" summarized in Appendix B, Table B2. That plan captured most of the features of smart price plans. The plan was also less likely to create loading problems for the distribution and transmission systems because it offers low rates only from 00:00 to 06:00 am. That period has the lowest electricity system power demands.

For residential consumers distribution costs are closely associated with the size of the consumer's physical connection to the distribution system. That connection does not change once it is installed. Distribution costs are now paid for primarily as a fixed monthly charge on consumers' bills. OSPE agrees that is the correct approach. OSPE has assigned all distribution cost and some regulatory costs to the monthly fixed charge for the OSPE Modified Low Overnight Smart Price Plan.

To enable consumers to economically displace fuel oil, propane and natural gas using surplus emission-free electricity (one of the key features of smart price plans) it was necessary to modify 2 of the rates within the Alectra Utilities Low Overnight Price Plan. The overnight off-peak retail rate was reduced from 4.21 ¢/kWh to 1.22 ¢/kWh of electricity. The on-peak retail rate was raised from 20.51 to 20.64 ¢/kWh. The distribution charge was also increased to make it entirely a fixed monthly charge with no variable energy component.

OSPE believes that overnight retail energy rates that are higher than the wholesale market energy rates effectively act as a subsidy to daily on-peak rates. This subsidy creates variances from optimal price signals, encourages additional on-peak demand, increases overall system costs and ultimately results in higher rates for the consumer.

The retail rate for overnight off-peak energy of 1.22 ¢/kWh was set to match the volume weighted average wholesale market energy price during the overnight off-peak hours from 00:00 to 06:00 am. That was necessary to lower the retail energy price sufficiently to incentivize urban consumers to displace their natural gas using surplus emission-free electricity at its actual marginal cost.

The volume weighted average wholesale market energy price during the overnight off-peak hours in 2018 was 1.22 ¢/kWh. The OEB applies a delivery energy markup of 2.21 ¢/kWh for Milton Hydro consumers. To achieve a retail energy rate of 1.22 ¢/kWh for each additional kWh of energy, the commodity price would have to be minus 0.99 ¢/kWh.

Effectively, the OEB approved delivery markup based on energy consumption would be collected only during off-peak, mid-peak and on-peak periods and not during the overnight off-peak period.

The retail rate for on-peak energy was raised for the following reasons:

- To offset the lost revenue from the overnight off-peak rate reduction
- To better match the higher cost of supplying on-peak energy consumption
- To further incentivize consumers to reduce on-peak energy consumption
- To further incentivize consumers to level their hourly energy consumption

The resulting OSPE Modified Low Overnight TOU Smart Price Plan for residential consumers is summarized in Table C-1 and Figure C-1 below. Appendix G provides detailed analysis for various cost reduction strategies.

Table C-1
Comparison of Standard TOU Price Plan with the OSPE Modified Low Overnight Smart Price Plan (Milton Hydro) May 1, 2018 Rates (All Components Included – Typical Home)

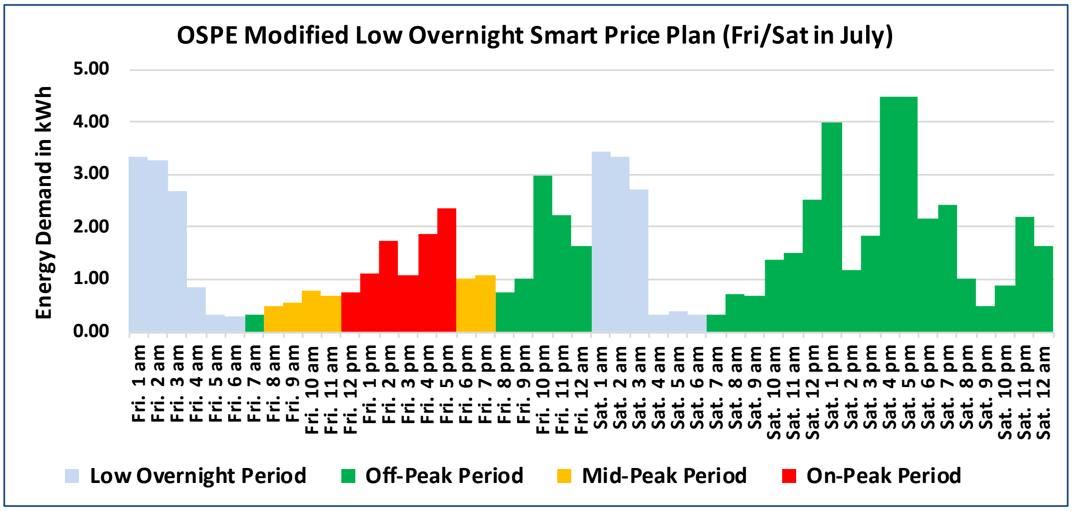
Electricity Charges	Standard TOU Price Plan	Modified Low Overnight Smart Price Plan	Billing Units
Fixed Monthly Charge	25.56	28.34	$/month
Energy: TOU On-peak Rate	0.1541	0.2064	$/kWh
TOU Mid-peak Rate	0.1161	0.1141	$/kWh
TOU Off-peak Rate	0.0871	0.0871	$/kWh
TOU Overnight Rate	-	0.0122	$/kWh
Surplus Energy Rate	-	0.0062 (4)	$/kWh
Sales Tax Rate	5	5	%
Total Bill (before taxes, load leveling and fossil fuel displacement)	**1,247 (3)**	**1,247 (3)**	**$/yr**

Notes:

1. The table assumes the same hourly load profile for both plans.
2. The table includes the Fair Hydro Plan rate reduction until Dec 2021.
3. The annual “total bill” above does not include load shifting or surplus electricity use for fossil fuel displacement. If the consumer’s behaviour remains identical before and after they adopt the smart price plan, they will pay the same amount. If they modify their behaviour they will save money. If they displace other forms of energy (such as gasoline with an electric or plug-in hybrid car) they will save even more.

4. The surplus energy rate applies to surplus emission-free electricity whenever it becomes available any time of day for fossil fuel displacement. However, to offer the surplus electricity rate any time of day would require the LDC to have additional communication capability with the consumer's load control equipment.
5. All rates are subject to regular review (typically semi-annually).

Figure C-1
OSPE Modified Low Overnight Smart Price Plan (Milton Hydro)



Note: Load shifting and electricity use for fossil fuel displacement are not shown above.

Table C-2
OSPE Modified Low Overnight Smart Price Plan (Milton Hydro)

Period	Summer May - Oct	Winter Nov - Apr	C-Price ¢/kWh	R-Price ¢/kWh
Overnight Off-Peak	12am - 6am	12am - 6am	- 0.99	1.22
Off-Peak	Weekday: 6am - 7am Weekday: 7pm – 12am Weekend: 6am – 12am	Weekday: 6am - 7am Weekday: 7pm – 12am Weekend: 6am – 12am	6.5	8.71
Mid-Peak	Weekday: 7am - 11am Weekday: 5pm – 7pm	Weekday: 11am – 5pm	9.2	11.41
On-Peak	Weekday: 11am – 5pm	Weekday: 7am - 11am Weekday: 5pm – 7pm	18.43	20.64

Notes for Table C-2:

- C-Price is the Commodity Price; R-Price is the full Retail Price of 1 more kWh.
- Weekend includes 10 statutory holidays. Rates effective May 1, 2018.
- The 2018 delivery fixed monthly charge is $340.08/yr or $28.34/mon.
- The plan above is designed for Milton Hydro residential consumers.
- All rates are subject to regular review (typically semi-annually).

Table C-2 provides additional details of the commodity prices and the adjustments necessary to achieve the correct wholesale market energy price during the midnight to 6 am time period.

The least complicated implementation substitutes the OSPE Modified Low Overnight Price Plan for the Alectra Utilities Low Overnight Price Plan with no other changes. Other improvements to the plan are possible but would make the plan more complicated to deploy.

Alectra Utilities has a "Variable Peak Pricing with CPP Price Plan" pilot (see Appendix B, Table B3). That plan has some very attractive features for a price plan. The plan fixes the on-peak period during working days at 3 pm to 9 pm all year. That on-peak period is better aligned with the actual electricity system on-peak period. The period is also easier for the consumer to remember because it does not change during the year. Also, the on-peak prices in that plan vary during the year according to the electricity system power demand. This better aligns the retail rates with the actual cost of supplying peak power demand at different times of the year. For Milton Hydro consumers, during days with the highest electricity system demand, the on-peak energy rate would rise to 41.91 ¢/kWh. The plan also includes 12 Critical Peak Pricing (CPP) events when system reserves are being challenged. The CPP rate would be 51.81 ¢/kWh.

If communication capabilities between the LDC and consumer were available, it would be possible to provide the lower energy rate of 0.62¢/kWh whenever surplus emission-free electricity was available even during a windy and sunny afternoon. The type of communication required will depend on the implementation details the LDC chooses. One-way communication to the consumer's equipment is sufficient if the number of hours the surplus is made available is limited to low electricity system demand periods. However, if the LDC wants to make surplus electricity available during all hours of the year the communication link will likely need to be two-way so that consumers do not game the rates to avoid paying their fair share of the fixed cost of the electricity system for their dependable on-peak electricity needs. The design details of such a link are beyond the scope of this report.

Combining the best features of the Table B2 and Table B3 Alectra Utility pilot plans with communication capability would create a very effective smart price plan. OSPE encourages Alectra Utilities to design and seek OEB approval to deploy such a smart price plan.

Fossil fuel displacement can be done easily and at low cost with thermostat-controlled heaters and timers using the OSPE Modified Low Overnight Smart Price Plan. However, the OSPE Modified Low Overnight Smart Price Plan has three disadvantages:

- The plan does not allow the consumer to access surplus electricity at its lower marginal cost outside the overnight period of 00:00 to 06:00 am. That is a disadvantage to the residential consumer but may be a benefit for the commercial and industrial consumers who then have access to surplus emission-free electricity outside the overnight period without competition from residential consumers.
- The plan allows the consumer's overnight peak demand to become larger than the consumer's daytime peak demand. This should not be a problem in the early deployment years. But if most residential consumers became subscribers to this smart price plan, the overall electricity system peak load could shift to the overnight period because residential service represents about 1/3 of total system energy demand based on IESO's Sep 2016 Ontario Power Outlook. That peak demand shift to the overnight period could be avoided by modifying the price plan to limit the amount of surplus electricity that can be consumed by the consumer.
- During the winter and summer, there will be a fraction of hours during the overnight period when fossil fuel plants will be operating to supply load. The plan does not distinguish between emission-free electricity and gas-fired electricity. The plan will allow residential consumers to displace fossil fuels with natural gas-fired electricity during hours when natural gas-fired plants are running to meet the higher winter overnight demand. During those hours, carbon dioxide emissions will double for each kWh of thermal energy the consumer needs. The reason is that natural gas-fired plants operate at less than 50% overall thermal efficiency and use more than 2 kWh of thermal energy to produce 1 kWh of electricity. That 1 kWh of electricity is later converted to 1 kWh of thermal energy using resistance heaters in the consumer's home. Consequently, the overall emissions from the gas-fired plant will be about double what the emissions would have been if a high-efficiency furnace or water heater had been used to supply that 1 kwh of thermal energy in the home.

Appendix D - OSPE's Energy Plus Peak Demand Smart Price Plan

The OSPE Energy Plus Peak Demand Smart Price Plan was designed for residential consumers. The plan was inspired by design suggestions from OSPE member, Dr. Charles Rhodes.

Most of the costs of electricity production in a low emission electricity system are fixed and are associated with peak power demand (required system capacity), not energy production.

The OSPE Energy Plus Peak Demand Smart Price Plan is designed to charge for energy consumption separately from peak power demand. Off-peak energy is available at a very low price. On-peak energy is expensive because the additional peak power demand charge is applied during on-peak periods.

The plan is designed to be used with an automatic load control system. Manual adjustments are not practical to achieve load shifts and fossil fuel displacement with surplus electricity. The adjustments are required too frequently and typically when consumers are not at home or are sleeping. It is important not to create inadvertent higher peak power demands because this plan will charge for that additional peak power demand at a high rate. The high peak power demand rate is required to pay for all the system fixed costs. The energy rate is set to recover only the low wholesale market energy price.

OSPE has assigned all distribution cost and some regulatory costs to the monthly fixed charge in the OSPE Energy Plus Peak Demand Smart Price Plan.

Separating the 3 cost components, namely costs associated with peak power demand, costs associated with energy consumption and costs associated with connection size helps to better align prices with the actual costs of providing electricity services in a low emission electricity system. That separation also more fairly compensates consumers who generate some of their own electricity without transferring system costs impacted by that generation to other consumers.

The OSPE Energy Plus Peak Demand Smart Price Plan more fairly assigns system costs based on the electricity services that each consumer uses. This also includes consumers who produce some of their own electricity. OSPE has not however evaluated the rate that should be charged for over-production by consumers who generate their own power. The current net-metering regulations do not pay for overproduction accumulated over a 12-month period.

A disadvantage of this plan is that many consumers do not understand the difference between energy and power. This plan will require some effort by the LDCs, or their industry association in Ontario, the Electricity Distributors

Association, to educate consumers on the difference between energy and power so consumers will understand their bill. To help readers of this report better understand this plan some explanatory information is provided below.

To illustrate the difference between energy and power, let us look at the case of an air conditioner (A/C). A high efficiency central A/C for a typical home uses about 4 kW of power. It runs intermittently to cool the home. When the A/C is running it draws 4 kW of power and over a period of time it consumes energy at a rate of 4 kWh of energy for every hour of running time. If the A/C only runs for 20 minutes, it still uses 4 kW of power but only for 20 minutes. During that 20 minutes the A/C only consumes 1.3 kWh of energy (the 4 kW of power multiplied by 1/3 of the hour, or, 4 kW * 1/3 h = 1.3 kWh). To operate properly the A/C must draw the full 4 kW of power from the electricity system. The electricity system must therefore provide the full 4 kW of generating plant power capacity to supply that 1.3 kWh of energy demand. In this example we have ignored the short power surge during the first few seconds that the A/C is starting up.

If the electricity system does not have the full 4 kW of additional capacity the voltage will fall and the A/C will not run. The electricity system therefore provides 2 essential electrical services. It provides power in kW and energy in kWh. The cost of providing those services is very different. Power comes from the installed capacity of generation and transmission. Energy comes from consuming the fuel supply needed to produce the electricity.

In a fossil fueled electricity system, the energy is supplied by burning fossil fuels and the cost for energy is high. Ontario has just completed the transformation of its electricity system to a very low emission system. In a low emission electrical system the energy is supplied primarily by wind, sun, nuclear fuel and water. All of these sources have very low fuel costs in Ontario ranging from zero to 1.44 ¢/kWh. In 2018 the volume weighted average cost of energy production was 2.43 ¢/kWh. That price included the cost of some natural gas fuel and industrial load reductions. During hours when natural gas generation and load reductions were not required to balance supply with load, the volume weighted average energy price in 2018 was only 0.62 ¢/kWh.

Emission-free generation capacity has high upfront fixed costs for dependable installed capacity and low fuel costs whereas high-emission generation has much lower upfront costs for dependable installed capacity but significantly higher fuel costs.

The OSPE Energy Plus Peak Demand Smart Price Plan is designed to better align retail prices for energy consumption and peak power demand with the underlying costs of providing each. The consumer's peak power demand measures the consumer's use of installed capacity. The current residential TOU price plans do not directly measure the consumer's use of installed capacity.

In Ontario we want consumers to use electricity sparingly during periods of high power demand to minimize the need for installed capacity. Energy is not expensive in a very low emission electricity system because the fuel costs are very low. In Ontario we also want consumers to draw their energy from the system when generating capacity is idle, typically at night. By separately charging for peak power demand and energy consumption we can more easily incentivize consumers to reduce their electricity use during system on-peak periods and draw more of their electricity during system off-peak periods. When consumers draw energy during off-peak periods, they should only pay for the energy they use because they impose no additional capacity requirements on the electricity system.

When consumers draw their dependable energy needs during on-peak periods they should pay for both the energy and the peak power they use. However, emission-free generation production can be higher than the dependable electricity demand on windy, sunny afternoons during low demand days especially in the shoulder seasons of spring and fall. Rather than curtailing that production we could make it available as low reliability, interruptible electricity and price it according to its marginal cost of production – the wholesale market energy price. When the surplus disappears, the consumer is expected to stop drawing low reliability electricity from the system. If they do not stop, the LDC charges them for dependable electricity. The LDC would apply both the energy and peak demand changes. To do the billing correctly the LDC needs to differentiate between dependable electricity use and surplus emission-free electricity use.

The energy price for the OSPE Energy Plus Peak Demand Smart Price Plan is obtained from the wholesale market energy price. The wholesale market energy price is sufficiently close to the true marginal cost of energy. The small amounts of fixed cost paid to low marginal cost producers that are included in the wholesale market energy price can be considered a small contribution to overall system costs. That helps to lower the cost of energy for consumers that are not able to subscribe to the new smart plan.

Residential and small commercial/industrial consumers do not consume sufficient electricity to make it practical at the present time to install the required metering and communication equipment and back-office billing systems to charge them based on either the real-time 5-minute market clearing price or the hourly HOEP price. To simplify billing for the LDCs and to smooth out price fluctuations for small consumers, OSPE suggests the volume weighted average price for the previous year (or alternatively 6 months) be held constant for billing purposes and adjusted for any errors compared to actual average prices at the next update. The OEB currently does this for the TOU price plans every 6 months.

The OSPE Energy Plus Peak Demand Smart Price Plan uses two energy rates:

- A volume weighted average energy price calculated across all hours. That price was 2.43 ¢/kWh in 2018. This rate is sufficiently low to economically displace propane and heating oil and incentivize consumers to buy electric cars by charging electric vehicles at the 2.43 ¢/kWh during low demand periods rather than the 8.71 ¢/kW during the TOU price plan's off-peak periods.
- A volume weighted average energy price calculated only during hours when there was surplus emission-free electricity available. That price was 0.62 ¢/kWh in 2018. This low rate is needed to economically displace natural gas in urban areas. It can also provide a further incentive for electric car owners to charge their vehicles when there is excess emission-free electricity available so that their vehicle's energy supply is truly emission-free.

The 0.62 ¢/kWh rate requires communication capability between the LDC and the consumer's energy management system to indicate when surplus emission-free electricity is available. LDC's with Advanced Metering Infrastructure (AMI) or equivalent communication functionality on the public internet with suitable cyber security protocols will be able to offer this low rate to their consumers when surplus emission-free electricity is available.

Some US utilities require consumers with electric cars to report their off-peak electric car charging loads in order to receive a discounted rate on that consumption for charging during low demand periods. The reporting service is available from third parties such as FleetCarma, a Waterloo, Ontario company.[29] FleetCarma provides the monitoring equipment and reports the usage to the LDC on the consumer's behalf for billing adjustments. Similar approaches can be used for fossil fuel displacement if the OEB or LDC wanted very accurate load measurements. Less accurate measurements can be done without two-way communication capability.

The energy management system can allow as much off-peak electricity consumption as the consumer needs or it can limit the extra electricity use up to the consumer's monthly average peak power demand. There are two problems with unlimited use of off-peak electricity.

- Because winter hourly thermal energy consumption on the coldest days are about 5 times higher than summer peak hourly electrical energy consumption, if we allowed unlimited use by all consumers we would shift

[29] FleetCarma, Smartcharge Rewards program for electric car owners and LDCs, accessed February 23, 2019, https://www.fleetcarma.com/smartcharge-rewards/
The inflexibility of current OEB approved retail price plans has a further adverse impact. It forces innovative technology developers to deploy their technologies outside of Ontario rather than in their home market here in Ontario.

the system-wide peak from summer daytime hours to winter night-time hours and the winter peak would be much higher than the summer peak. That would require more installed capacity at a significantly higher additional cost for the electricity system.

- When consumer demand for surplus emission-free electricity exceeds the supply, natural gas-fired plants will need to start up to supply the demand. This has two negative consequences:
  - Wholesale market energy price will rise significantly because a natural gas-fired plant has a higher marginal cost of energy production than emission-free plants
  - Emissions will rise because when electricity is made with natural gas-fired plants the emissions are 400 grams carbon dioxide per kWh of electricity. High efficiency furnaces and water heaters produce about ½ those emissions per kWh of thermal energy.

OSPE analyzed both limited and unlimited fossil fuel displacement. Limited displacement means that the use of surplus electricity is limited so that the total electrical power demand in any hour does not exceed the consumer's monthly average peak power demand. Unlimited displacement means that the use of surplus electricity is not limited. The analysis was done to see how much additional energy savings and emission reductions a consumer can achieve in the early years of deployment when there is plenty of electricity system capacity to supply whatever thermal load demand the consumer requires.

The consumer's energy saving and emission reduction for unlimited fossil fuel displacement is about double compared to limited displacement. This suggests providing unlimited displacement in the early years of smart price plan deployment would be helpful. Later, when subscriber numbers are high enough to cause concerns about system-wide load demands at night the smart price plans can be modified to allow only limited displacement. This approach would provide early adopter advantage. It would reduce the payback period for equipment investments, encourage faster smart price plan deployment and achieve more rapid emission reductions.

The OSPE Energy Plus Peak Demand Smart Price Plan provides the LDC the option to use communication capability to implement better control over the use of surplus emission-free electricity. The LDC can assign consumers to load blocks. The load blocks can then be given access to surplus emission-free electricity in keeping with the ability of the LDC's various feeders to supply that load.

The peak power demand rate for the OSPE Energy Plus Peak Demand Smart Price Plan had to be determined by a more complicated analysis to better understand the relationship between the IESO reported actual system costs, the residential consumer's share of those system costs and the impact of the Fair Hydro Plan on revenues. This analysis is explained below.

Billing consumers by peak power demand requires that we accommodate the following considerations:

- Billing is currently done monthly using monthly data. Electrical capacity is constructed over several years and cannot be lowered or raised to adjust to monthly variations. However, in order to simplify LDC billing, monthly billing is based on monthly demand data.
- Consumers in a rate group do not create their individual peak power demand in the same time interval in their rate group. An individual consumer's peak load needs to be discounted to assess the impact of that load on the overall system peak demand. One way to do that is to use a monthly average of each day's peak hourly power demand.
- Short large spikes in power demand by an individual consumer should not affect the monthly bill so some filtering or averaging of the instantaneous peak power demand is required. This report uses the hourly average power demand calculated by taking the energy consumed in a one-hour interval and dividing by 1 hour to establish the hourly average power demand (ie: kWh/h = kW).
- The OEB currently requires new Price Plans to be revenue neutral based on a typical consumer in the same rate group. OSPE used the load profile for a residential consumer that used the same annual energy amount as the OEB's typical residential consumer uses per year.

From an electricity system's cost perspective, a consumer who requires dependable electricity during the system-wide peak hours is more costly to service than a consumer whose peak power demand occurs during the system-wide off-peak hours.[30] Ideally, we would like to reflect that difference in the cost of providing that service in the consumer's billing. This more accurate difference in the consumer's cost of service can be accomplished by calculating the consumer's average peak power demand only during the system-wide peak hours. However, there is no guarantee that the system-wide peak hours will remain stationary. In fact, peak hours have been shifting as more people install behind-the-meter solar generation and also shift their loads to later hours. Chasing a moving system-wide peak power demand period is confusing for consumers. Consequently, for the purposes of this report, OSPE uses the monthly average peak power demand regardless of the time in a 24-hour day those peaks occur for both the electricity system and the consumer.

This report calculates the monthly average peak power demand for both the consumer and the electricity system by first finding hour with the highest energy

[30] Consumers who use electricity during the system on-peak hours impose additional installed capacity demands on the electricity system. Additional capacity is expensive.

consumption, converting that energy into an hourly average peak power demand (kWh divided by 1 hour) and then averaging all the daily peak power demands for the whole month.

The annual cost of running the electricity system is published by the IESO in its periodic Ontario Power Outlook. OSPE used the September 2016 version. OSPE used the IESO 2018 values expressed in 2016$s by the IESO and escalated the 2016$ by 2% for each year to get the system costs in 2018$s.

The total fixed costs reported by IESO to operate the electricity system for the whole year (including the system reserve capacity) was divided by the sum of the 12 system-wide monthly average peak power demands. The result was a peak power demand rate of $67.53 per kW per month[31] in order to recover all the fixed costs of operating the power system using monthly billing. Only the costs associated with providing power demand were included. Those system costs were the generation costs, transmission costs, conservation costs and wholesale market operation costs. Energy costs and distribution costs were excluded because they are accounted for separately in the OSPE Energy Plus Peak Demand Smart Price Plan.

The monthly peak power demand rate required to achieve annual revenue neutrality requirement between the standard TOU price plan and the OSPE Energy Plus Peak Demand Smart Price Plan was determined to be $32.54 /kW/month for the smart price plan prior to the Fair Hydro Plan rate reduction. Since the $67.53 per kW per month and $32.54 per kW per month don't match that means residential consumers as a group do not pay their fair share of the electricity system fixed costs.

The $32.54 /kW/month was further adjusted to reflect the Fair Hydro Plan rate reduction for residential consumers for 2018 based on OEB data published on its website. The peak power demand rate, including the Fair Hydro Plan discount, was calculated to be $22.78 /kW/month. The difference between $32.54 /kW/month and $22.78 /kW/month is being financed by a deferral account. Those costs will be recovered after the Fair Hydro Plan expires at the end of 2021.

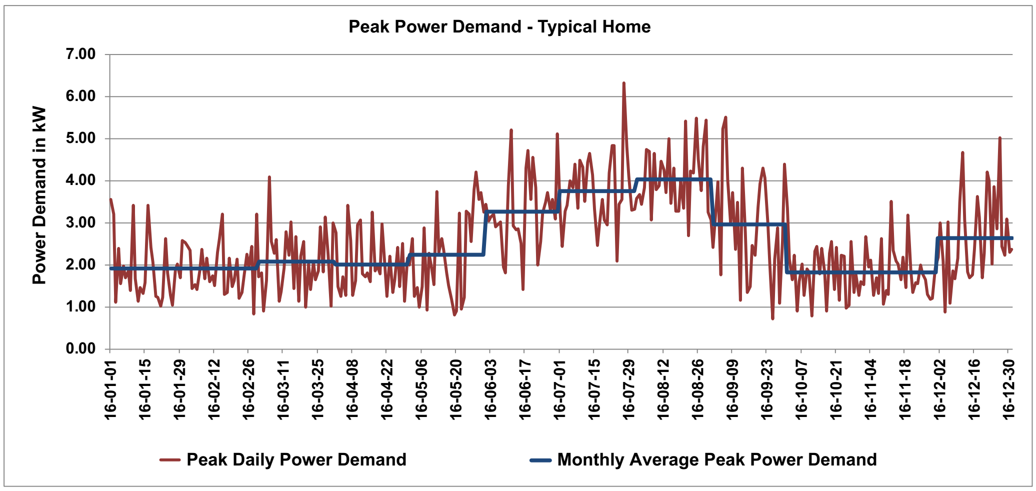
The residential consumer that OSPE chose for this analysis is a specific consumer with the same annual energy consumption as the Ontario typical residential consumer. However, OSPE did not have access to the typical Ontario residential consumer's hourly load profile. The consumer's monthly average peak power demands that OSPE calculated for this report to arrive at various price plan rates was for one specific consumer. The resulting rates will likely need to be adjusted after a more comprehensive analysis is done by the OEB of a larger sample of

[31] The calculations that determined the monthly peak power demand rates were performed in a separate spreadsheet file that is not included in this appendix.

consumers before the OSPE Energy Plus Peak Demand Smart Price Plan can be deployed.

Figure D-1 below shows the highest hourly power demand each day (called the peak daily power demand) and the monthly average peak power demand. The resulting rate structure of the OSPE Energy Plus Peak Demand Smart Price Plan is detailed in Table D-1 below.

Figure D-1
Daily Peak and Monthly Average Power Demand
Typical Residential Consumer



Note: Load shifts and electricity use for fossil fuel displacement are not shown above.

Table D-1
Comparison of Standard TOU Price Plan with the OSPE Energy Plus Peak Demand Smart Price Plan (Milton Hydro)
May 1, 2018 Rates (All Components Included – Typical Home)

Electricity Charges	**Standard TOU Price Plan**	**Energy Plus Peak Demand Smart Price Plan**	**Billing Units**
Fixed Monthly Charge	25.56	28.34	$/month
Energy: TOU On-peak Rate	0.1541	-	$/kWh
TOU Mid-peak Rate	0.1161	-	$/kWh
TOU Off-peak Rate	0.0871	-	$/kWh
Monthly Peak Demand Rate	-	22.78	$/kW/month
Energy Rate (all except surplus)	-	0.0243	$/kWh
Surplus Energy Rate	-	0.0062 (4)	$/kWh
Sales Tax Rate	5	5	%
Total Bill (before taxes, load leveling and fossil fuel displacement)	**1,247 (3)**	**1,247 (3)**	**$/yr**

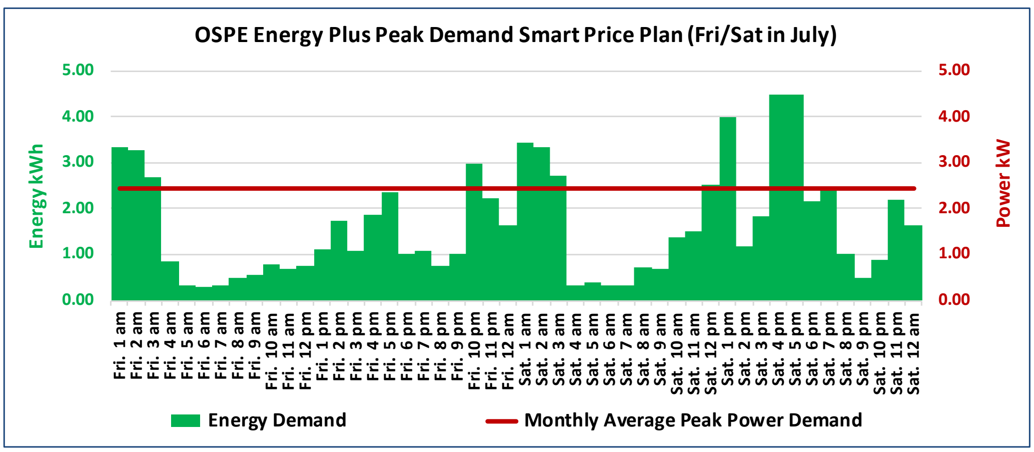
Notes for Table D-1:

1. The table assumes the same hourly load profile for both plans.
2. The table includes the Fair Hydro Plan rate reduction until Dec 2021.
3. The annual "total bill" above does not include load shifting or surplus electricity use for fossil fuel displacement. If the consumer's behaviour remains identical before and after they adopt the smart price plan, they will pay the same amount. If they modify their behaviour they will save money. If they displace other forms of energy (such as gasoline with an electric or plug-in hybrid car) they will save even more.
4. The surplus energy rate applies to surplus emission-free electricity for fossil fuel displacement. However, that rate requires communication capability at the LDC.
5. All rates are subject to regular review (typically semi-annually).

The resulting rate structure of the OSPE Energy Plus Peak Demand Smart Price Plan is diagrammatically illustrated in Figure D-2 below.

Appendix G provides detailed analysis for various cost reduction strategies.

Figure D-2
OSPE Energy Plus Peak Demand Smart Price Plan (Milton Hydro)



Notes for Figure D-2:

1. Workdays, weekends and holidays are all treated the same way. A July Fri/Sat is shown.
2. Load shifting and energy consumption for fossil fuel displacement is not shown above.
3. The monthly average peak power demand is calculated by averaging each day's highest hourly average peak power demand. The hourly average peak power demand in kW is the total accumulated energy consumption that hour divided by one hour (kWh/h).

For discussion purposes, energy consumed in any hour below the monthly average peak power demand (red line in Figure D-2 below) is charged at only the energy rate of 0.0243 $/kWh or 2.43 ¢/kWh. Strictly speaking, each hourly consumption would have to be below that day's highest demand hour to avoid creating a higher average monthly peak power demand.

For discussion purposes, dependable energy consumed in any hour above the red line in figure D-2 will increase the monthly average peak power demand. Consequently, that energy will be expensive. For a 30-day month, each additional kWh of electricity consumption that increases the monthly average peak power demand (the red line in Figure D-2) would cost the consumer:

$22.78 ÷ 30 + $0.0243 = 0.7836 $/kWh or 78.36 ¢/kWh

This high cost for increasing the monthly average peak power demand is the primary reason why it is important for consumers to commit to installing an automatic load control system if they subscribe to the OSPE Energy Plus Peak Demand Smart Price Plan. Manual load management is not practical because it is impossible to consistently compensate manually for a sudden rise in electrical power demand from a large household appliance. The automatic energy management system can make available substantial amounts of low-cost electricity during the consumer's low demand periods and continuously adjust the surplus interruptible electricity flow based on other loads in the home that need dependable electricity. Those low-cost energy periods and the energy amounts are visually represented in Figure D-2 as the blank (white) areas under the red line.

During the summer only a portion of that low-cost surplus electricity can be used provided that the consumer has fossil fueled hot water heaters. In the winter a greater portion can be used for fossil fuel displacement for space heating.

Surplus electricity use is not shown in the diagrams above. The surplus electricity energy rate would be applied only if surplus emission-free electricity is available. The LDC would have to have a communication capability with the consumer's load controller to offer the surplus emission-free electricity energy rate of 0.62 ¢/kWh.

Not all LDCs will be able to offer communication capability with the consumers load control equipment at the early stages of deployment of the smart price plan. For consumers in areas where their LDC does not have additional communication capability, surplus electricity would be available at the average wholesale market energy rate of $0.0243 /kWh or 2.43 ¢/kWh. As indicated earlier this is a sufficiently low rate to displace propane and fuel oil for thermal energy needs but not low enough to displace natural gas. That rate also allows consumers to displace propane and fuel oil during off-peak periods even if surplus electricity is not available. This consumption would help level the overall electricity system load and contribute to improved electricity system economic performance albeit with a slightly higher emission profile because natural gas generation might be called upon to provide electricity when renewable generation is not available during some of those off-peak hours.

If the LDC does have additional communication capability, the OSPE Energy Plus Peak Demand Smart Price Plan offers the best value for consumers and the highest emission reductions. It offers the lowest energy rate for the entire day except for the highest load demand hour each day. Appendix G provides detailed analysis for various cost reduction strategies.

The type of communication required will depend on the implementation details the LDC chooses. One-way communication to the consumer's equipment is sufficient if the number of hours the surplus is made available is limited to low electricity system demand periods. However, if the LDC wants to make surplus electricity available during all hours of the day, and depending on the billing accuracy requirements, the communication link may need to be two-way so that consumers do not avoid paying their fair share of the fixed cost of the electricity system. The design details of such a link are beyond the scope of this report.

Appendix E - OSPE's Energy Only Smart Price Plans

The OSPE Energy Only Smart Price Plan was designed for residential consumers who:

- do not understand the difference between energy and power,
- prefer to be billed on energy consumption only, and
- wish to take advantage of low-cost surplus electricity.

OSPE began to develop this plan in 2010 after the government made a commitment to install 7,500 MW of wind generation. OSPE's analysis at the time[32] indicated much of that energy would come at night and correctly predicted that most of it would be wasted.

OSPE wanted to determine if it could design a smart price plan that would encourage consumers to shift some of their dependable on-peak loads to off-peak periods so they could use the available surplus wind generation that would be available at night in future years. The plan has evolved over the subsequent years.

Conceptually, OSPE's Energy Only Smart Price Plan differentiates between base-load power demand (round the clock energy consumption) and peak-load power demand (energy consumed only during the daytime).

To develop the OSPE Energy Only Smart Price Plan a number of design principles were followed:

- All distribution costs (and some regulatory costs) are recovered with a fixed monthly charge.
- The base-load energy rates were calculated based on the May 1, 2018 OEB costs for various base-load generation types in proportion to their contributions to energy production. Solar and natural gas generation costs were assigned to the peak-load category. The May 1, 2018 base-load generation costs were:
  - Hydroelectric 6.2 ¢/kWh
  - Nuclear 7.7 ¢/kWh
  - Wind 15.9 ¢/kWh
- All energy rates for this plan include a 21% mark-up for transmission, conservation and regulatory costs based on the IESO September 2016 Ontario Power Outlook's estimated amount of those costs relative to generation costs.

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[32] Ontario Society of Professional Engineers, *Wind and the Electrical Grid – Mitigating the Rise in Electricity Rates and Greenhouse Gas Emissions*, (March, 2012). Accessed Jan. 29, 2019. https://www.ospe.on.ca/public/documents/advocacy/2012-wind-electrical-grid.pdf

- A consumer's dependable base-load electrical needs should have a rate consistent with the total system cost of supplying base-load electricity. That rate was defined as the Base-load Rate which is made up of the blended costs of hydroelectric, wind and nuclear generation plus the 21% mark-up mentioned above. The base-load rate was calculated to be 9.62 cents/kWh in 2018 without the Fair Hydro Plan discount and 7.24 cents/kWh with the Fair Hydro Plan discount. This creates a single base-load rate and simplifies the monthly billing calculations. The consumer's maximum base-load kWh allowance for each hour is determined from the average hourly energy consumption from 00:00 am to 06:00 am EST averaged over the year for a typical Ontario residential consumer. That allowance is defined as the Base-load Band and was calculated to be from 0 to 0.79 kWh for each hour.
- For the purposes of creating an energy only price plan, OSPE chose to split the peak-load demand into 2 additional consumption bands above the Base-load Band. They are defined in this report as the Intermediate Load Band and the Peak-load Band. The Intermediate Load Band lies between the Base-load Band and the Peak-load Band.
- The Intermediate Load Band covers consumption levels above the Base-load Band up to 3 times Base-load Band's maximum value. The Intermediate Band is therefore from 0.79 kWh up to 2.37 kWh in each hour. The required Intermediate Load Rate was defined to be the average between the Base-load Rate and the Peak-load Rate and was calculated to be 14.22 ¢/kWh.
- The Peak-load Band covers all consumption higher than the Intermediate Band maximum value. The Peak-load Band is any consumption above 2.37 kWh in any hour. The required Peak-load Rate was calculated to be 21.20 ¢/kWh. This rate is required to achieve the same annual revenue for the LDC as the standard TOU price plan with the same load profile.
- There is some flexibility with respect to the size of the Intermediate Load Band and its energy rate. Those values impact the Peak-load Rate. OSPE wanted the Peak-load Rate to be approximately 3 times the Base-load Rate to encourage conservation and load shifting. The 3 bands and their respective rates need to be adjusted together to keep the total bill revenue neutral with respect to the standard TOU price plan. That is an OEB requirement for approval of new price plans. OSPE's choice of Intermediate Load Band size and energy rate resulted in the Peak-load Rate being 2.9 times higher than the Base-load Rate. That was close enough to 3 that OSPE did not see the need to further adjust the band size or rate for the Intermediate Load Band.
- A consumer's use of surplus emission-free electricity should have a rate consistent with the wholesale market energy price during periods when surplus emission-free electricity is available. No additional markups should be imposed because that energy is interruptible and imposes no capacity demands on the electricity system. That price was 0.62 ¢/kWh in 2018 on

a volume weighted basis. However, to offer that rate to consumers the LDC would need to have additional communication capability between the LDC and the consumers load control equipment. The type of communication required will depend on the implementation details the LDC chooses. One-way communication to the consumer's equipment is sufficient if the number of hours the surplus is made available is limited to low electricity system demand periods. However, if the LDC wants to make surplus electricity available during all hours of the day the communication link will likely need to be two-way so that consumers do not avoid paying their fair share of the fixed cost of the electricity system. The design details of such a link are beyond the scope of this report.

In the original version of the OSPE Energy Only Smart Price Plan the base-load allocation for the whole day was determined each month by calculating that specific consumer's the average power demand at night. This meant that a consumer that increased their load at night by shifting their daytime load to the night-time would qualify for a larger base-load allocation for the whole month. The economic incentive to flatten the hourly load was very attractive. In fact, it turned out to be too attractive. During detailed hourly analysis for this report, OSPE discovered the incentives to flatten the hourly load was so attractive that it was financially rewarding to keep appliances running at night in order to qualify for a larger base-load allocation during the day. A consumer could lower their monthly bill by wasting energy at night. From an electrical system point of view the generation operated more efficiently with more base-load and less peak-load demand. Unfortunately, incentivizing consumers to waste energy at night is not environmentally sound because that would result in the need for more installed capacity that was not strictly needed.

The fix was relatively simple. Rather than a base-load allocation calculated monthly based on each consumer's load profile, the base-load allocation was fixed at a constant value determined by the annual base-load consumption of a typical Ontario residential consumer. Unfortunately, that change reduced the economic benefits of load shifting. OSPE has subsequently changed its focus on encouraging fossil fuel displacement. That saves consumers money on their total annual energy bills, is beneficial for the environment and keeps more dollars, otherwise spent on imported fossil fuels, in Ontario to help stimulate the local economy.

The resulting rate structure of the OSPE Energy Only Smart Price Plan for residential consumers is detailed in Table E-1 and presented graphically in Figure E-1 below. Appendix G provides detailed analysis for various cost reduction strategies.

Table E-1
Standard TOU Price Plan versus
OSPE Energy Only Smart Price Plan (Milton Hydro)
May 1, 2018 Rates (All Components Included – Typical Home)

Summary	Standard TOU Price Plan	Energy Only Smart Price Plan	Billing Units
Fixed Monthly Charge	25.56	28.34	$/month
Energy: TOU On-peak Rate	0.1541	-	$/kWh
TOU Mid-peak Rate	0.1161	-	$/kWh
TOU Off-peak Rate	0.0871	-	$/kWh
Energy: Peak-load Rate	-	0.2120	$/kWh
Intermediate Load Rate	-	0.1422	$/kWh
Base-load Rate		0.0724	$/kWh
Surplus Energy Rate		0.0062 (4)	$/kWh
Sales Tax Rate	5	5	%
Total Bill (before taxes, and load leveling and fossil fuel displacement)	**1,247 (3)**	**1,247 (3)**	**$/yr**

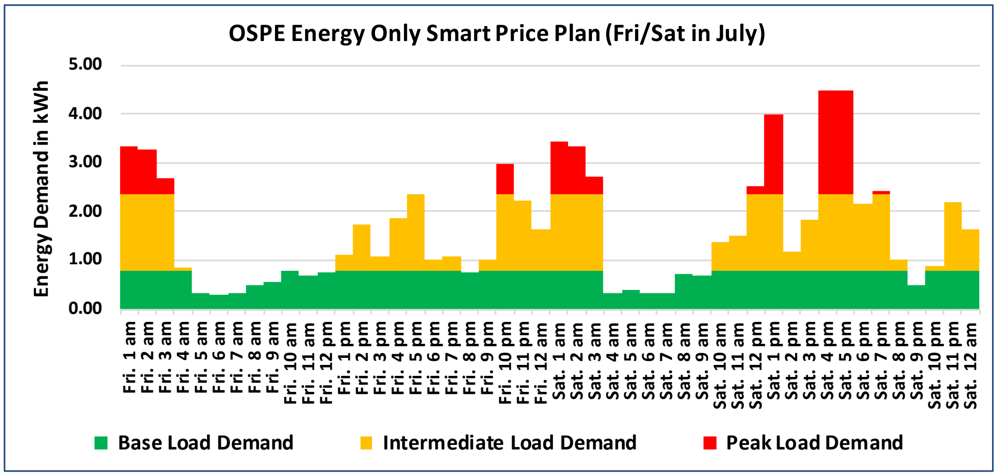
Notes:

1. The table assumes the same hourly load profile for both plans .
2. The table includes the Fair Hydro Plan rate reduction until Dec 2021.
3. The annual “total bill” above does not include load shifting or surplus electricity use for fossil fuel displacement. If the consumer’s behaviour remains identical before and after they adopt the smart price plan, they will pay the same amount. If they modify their behaviour they will save money. If they displace other forms of energy (such as gasoline with an electric or plug-in hybrid car) they will save even more.
4. The Surplus Energy Rate applies to surplus emission-free electricity for fossil fuel displacement. This rate requires communication capability at the LDC.
5. The Base-load Rate is charged only on the first 0.79 kWh of energy each hour.
6. The Intermediate Load Rate is charged only on hourly demand between 0.79 kWh and 2.37 kWh each hour.
7. The Peak-load Rate applies to hourly energy demand above 2.37 kWh each hour.
8. All rates are subject to regular review (typically semi-annually).

The resulting rate structure of the OSPE Energy Only Smart Price Plan for residential consumers is presented graphically in Figure E-1 below.

Appendix G provides detailed analysis for various cost reduction strategies.

Figure E-1
OSPE Energy Only Price Plan (Milton Hydro)



Notes for Figure E-1:

1. Workdays, weekends and holidays are all treated the same way.
2. Load shifts and electricity used for fossil fuel displacement aare not shown above.

OSPE suggests the OSPE Energy Only Smart Price Plan should be offered only in service areas where the LDC has communication capability.

Appendix F - Forecast of the Surplus Amount of Emission-Free Electricity

The actual historical total amount of surplus and curtailed (wasted) emission-free electricity in Ontario is summarized in Table F-1 below. The difference between the total surplus and curtailed amounts are the quantities of emission-free electricity that are exported to adjoining electricity systems at low prices of typically under 2 ¢/kWh.

Table F-1
Amount of Surplus Emission-Free Electricity in Ontario

Year	Curtailed Amounts TWh	Number of Homes Equivalent for Curtailed Amounts	Total Surplus TWh	Number of Homes Equivalent for Total Surplus
2014	3.6	380,000	10.0	1,040,000
2015	4.8	500,000	13.3	1,390,000
2016	7.6	840,000	15.9	1,770,000
2017	10.2	1,130,000	23.9	2,660,000

Note: Electricity consumption per average household has dropped from 800 kWh/month in 2014 to 750 kWh/month in 2017.

The curtailed amounts were reported by Ontario Power Generation in their financial reports for their hydroelectric plants. The IESO reports curtailment amounts in their year-end energy reports for wind, solar and nuclear plants. Hydroelectric curtailments for privately owned plants are not available.

Total surplus quantities were estimated from IESO's market data using the following formula:

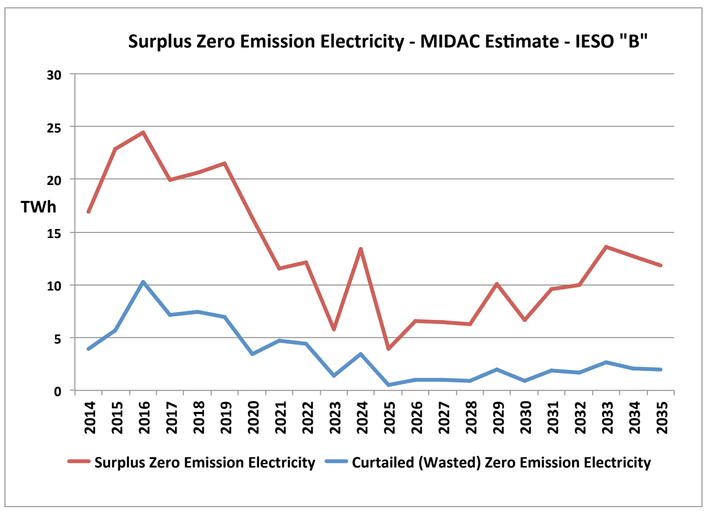
Total Surplus TWh = Net Exports TWh – Natural Gas TWh + Must-Run Gas TWh

Natural gas-fired generation production is assumed to be exported first so it is subtracted from IESO's net exports amount first. Then the must-run natural gas output used for spinning reserve is assumed to be needed within Ontario and the amount is added back into the total. The must run gas is estimated by OSPE to be 7.1 TWh per year based on minimum amounts of production from natural gas plants when market prices were below $14.4 /MWh. That price indicates that the largest OPG hydroelectric plants were being curtailed in order to keep the natural gas plants running for spinning reserve purposes during the day.

The current surpluses are expected to drop due to the nuclear refurbishment program and the Pickering plant retirement in 2024. The surplus will then rise again as the refurbished nuclear units return to service even with no new nuclear units are planned. The nuclear refurbishment program gives us time to reform our retail electricity price plans so that as the reactors return to service, Ontario consumers will be able to use that surplus electricity here in Ontario.

Figure F-1 below summarizes the forecasted amounts of surplus emission-free electricity from Ontario's electricity system. The forecasted amounts available from 2020 to 2035 was obtained from an analysis published in October 2016 by Market Intelligence & Data Analysis Corporation (MIDAC) and Next Hydrogen titled "Grid Integrated Electrolysis – Facilitating Carbon Emission Reductions in the Transportation, Industrial and Residential Sectors"[33]. Those forecasts were based Ontario's 2013 Long Term Energy Plan (LTEP) including the deferral of the Large Renewable Portfolio II and the IESO's September 2016 Ontario Power Outlook – Scenario B - Flat Demand. The 2016 IESO outlook was subsequently incorporated into the 2017 LTEP.

Figure F-1
Ontario's Estimated Surplus Emission-Free Electricity 2014 to 2035[34]



The spike up in surplus emission-free electricity in 2024 is caused by the forecasted return to service of two refurbished nuclear units before four Pickering nuclear units retire from service at the end of 2024.

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[33] "Grid Integrated Electrolysis–- Facilitating Carbon Emission Reductions in the Transportation, Industrial and Residential Sectors" prepared by MIDAC/Next Hydrogen, accessed November 1, 2018 from the IESO website at: http://www.ieso.ca/en/sector-participants/market-renewal/enabling-system-flexibility

[34] Figures F-1 to F-4 are from the October 31, 2016 report titled "Grid Integrated Electrolysis" prepared by MIDAC/Next Hydrogen, accessed November 1, 2018 from the IESO website at: http://www.ieso.ca/en/sector-participants/market-renewal/enabling-system-flexibility

Comparing Table F-1 and Figure F-1 above shows the 2016 curtailed amount (blue lower line in Figure F-1) was over-estimated by the model. The analysis was done during 2016 before the actual data was available. The 2017 curtailed amount was under-estimated by the model. Models are subject to a number of assumptions related to load projections and production output from existing plants. Therefore, actual values will differ from predicted values in any year.

IESO issued an updated Ontario Power Outlook in September 2018. The reference scenario shows about 1.6 TWh of surplus baseload generation (SBG) will be curtailed in 2035. Baseload generation in Ontario produces emission-free electricity. That quantity is lower than the 2.6 TWh in 2035 identified in the September 2016 IESO reference forecasts that OSPE used to prepare this report.

The 2018 IESO low demand scenario forecasts the curtailed amounts of surplus emission-free electricity at about 6 TWh in 2035. Ontario currently exports more emission-free electricity than it curtails. If that continues into the future, and the low demand scenario materializes the total available emission-free electricity in 2035 that will be surplus to Ontario's domestic needs in the 2018 IESO outlook could exceed 12 TWh. This OSPE report is currently forecasting about 11.8 TWh of emission-free electricity (exported plus curtailed) in 2035 using the 2016 IESO Ontario Power Outlook reference scenario B.

The 2018 forecast has some underlying assumptions that OSPE has some concerns about. For example, one of the assumptions is that carbon prices will be zero for natural gas generation until 2035. Under that assumption, the IESO 2018 forecasts indicate that carbon emissions from the electricity system will increase to over 300% of current emissions by 2035. OSPE believes the 2018 IESO update is inconsistent with global and federal government efforts to reduce carbon emissions. Several other OSPE concerns with the new 2018 IESO forecast are described below.

- IESO's definition of Surplus Baseload Generation (SBG) is the same as OSPE's definition of surplus emission-free electricity – hydroelectric, nuclear, wind and solar that are surplus to Ontario's domestic electricity demand. However, IESO's SBG data appears to exclude SBG quantities that can be successfully exported. That suggests IESO's SBG data in the 2018 Outlook represents only the curtailed amounts of SBG. Therefore IESO's 2018 Outlook SBG data needs to be adjusted by the exported amounts to determine the total quantities of surplus emission-free electricity available for fossil fuel displacement in Ontario.
- The surplus emission-free electricity quantities are strongly and inversely impacted by the forecasted load demand into the future.
- The 2010, 2013 and 2017 LTEPs using the associated IESO Ontario Power Outlook reference load forecasts have historically been too high. Actual surplus emission-free electricity quantities were higher than

forecasted. That resulted in subsequently higher than forecasted electricity rates which further suppressed subsequent consumer electricity demand.

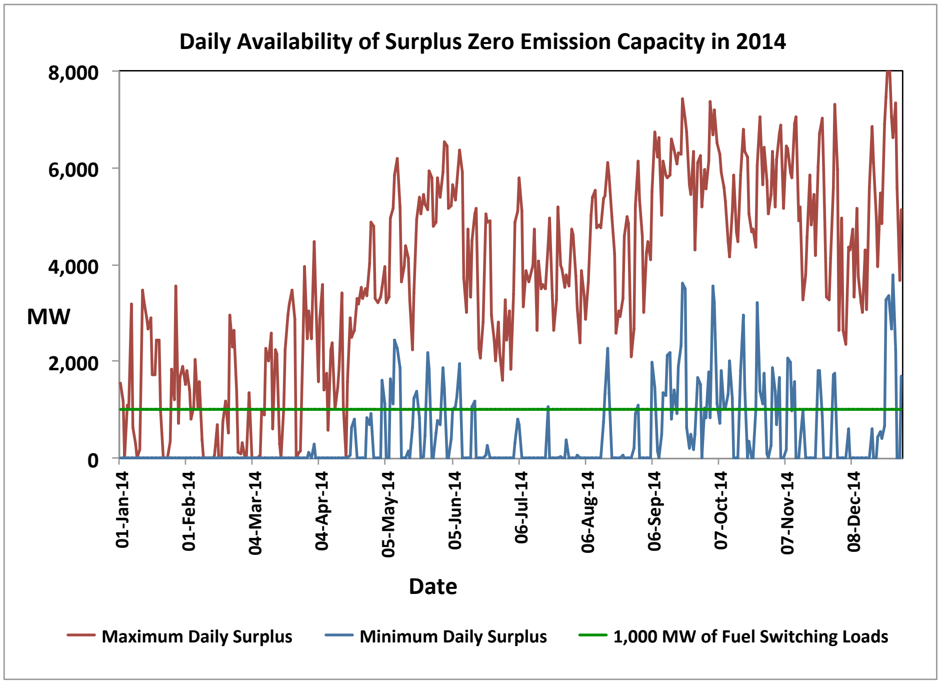
- The Fair Hydro Plan is scheduled to expire at the end of 2021. The deferral account is accumulating losses and interest on those losses faster than originally planned in the 2017 LTEP. The projected electricity rate increases after 2021 will likely be higher than the 2017 LTEP reference forecast. The higher prices will suppress consumer electricity demand beyond 2021 and increase the amounts of surplus emission-free electricity in future years.
- The 2018 IESO forecasts for fossil fuel use show emissions rising above 300% of current levels by 2035. That suggests natural gas fuel use will also increase to 300% of current consumption. The 2018 Outlook forecasts assume a carbon pricing impact of $0 per tonne carbon dioxide assuming most gas fired generation will be exempted from the federal government application of the federal carbon tax. That tax is projected to rise to $50 per tonne carbon dioxide by 2022. The IESO intends to revise the 2018 Outlook forecasts if the carbon tax impact is higher than the $0 per tonne carbon dioxide that has been assumed. If the higher carbon price is imposed on natural gas generation by the federal government, electricity prices will rise further. That will suppress consumer electricity demand forecasts and will increase the amounts of surplus emission-free electricity in future years.
- It is not clear the public will support the tripling of electricity sector emissions over the next 16 years in light of international efforts to reduce emissions. Low emission electrical systems inherently produce significant quantities of surplus emission-free electricity. If the public demands that emissions remain low in the electricity sector, the lower emission targets will result in higher quantities of surplus emission-free electricity in future years.

Based on OSPE's observations above OSPE believes it is prudent to continue to plan for the effective use of significant amounts of surplus emission-free electricity that will be available in future years. OSPE is therefore comfortable in performing its analysis in this report using the surpluses identified in Figure F-1 above which are consistent with the 2016 IESO Ontario Power Outlook forecasts.

To determine if we can economically justify creating a market for fossil fuel displacement technologies by reforming our retail electricity rates, we need to examine the amount of surplus emission-free electricity that is available hourly over the design life of the equipment. We also need to calculate the resulting capacity factors over the typical 20-year design life for the fossil fuel displacement equipment.

Figure F-2 below shows OSPE's estimated amount of surplus emission-free generating capacity that was available from Ontario's existing generating plants each day in 2014 using IESO hourly market data.

Figure F-2
Ontario Estimated Surplus Emission-Free Electricity in 2014



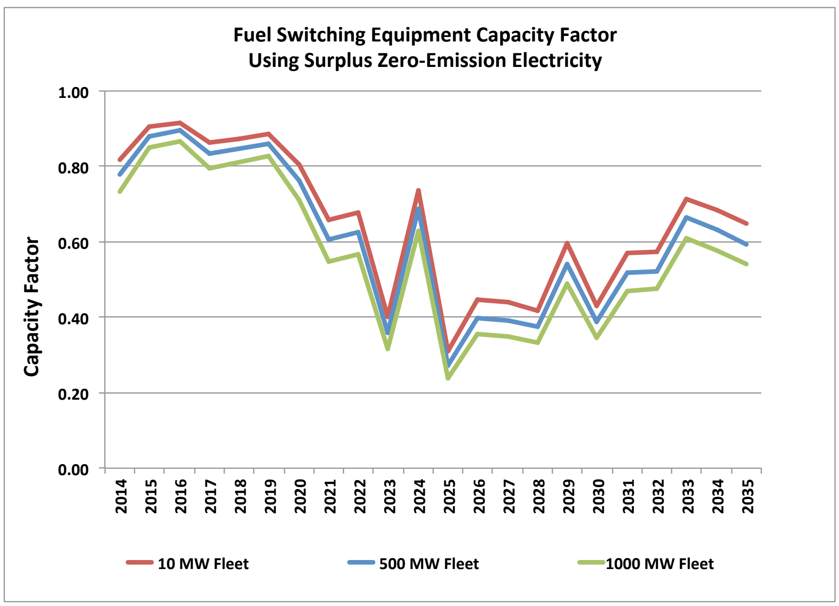
The green (flat) line in Figure F-2 represents a 1,000 MW provincial fleet of fossil fuel displacement technologies. This could be any configuration ranging from a very large 1,000 MW electrolyser installed in the Sarnia petrochemical valley or 2,000,000 small 0.5-kW heaters installed in hundreds of thousands of homes. The red (upper) line represents the maximum amount of surplus capacity each day in MW. The blue (lower) line represents the minimum amount of surplus capacity each day in MW. The three operating regimes are:

- When the blue line is above the green line, the fossil fuel displacement equipment can operate at full capacity all day using surplus emission-free electricity.
- When the blue line is below the green line the fossil fuel displacement equipment can only use surplus emission-free electricity for a portion of the day, typically at night.
- When the red line reaches zero, no surplus emission-free electricity is available that day and the fossil fuel displacement equipment must use fossil fuels at that time.

A simple analysis can determine the operating capacity factor for any size fleet of fossil fuel displacement equipment for each year over the study period. The operating capacity factor is the actual energy consumed in a given year divided by the energy that could have been used if the equipment operated at full rated capacity continuously all year.

Figure F-3 below shows the resulting capacity factor for three different size fleets of fossil fuel displacement equipment in each year during the 2014 to 2035 period. Notice that capacity factors for the fossil fuel displacement equipment fleet rises again from 2026 to 2033 after the remaining refurbished nuclear units return to service. As indicated earlier the spike in capacity factors in 2024 is caused by the return to service of two refurbished nuclear units in 2024 before four Pickering units are retired at the end of 2024.

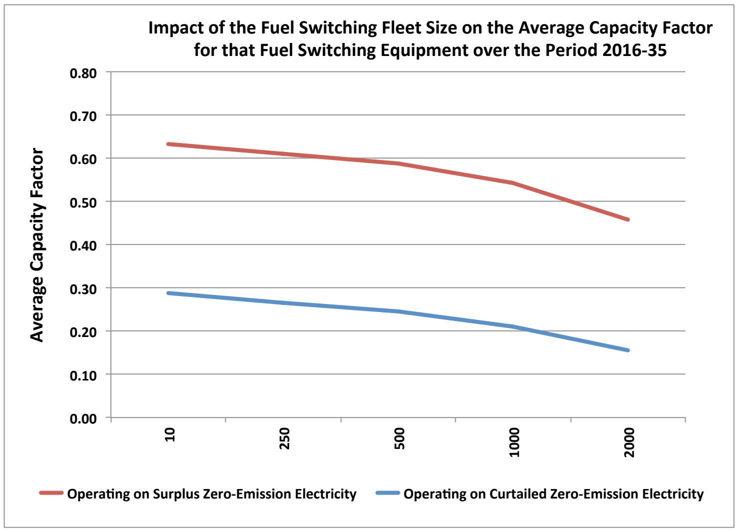
Figure F-3
Impact of the Fossil Fuel Displacement Equipment Fleet Size on Its Capacity Factor



The data can be reformatted to show how the capacity factor for a fleet of fossil fuel displacement technologies changes as we change the size of that fleet. We can also examine the impact on capacity factors if we choose to limit the equipment operation to periods when only “curtailed” emission-free electricity is available. Since “curtailed” emission-free electricity is only about 40% of the total surplus emission-free electricity the capacity factors will drop and adversely affect the economics of a fossil fuel displacement strategy. Preferably we should try to use as much of the total surplus emission-free electricity that is available for fossil fuel displacement applications. We should only export or curtail the residual amounts that cannot be economically used in Ontario.

Figure F-4 below shows how fleet size affects the capacity factor over the 20-year life of the fossil fuel displacement equipment from 2016 to 2035 for both curtailed and total surplus emission-free electricity. The capacity factors in Figure F-4 assume that the entire fleet operates simultaneously to consume whatever surplus is available up to the fleet capacity.

Figure F-4
Impact of the Fossil Fuel Displacement Equipment Fleet Size on Its Capacity Factor Over the 20-Year Design Life of the Equipment



As the cost of fossil fuel displacement equipment and load controllers drop the number of consumer subscriptions to the smart price plans will increase. The available surplus quantities will eventually not be sufficient to satisfy every consumer's total demand for surplus electricity. At that point the surplus quantities will have to be shared. As the demand for surplus electricity rises the price for that surplus electricity will also rise. Consumers will stop installing fossil fuel displacement equipment if the surplus quantities are not sufficient to justify the purchase of the required equipment. The market will find its own equilibrium point. We should expect only about 70% of the surplus electricity will be productively used for fossil fuel displacement.

The operating capacity factor of the fossil fuel displacement equipment is affected by the combination of the consumer's hourly thermal energy consumption, the number of consumers who participate in fossil fuel displacement and the hourly availability of surplus electricity. Estimating the actual operating capacity factor of a typical residential consumer's fossil fuel displacement equipment is difficult because we do not have hourly fossil fuel data for the typical consumer. However, we can make some assumptions based on monthly average fossil fuel consumption for our sample residential consumer. This will allow us to estimate the likely fossil fuel displacement and what that would mean in total annual energy cost savings for a typical residential consumer.

In 2017 surplus emission-free electricity was available 61% of the hours during the year. During the winter heating season from Oct 1 to Apr 30 surplus emission-free electricity was available:

- at least 1 hour for 100% of the days,
- at least 3 hours for 94% of the days,
- at least 12 hours for 73% of the days, and
- at least 22 hours for 32% of the days

During the summer cooling season from May 1 to Sep 30 emission-free electricity was available:

- at least 1 hour for 95% of the days,
- at least 3 hours for 81% of the days, and
- at least 12 hours for 43% of the days.

Since fossil fuel displacement equipment and load controllers will cost money the consumer will want to see a price advantage between surplus emission-free electricity and the fossil fuel they are currently using for their thermal energy needs. The consumer will also want to be sure that over the 20-year life of most heating equipment there will be enough surplus emission-free electricity to recover the cost of the equipment. Residential consumers will typically be satisfied with a 5-year payback because they have fewer investment options compared to businesses that typically want to see a 2-year payback.

There are two interesting facts about fossil fuel displacement. Firstly, Ontario residential consumers currently pay a lower sales tax rate for electricity compared to fossil fuels. Fossil fuels are taxed at the HST rate of 13%. Electricity is taxed at the GST rate of 5%. Unless that provincial government policy changes there is a built in 8% tax advantage to using electricity rather than fossil fuels in Ontario.

Secondly, electric vehicles do not pay the provincial road tax currently incorporated into gasoline and diesel fuels. Whether this tax policy can be sustained as more consumers buy electric cars is beyond the scope of this report.

Appendix G - Effectiveness of Various Cost Savings Strategies

Before performing any analysis, we need the hourly electricity and fossil fuel consumption data for a typical home. Total annual electricity consumption data for a typical Ontario home is available from the IESO or OEB. Hourly consumption data for a typical home for electricity and fossil fuel use is not available.

To undertake the analysis OSPE selected a home that has an annual electricity consumption close to a typical home and then used that home's 2016 hourly electricity consumption data as typical for the purposes of the analysis in this report. Hourly load profiles will vary with consumer habits and with weather changes. We should expect some variation in results among residential consumers compared to the results of this report. However, the analysis results using one home do provide insights on how specific retail price policy changes will impact residential consumers' bills.

The electrical load pattern of the home that OSPE used for the analysis in this report is shown below in Figure G-1. The home's energy-related design details are described in Appendix A. The 2015 consumption of a typical residential consumer in Ontario was identified by the IESO as 746 kWh/month or 8.95 MWh/year. The 2017 Long Term Energy Plan (LTEP) identified the 2016 typical residential electricity consumption as 750 kWh/month or 9,000 kWh/year. In this analysis the actual home we used has a 2016 annual electricity consumption of 8,845 kWh. This is within 1.8% of the LTEP data for 2016.

A review of Figure G-1 shows the winter electrical load is not heavily affected by space heating because the home has natural gas forced-air heating equipment. The large rise in the summer maximum average hourly load reflects the air conditioning load. The home has electrical cooking appliances. The rise in maximum average hourly load just before Christmas reflects this consumer's baking and other cooking loads needed to prepare treats for Christmas and New Year holiday meals for family and friends. The home is occupied most days by 3 adults so there is an electrical cooking load for all three meals.

OSPE analyzed the hourly cost of electrical service for the consumption shown in Figure G-1 using the Fair Hydro Plan rates effective May 1, 2018 and also for rates published by the OEB without the Fair Hydro Plan[35]. This was done to see the size of the deferred amounts that will come due when the Fair Hydro Plan

[35] OEB regulated price plan rates without the Fair Hydro Plan. Accessed October 27, 2018 at: https://www.oeb.ca/sites/default/files/RPP-Supply-Cost-Report-20180501-20190430-correction.pdf

expires at the end of 2021. The results are summarized in Table G-1 below and provide a baseline against any changes we will analyze:

Figure G-1
Typical Daily Residential Load over a 1-Year Period[36]

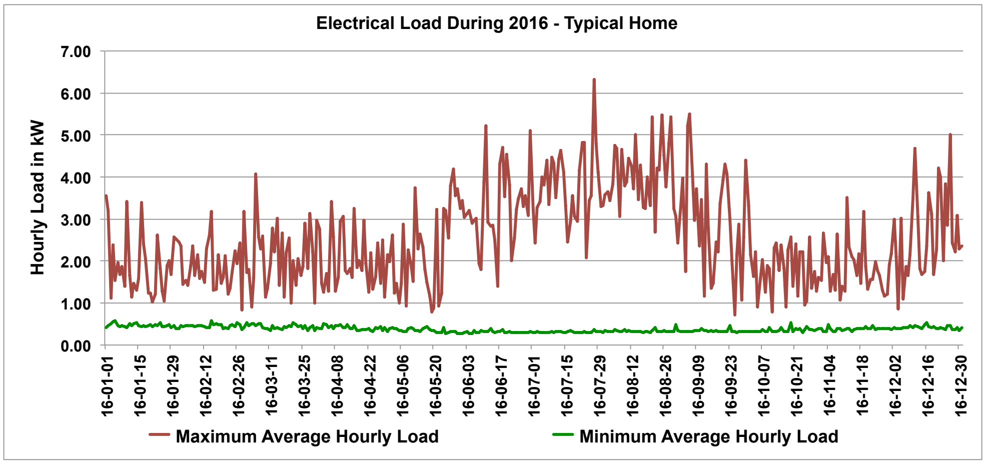


Table G-1
Cost of Electrical Service for 2018 for a Typical Ontario Home
(does not include taxes or government subsidies)

Residential Plan	Annual Cost	All-in Cost per kWh
TOU Price Plan with Fair Hydro Plan	$1,247	14.1 ¢
TOU Price Plan without Fair Hydro Plan	$1,650	18.7 ¢

To evaluate the effectiveness of the various price plans to reduce consumer's energy bills OSPE analyzed 4 different cost reduction strategies:

- Automatic load flattening that requires electrical storage
- Manual load shifting from on-peak to off-peak hours (eg: electric vehicle charging and delaying use of appliances to off-peak periods)
- Energy conservation (reduced consumption by any means)
- Fossil fuel displacement using surplus electricity for water heating and space heating.

[36] The homeowner's hourly consumption data for 2016 was downloaded from the IESO smart meter data repository and included in this report with permission from the homeowner.

This report does not analyze combinations of the above strategies nor industrial applications of surplus electricity such as steam production or hydrogen production.

The savings which are presented in Appendix G apply to Milton Hydro residential consumers and do not include sales taxes or government subsidies nor differences in the sales tax rates between fossil fuels and electricity.

Savings using a Manual Load Shifting Strategy

There are some flexible electrical loads that can be shifted without the need for a separate electrical storage system. For example, we can wash dishes and wash and dry clothing during off-peak periods rather than on-peak periods.

Flexible thermal loads powered by electricity can also be shifted without the need for a separate electrical storage system. A home can be pre-cooled at night during the summer by a couple of degrees with a programmable thermostat. That pre-cooling offsets some of the electrical air-conditioner load during the day. Also, for homes that are heated electrically, pre-heating the home at night in the winter by a couple of degrees can reduce the electrical heating load during the day. The required thermal storage is already built into the home's structure and contents.

Similarly, electric cars have their own built-in electrical storage so they can be charged during off-peak periods rather than on-peak periods.

These types of load shifts result in savings for each kWh that is shifted from the higher cost on-peak period to the lower cost off-peak period. Savings can also be realized by shifting loads from mid-peak periods to off-peak periods, however, the savings will be lower. Load shifts within holiday and weekend days do not save any money for most TOU price plans because all hours on weekends and holidays are at the same off-peak rate.

When energy consumption is shifted in time the consumer saves the higher rate but must pay for the energy at the lower rate. The consumer saves only the difference. Table G-2 below summarizes the savings that are possible for each price plan for each kWh that is shifted.

The OSPE analysis shows that manual load shifts are an effective way to reduce the rate paid for electricity when the difference between on-peak and off-peaks rates are large. However, it is difficult for a residential consumer to find enough high-power, long-running loads that can be manual shifted to save a significant amount of money. Most consumers find that manual load shifts produce modest bill reductions even with the best price plans. The exception is electric cars.

Table G-2
Bill Savings for Every kWh of Manual Load Shifting

Description of Retail Price Plan	On-Peak to Off-Peak Shift Savings (¢/kWh)	Mid-Peak to Off-Peak Shift Savings (¢/kWh)
Standard Residential TOU Price Plan	6.70	2.90
OEB Approved Pilots:		
Enhanced Time-of-Use	13.10	8.80
Low Overnight (2)	16.30, 11.80	7.20, 2.70
Variable Peak Pricing with CPP (3), (4)	44.7, 34.8, 14.9, 5.0	-
Quick-Ramping CPP (3)	44.40, 7.70	3.90
Seasonal Time-of-Use with CPP (3), (4), (5)	21.00, 7.90	-
Seasonal Time-of-Use (4), (5)	8.10	-
Super-Peak Time-of-Use (3), (4)	18.90, 3.20	-
Alternative Quick-Ramping CPP (3)	53.50, 7.20	3.40
OSPE Smart Price Plans:		
Modified Low Overnight (2)	19.42, 11.93	10.19, 2.70
Energy Plus Peak Demand (4), (6)	74.84, 2.46	-
Energy Only	13.96	6.98

Notes: (1) The 5 Hydro One price plan pilots have been withdrawn and are not listed above.
(2) These plans have 2 off-peak rates.
(3) These plans have multiple on-peak rates.
(4) These plans do not have a mid-peak rate.
(5) These plans have no savings during shoulder months, Sep-Nov and Mar-May.
(6) The OSPE Energy Plus Peak Demand smart price plan provides a $22.78/kW/month bill reduction for each kW reduction in the monthly average peak power demand. If the power demand is shifted away for the whole hour from the highest daily hourly demand, every day for the whole month the equivalent savings would be 74.84 ¢/kWh. However, if the peak power demand reduction occurs for the whole hour but only on one day of the month the equivalent savings would be 2.46 ¢/kWh. This plan rewards the consumer much more for lowering all the daily peaks each month because that has the greatest value for the electricity system.

Electric car batteries can be charged during off-peak periods. Substantial bill savings are achievable because the cars have a high-power demand for a significant period of time and consume significant amounts of electricity. The price plans with the lowest off-peak rates produce the highest bill savings for electric car owners.

The standard TOU price plan provides a saving of $268 per year if the consumer charges their electric car during off-peak periods instead of on-peak periods. The OSPE Modified Low Overnight Smart Price Plan has the lowest rates between midnight and 6 am. An electric car owner will see an additional saving of about $311 per year if they subscribe to the OSPE Modified Low Overnight Smart Price Plan instead of the standard TOU price plan. The analysis assumes the consumer will charge their electric car between midnight and 6 am and use surplus emission-free electricity 50% of the time.

Savings with an Energy Conservation (Load Reduction) Strategy

All price plans result in savings if a consumer practices conservation and energy efficiency and reduces their load at any time. The savings will depend on the rates in effect at the time of the load reduction.

The price plans with the highest rates during periods when consumers use the most electricity typically produce the largest bill reductions. But as in the case of manual load shifts, reducing power demand for a long enough period of time to achieve a significant reduction in energy consumption is difficult for most residential consumers. Most conservation efforts produce modest bill reductions even with the best price plans.

Table G-3 below summarizes the maximum and minimum savings that can be realized with each price plan for every kWh reduction in energy consumption. The maximum rates for most TOU price plans do not apply on weekends and holidays because all hours on those days are at off-peak rates. Plans with CPP rates only have a limited number of hours each year when those much higher CPP rates apply. Therefore, CPP plans do not produce large bill reductions.

Table G-3
Bill Savings for Every kWh of Reduced Consumption

Description of Retail Price Plan	Max. Savings ¢/kWh	Min. Savings ¢/kWh
Standard Residential TOU Price Plan	15.41	8.71
OEB Approved Pilots:		
Enhanced Time-of-Use	19.81	6.61
Low Overnight	20.51	4.21
Variable Peak Pricing with CPP	51.81	7.11
Quick-Ramping CPP	52.11	7.11
Seasonal Time-of-Use with CPP	28.51	7.51
Seasonal Time-of-Use	15.71	7.61
Super-Peak Time-of-Use”	27.41	8.51
Alternative Quick-Ramping CPP	61.71	8.21
OSPE Smart Price Plans:		
Modified Low Overnight	20.64	1.22
Energy Plus Peak Demand (1)	77.27, 4.89	2.43
Energy Only	21.20	7.24

Notes for Table G-3:

(1) The OSPE Energy Plus Peak Demand smart price plan provides a $22.78/kW/month bill reduction for each kW reduction in the monthly average peak power demand and 2.43 ¢/kWh in energy savings. If the energy reduction lowers the daily peak power demand for the whole hour, every day, for the whole month the savings would be worth 77.27 ¢/kWh. However, if the energy reduction lowers the daily peak power demand for only one day of the month the savings would be worth only 4.89 ¢/kWh. If the energy reduction does not lower the daily peak power demand the savings would be worth only 2.43 ¢/kWh.

(2) All rates are subject to regular reviews (typically semi-annually).

Savings with an Automatic Load Flattening Strategy Using Electrical Storage

The electricity system can supply a flat power demand at relatively low cost. However, to conveniently achieve a flat power profile consistently from day-to-day will require an energy management system that includes both an automatic load controller and energy storage equipment.

Inflexible on-peak electrical loads that cannot be moved in time from on-peak to off-peak periods will require an electrical load controller and electrical storage system. An example of an inflexible load is preparation of meals using electrical appliances. Inflexible electrical loads can only be shifted to off-load periods by charging the electrical storage system off-peak and then drawing the electricity out of the electrical storage system when that electricity is needed during the on-peak period. The total amount of energy consumed from the electricity system will be higher by the amount of losses incurred in charging and discharging the electrical storage system.

OSPE's analysis considers the use of electrical storage to shift inflexible electrical loads. OSPE has assumed a 5% charging loss and a 5% discharging loss in the electrical storage system. OSPE also assumes the load flattening will occur on a daily basis only and not on a weekly or seasonal basis. This assumption lowers the cost of electrical storage but leaves some load variations that the electricity system must accommodate.

OSPE analyzed 2 load shifting options. The first option flattens the dependable load demand over the whole 24-hour period. The second option transfers all dependable load demand out of the on-peak and mid-peak periods and moves them to the off-peak periods to maximize the savings in electricity costs. This can impose unacceptably large and rapid load changes on the electricity system if too many consumers do the same thing. This second option is not recommended but is included to show the maximum annual savings if all the load was shifted from the higher to lower cost periods. The original load profile and the 2 new profiles after the load is shifted are shown in Figure G-2 and Figure G-3 below.

Figure G-2
Flat 24-Hour Load Profile
(Hourly Averages for the Whole Year are Shown)

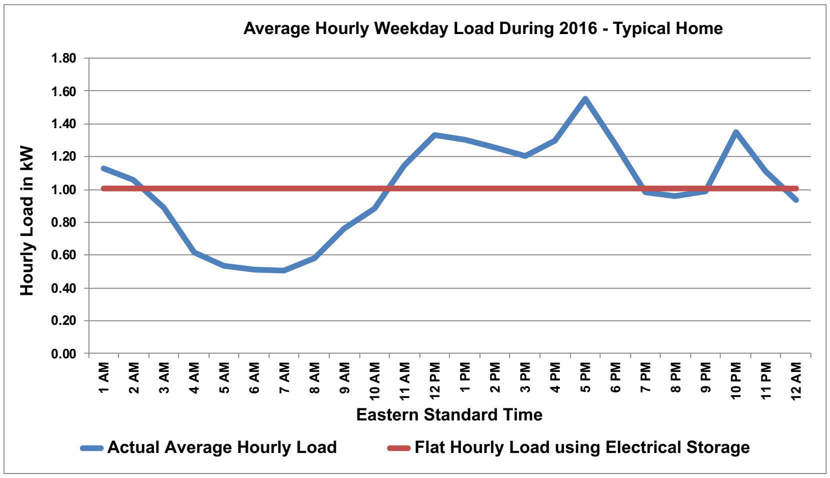
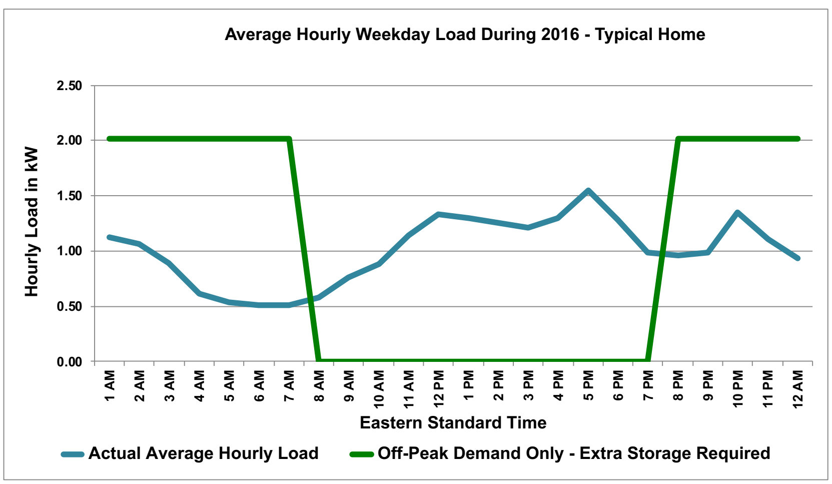


Figure G-3
Flat Off-Peak Only Load Profile
(Hourly Averages for the Whole Year are Shown)



To achieve the flat 24-hour load profile a 28 kWh electrical storage system is required for the sample consumer OSPE analyzed. That storage is approximately equivalent to 2 Tesla PowerWall storage systems. The 2018 commercial price for an installed residential storage system with the associated chargers, inverters and control system integrated with the home's electricity system is approximately $25,000 Canadian. The price above assumes that the PowerWall is close to the main electrical panel and that all existing electrical systems are up to code. This cost does not include an optional solar installation or integration with an existing solar installation.[37]

To maximize energy bill savings, we could shift all electrical load out of the on-peak and mid-peak periods and into the off-peak periods using additional amounts of electrical storage. This is not a practical load profile because it would stress the electricity system if enough consumers implemented it. To achieve a flat load profile only during off-peak periods a 42 kWh electrical storage system is required. That is equivalent to approximately three Tesla PowerWall storage systems with an installed price of about $35,000 Canadian.

Table G-4 below summarizes the annual electricity costs for each of the price plans OSPE analyzed before and after the load shift for the typical residential consumer.

Table G-4

Annual Electricity Costs for Typical Residential Consumer Using Automatic Load Shifting/Levelling and Electrical Storage

Description of Retail Price Plan	Before Load Shift (Annual $)	24-Hour Flat Load (Annual $)	Flat Off-Peak Load Only (Annual $)
Standard Residential TOU Price Plan	1,247	1,243	1,105
OEB Approved Pilots:			
Enhanced Time-of-Use	1,270	1,242	913
Low Overnight	1,265	1,218	938
Variable Peak Pricing with CPP	1,194	1,190	959
Quick-Ramping CPP	1,255	1,236	1,023
Seasonal Time-of-Use with CPP	1,239	1,257	1,128
Seasonal Time-of-Use	1,217	1,234	1,127
Super-Peak Time-of-Use”	1,285	1,270	1,087
Alternative Quick-Ramping CPP	1,222	1,206	1,014
OSPE Smart Price Plans:			
Modified Low Overnight	1,247	1,184	N/A
Energy Plus Peak Demand	1,247	995	N/A
Energy Only	1,247	912	N/A

Notes for Table G-4:
(1) The 5 Hydro One price plan pilots have been withdrawn and are not listed above.

[37] Estimated price for an installed Tesla PowerWall residential energy storage system. Accessed on October 28, 2018 at: http://mpowersolutions.ca/faq

(2) N/A means "not analyzed" because smart plans should be used to improve overall electricity system performance and not to deliberately stress the system.

Table G-2 shows that the annual savings are insufficient for any plan to justify the investment in electrical storage equipment. This is true for both load shifting strategies. However, if storage was provided and justified for other reasons such as emergency backup power, some modest amount of load shifting could be economically performed to reduce the highest peak loads during the day.

Savings with a Fossil Fuel Displacement Strategy

Rather than trying to shift electrical load to different time periods we can use a completely different strategy to reduce consumers' annual energy bills, improve electricity system operation and reduce environmental emissions.

We can use any available surplus emission-free electricity during low electrical demand periods to displace our fossil fuel use for hot water, space heating, steam production, transportation energy and hydrogen production.

To make all of these options economically viable the retail electricity rate for each unit of emission-free electrical energy (kWh) must be less than the marginal price of the same amount of useful energy from fossil fuels, adjusted for combustion inefficiencies and any carbon pricing imposed by governments.

Fortunately, the marginal or wholesale market energy price of emission-free electricity is lower than the marginal price (volume-based price) of fossil fuels like gasoline, diesel fuel, propane, fuel oil and natural gas. Smart price plans that allow consumers to buy surplus emission-free electricity at its wholesale market energy price will allow consumers to economically displace their fossil fuels.

In this report we have analyzed the use of electrical resistance heating equipment for fossil fuel displacement. Heat pumps can boost the energy output of electrical heating equipment over a 1-year service period by 2 to 4 times compared to resistance heaters depending on the type of heat pump and local weather conditions. However, we have not analyzed the use of electrical heat pumps in this report because they are significantly more expensive than resistance heating equipment.

A typical residential consumer who uses fossil fuels for space heating and hot water will use about 17.8 MWh of fossil fuel energy to deliver 15.1 MWh of usable thermal energy assuming an appliance lifetime combustion efficiency factor of 85%. A typical consumer's highest monthly winter energy consumption will be about 2,800 kWh (thermal) for hot water and space heating and 750 kWh (electrical) for electrical appliances. The highest monthly summer energy consumption will be about 300 kWh (thermal) for hot water and 1,200 kWh (electrical) for electrical appliances including air conditioning. The shoulder seasons in May/June and Sep/Oct will see energy consumption of about 600 kWh (thermal) for hot water and some space heating and 600 kWh (electrical) for electrical appliances. Thermal energy consumption for water heating persists all year.

Over the course of a year, a typical Ontario residential consumer needs 70% more thermal energy than electrical energy. Most of that demand is during the winter. The amount of fossil fuel use that can be displaced by surplus emission-free electricity will depend on several factors:

- When and how much surplus electricity is available.
- When and how much thermal energy consumption is needed.
- The size of the electrical heating equipment for space heating and hot water heating.
- The available electrical power that is permitted to be used for fossil fuel displacement by the smart price plan or LDC (peak demand concerns).
- The functional capability of the energy management or load control equipment and LDC communication capability.
- The provisions in the smart price plan and LDC communication capability to use surplus emission-free electricity at an energy equivalent price lower than the fossil fuels the consumer uses.
- The total number of consumers who subscribe to the smart price plans and who are competing to use the limited supply of surplus emission-free electricity.

A residential consumer who wants to participate in fossil fuel displacement will need to have either dual fuel heating equipment or alternatively two sets of heating equipment (one fossil fuel and one electric). They will also need either an energy management system or basic control equipment that can switch back and forth between the fossil fuel supply and the electricity supply to take advantage of the lowest marginal energy cost supply.

The OSPE Modified Low Overnight Smart Price Plan

The OSPE Modified Low Overnight Smart Price Plan is the easiest and cheapest to use for fossil fuel displacement but it only makes low cost electricity available between midnight and 6 am. Fortunately, that is the most likely period when surplus emission-free electricity will be available. The most basic from of this price plan does not require the LDC to have additional communication capability with the consumer. The electrical equipment can be relatively simple. For space heating all that is required are some low power room electric heaters with a self-contained mechanical thermostat set slightly higher than the normal furnace temperature setting. The heaters can be plugged into a timer that is then plugged into a convenient wall outlet. The heaters should be small enough (typically 500 W) so they do not overload the normal house circuits. The cost of that equipment is about $100 plus tax for each 500 W heater/timer. Such equipment will only be able to use emission-free electricity during specific hours of the day – typically overnight.

Surplus electricity is typically available for the majority of hours during the year. Surpluses are also available during the day, especially in spring and fall on windy and sunny days. The midnight to 6 am period represents only 25% of the time. The surplus emission-free electricity outside those 6 hours cannot be captured by the simple low-cost implementation described above. Also, there are a few hours during the heating season on very cold nights when there is no surplus emission-free electricity. The heaters will still be calling for heat. The simple low-cost implementation described above will still provide the heat. For those few hours the electricity will come from a natural gas fired power plant at double the emissions of a high efficiency furnace. OSPE has not analyzed this simple low-cost implementation in detail because it is not the ideal way to implement a fossil fuel displacement strategy.

If the LDC has communication capability with the consumer the power to the heaters can be activated by price signals from the LDC. The consumer would have to have an energy management system and a residential smart plug for each heater, but no timer would be needed. The room heaters will then operate if there is a need for heat whenever surplus emission-free electricity is made available at any time of day. The energy management system could also undertake the temperature control function. That would allow for more sophisticated control strategies including heating rooms above the normal setpoint to maximize the use of low-cost surplus emission-free electricity when it is available. Dedicated electric circuits and larger heating equipment can be installed to maximize the use of low-cost surplus emission-free electricity at a higher upfront cost.

If the LDC has the additional communication capability with the consumer the OSPE Modified Low Overnight Smart Price Plan is designed to take advantage of surplus emission-free electricity when available at any time of day.

OSPE Energy Plus Peak Demand Smart Price Plan

The OSPE Energy Plus Peak Demand Smart Price Plan can economically displace propane and fuel oil during hours that do not align with the consumer's highest daily hourly power demand. The electricity energy rate for this smart price plan is only 2.43 ¢/kWh during the 23 hours each day that do not have the consumer's highest power demand. This energy rate is lower than the cost of propane and fuel oil. However, the energy rate is not low enough to displace natural gas economically.

To displace natural gas economically, the LDC must have a communication capability with the consumer. The LDC must indicate the time when surplus emission-free electricity is available or alternatively transmit a wholesale market price at or below 1.44 ¢/kWh indicating that surplus emission-fee electricity is available to that consumer. The LDC would credit the consumer's bill at the end of the month using the lower rate for the additional electricity the consumer used at the prescribed time. Depending on the accuracy required by the OEB or LDC, two-way communication may be required to receive information on how much energy the consumer used for fossil fuel displacement during the time that the surplus was available.

The advantages of getting that low-cost electricity most of the day is counter balanced by the high peak power demand charges should the consumer inadvertently create a higher monthly average peak power demand. This plan requires an energy management system with some predictive load consumption capability to avoid creating inadvertent higher average monthly peak power demand charge of $22.78 per peak kW per month.

Private companies now offer both computer-based and low-cost internet-based energy management solutions that integrate with the LDCs advanced metering infrastructure or the LDCs internet-based infrastructure. However, not all LDCs provide their consumers with the latest communication capabilities. Consequently, not all the features of the OSPE Energy Plus Peak Demand Smart Price Plan may be available to all subscribers of the plan.

OSPE Energy Only Smart Price Plan

The OSPE Energy Only Smart Price Plan will only allow consumers to displace fossil fuels with surplus emission-free electricity if the LDC has additional communication capability with the consumer. Without that additional communication capability with the consumer this plan is only useful for load shifting, load leveling and conservation/energy efficiency purposes.

As more consumers purchase electric cars and participate in fossil fuel displacement, the amount of surplus emission-free electricity will decline. A point will be reached where it is no longer economic for consumers on the standard TOU price plan to switch to the smart price plans. Any remaining surplus electricity could be exported, or failing that, it could be curtailed. The availability of surplus electricity should be monitored by the IESO and/or LDCs and the data should be made available to their consumers on a regular basis. The consumers can then make informed decisions on whether to subscribe to the voluntary smart price plans.

Figures F-1 through F-4 in Appendix F demonstrated that there is ample surplus emission-free electricity for fossil fuel displacement from 2020 to 2035. Figures-F-

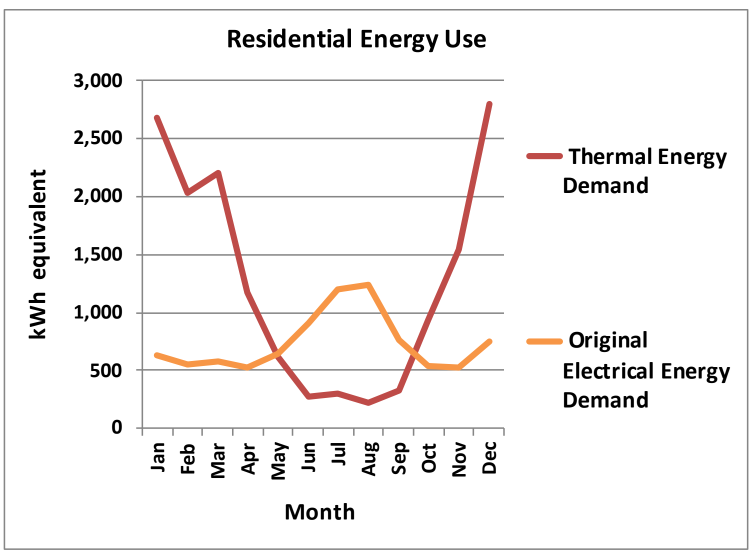
1 to F-4 in Appendix F, suggest that once the smart price plans are deployed and the market for fossil fuel displacement technologies has matured we should be able to:

- economically use at least 70% of the surplus within Ontario for fossil fuel displacement, electric car charging and hydrogen production.
- export the remaining surplus emission-free electricity, and
- very infrequently curtail any residual emission-free electricity.

OSPE undertook a detailed analysis to determine the maximum amount that consumers could save annually on their total energy bill if they were allowed to purchase surplus emission-free electricity at the wholesale market energy price. The analysis was done by modelling the OSPE Energy Plus Peak Demand Smart Price Plan with an energy management system and communication capability with the LDC. The analysis results are presented below.

Figure G-3 below shows the electrical and thermal energy consumed in a typical Ontario home with fossil fuel hot water and space heating and electrical air conditioning.

Figure G-3
Residential Electrical and Thermal Energy Consumption



In the early years of deployment there will not be enough subscribers to use all the surplus electricity except those few hours when the surplus is relatively small. However, as the number of subscribers increase the surplus will have to be shared and less fossil fuel displacement by each consumer will take place. This provides first subscriber advantage because they are more likely to see financial benefits early to pay for the equipment they need. The early subscriber advantage should help to attract financially comfortable subscribers that can afford to purchase the most capable energy management systems. These early subscribers will also provide a demand for this equipment which in turn will drive innovation and lower the costs of this equipment. In the early years of deploying the smart price plans there is no technical reason to limit individual consumers' use of surplus emission-free electricity if the electricity system can deliver that energy to them.

After the market for fossil fuel displacement matures the surplus will need to be shared on a reasonable basis. At that point it would be reasonable to limit the total power demand during use of surplus electricity to that consumer's monthly average peak power demand. That will ensure the surplus electricity is shared on a reasonable basis and will also eliminate any potential for electricity system congestion. If the LDC has the additional communication capability with the consumer the IESO and LDC can proactively allocate the available surplus electricity on any fair basis that the OEB or LDC choose.

For the purposes of this report, OSPE chose two surplus electricity consumption options for its detailed analysis:

- the use of surplus electricity is limited such that only the remaining power demand below the monthly average peak power demand is used for fossil fuel displacement. The monthly average peak power demand is calculated using only the normal electricity power demand without the fossil fuel displacement power demand.
- unlimited use of surplus electricity.

OSPE used the fossil fuels prices in Table 5-1 and the 2018 weighted average wholesale market energy price of 0.62 ¢/kWh for surplus emission-free electricity to calculate the savings from fossil fuel displacement.

Figure G-4 below shows the maximum amount of thermal energy that can be supplied if the consumer's use of surplus emission-free electricity is limited to the consumer's monthly average peak power demand.

Figure G-4
Thermal Energy that Can Be Supplied by Surplus Emission-Free Electricity (Limited by the Monthly Average Peak Power Demand)

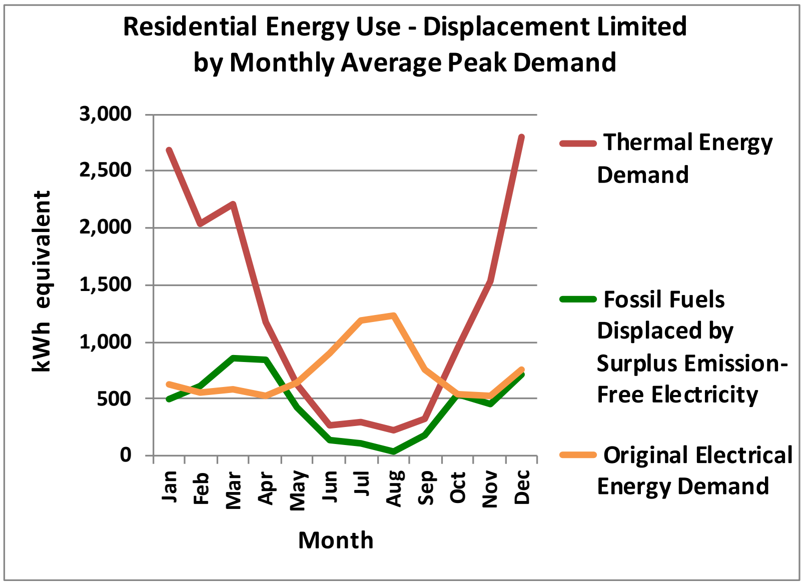


Table G-5
Annual Net Cost Savings by Typical Residential Fossil Fuel Consumer Using a Fossil Fuel Displacement Cost Reduction Strategy Limited by the Monthly Average Peak Power Demand

Month	Power Limit kW	Fossil Fuel Displacement	Nat. Gas Savings	Propane Savings $/yr	Fuel Oil Savings $/yr
Jan	1.91	19%	$5.87	$36.24	$66.11
Feb	1.90	30%	$7.18	$44.27	$80.75
Mar	2.06	39%	$10.18	$62.79	$114.53
Apr	2.00	73%	$10.02	$61.80	$112.73
May	2.23	68%	$5.04	$31.08	$56.69
Jun	3.26	49%	$1.56	$9.63	$17.57
Jul	3.75	38%	$1.35	$8.31	$15.15
Aug	4.04	20%	$0.51	$3.12	$5.70
Sep	2.96	55%	$2.11	$13.00	$23.72
Oct	1.81	58%	$6.42	$39.64	$72.31
Nov	1.82	30%	$5.45	$33.63	$61.35
Dec	2.64	25%	$8.42	$36.24	$66.11
$0/t CO_2 Price Annual	**2.53**	**36%**	**$64.10**	**$395.44**	**$721.36**
$20/t CO_2 Price Annual	**2.53**	**36%**	**$85.82**	**$422.60**	**$753.95**
$50/t CO_2 Price Annual	**2.53**	**36%**	**$118.42**	**$460.62**	**$802.83**

Notes:

2. The price for electricity is based on the OSPE Energy Plus Peak Demand Smart Price Plan in Table D-1. The average HOEP during periods when surplus emission-free electricity was available was 0.62 ¢/kWh. Prices for fossil fuels are listed in the residential column of Table G-5.
3. In addition to the savings above the consumer also saves 8% sales tax on any fossil fuels that are displaced by electricity which currently enjoys a lower sales tax rate.

Table G-5 above shows the maximum annual energy cost savings that would have been available in 2018. Table G-5 applies early in the deployment of smart price plans when there is more surplus electricity than the need for it. Once the fossil fuel displacement market has matured the surplus quantities will have to be shared and the savings will be smaller than those shown in Table G-5.

Table G-5 above shows that the greatest savings will accrue to consumers that use the most expensive fossil fuels. Those consumers will likely volunteer first for the new smart price plans. Propane and heating oil are used primarily in rural Ontario. Urban consumers in Ontario typically use natural gas for water heating and space heating.

The second situation OSPE analyzed allowed unlimited amounts of surplus emission-free electricity to be used for fossil fuel displacement. Figure G-5 below shows the larger amount of thermal energy that can be supplied.

Figure G-5
Thermal Energy that Can Be Supplied by Surplus Emission-Free Electricity (Not Limited by the Monthly Average Peak Power Demand)

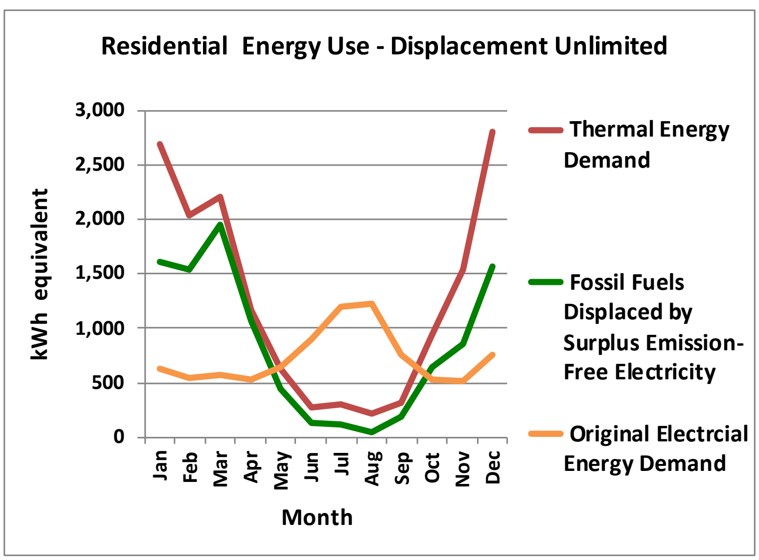


Table G-6
Annual Net Cost Savings by Typical Residential Fossil Fuel Consumer Using a Fossil Fuel Displacement Cost Reduction Strategy (Not Limited by the Monthly Average Peak Power Demand)

Month	Power Limit kW	Fossil Fuel Displacement	Nat. Gas Savings $	Propane Savings $	Fuel Oil Savings $
Jan	Unlimited	60% (3)	$19.06	$117.57	$214.47
Feb	Unlimited	76% (3)	$18.11	$111.76	$203.87
Mar	Unlimited	89% (3)	$23.10	$142.54	$260.02
Apr	Unlimited	92% (3)	$12.63	$77.93	$142.16
May	Unlimited	72% (3)	$5.32	$32.81	$59.84
Jun	Unlimited	51%	$1.65	$10.20	$18.60
Jul	Unlimited	39%	$1.38	$8.54	$15.58
Aug	Unlimited	20%	$0.52	$3.18	$5.81
Sep	Unlimited	57%	$2.17	$13.39	$24.42
Oct	Unlimited	68%	$7.58	$46.78	$85.34
Nov/	Unlimited	55%	$10.06	$62.08	$113.25
Dec	Unlimited	56%	$18.45	$113.86	$207.70
$0/t CO_2 Price Annual	**Unlimited**	**67%**	**$120.05**	**$740.65**	**$1,351.07**
$20/t CO_2 Price Annual	**Unlimited**	**67%**	**$160.75**	**$791.52**	**$1,412.12**
$50/t CO_2 Price Annual	**Unlimited**	**67%**	**$221.79**	**$862.73**	**$1,503.68**

Notes for Table G-6:

1. The price for electricity is based on the OSPE Energy Plus Peak Demand Smart Price Plan in Table D-1. The electricity price was 0.62 ¢/kWh, the average HOEP during periods when surplus emission-free electricity was available. Fossil fuel prices were taken from the residential column of Table G-5.
2. In addition to the savings above the consumer also saves 8% sales tax on any fossil fuels that are displaced by electricity which currently enjoys a lower sales tax rate.
3. These high percentages are likely only achievable in the early years of deployment of smart price plans when the numbers of subscribers are lower.

Table G-6 above shows the maximum annual energy cost savings that would have been available in 2018 for a typical residential consumer in Milton Ontario if they had unlimited access to surplus emission-free electricity to displace their fossil fuel use. Table G-6 applies early in the deployment of smart price plans when there is more surplus electricity than the need for it. Once the fossil fuel displacement market has matured the surplus quantities will have to be shared and the savings will be smaller than those shown in Table G-6 below. This is especially true in late Dec to late April when the amount of surplus electricity is typically lower.

An analysis of the operating capacity factor of various fleet sizes of fossil fuel displacement equipment is shown in Appendix E, Figure E-4. The actual amount of surplus emission-free electricity in future years will depend on the supply mix the government chooses to use in future years. If emission reduction becomes a high enough priority in future, the government can choose to deliberately add additional amounts of emission-free generation and that will create larger amounts of surplus emission-free electricity that will be used for fossil fuel displacement if the smart price plans are available to consumers.

We don't want to encourage the use of electricity produced from natural gas-fired generation, even if the plants are idle, to supply resistance heaters. That would double emissions to meet our heating needs. Fossil fueled power plants are only about 30 to 50% efficient whereas new gas-fired furnaces, boilers and water heaters are typically at least 85% efficient over their lifetime. Homes with ground sourced heat pumps GSHPs are up to 4 times more energy efficient over a period of 1 year compared to resistance heaters. GSHPs can achieve emission reductions even if they use electricity from natural gas fired generation.

Fortunately, it is easy to detect when natural gas-fired plants are being used to meet electrical load requirements. Fossil fuelled generating plants have a higher marginal cost of production than emission-free generating plants. When fossil fuelled plants are operating to meet the load requirement they set the clearing price on the wholesale electricity market at a higher price, typically above \$20/MWh (or above 2 ¢/kWh) with natural gas prices at about \$3 US per million British Thermal Units (including carbon pricing).

Emission Reduction Potential

Table G-7 below summarizes OSPE's estimate of the maximum carbon dioxide emission reduction that can be achieved using the available surplus emission-free electricity to displace natural gas.

The quantities of surplus emission-free electricity can vary due to economic conditions, generation technology choices by planners, effectiveness of conservation programs and weather conditions. Table G-7 below was based on the model forecasts of surplus emission-free electricity from 2016 to 2035 presented in Appendix E.

The number of residential consumers that can be supplied by 9.8 TWh/yr of surplus emission-free electricity, assuming that 70% of the surplus emission-free electricity is used for fossil fuel displacement, are summarized below:

- 1,300,000 homes with 36% fossil fuel displacement (limited access)
- 700,000 homes with 67% fossil fuel displacement (unlimited access)

Unlimited access to surplus emission-free electricity would create new consumer load peaks during their off-peak periods. If too many subscribers to the smart price plan are located on the same distribution system circuit, this could create some local distribution circuit congestion. The problem can be avoided by limiting the amount of surplus emission-free electricity the consumer can use to the consumer's monthly average peak power demand based on the consumers use of dependable electricity only.

Table G-7
Maximum Amount of Emission Reductions from Using Surplus Emission-Free Electricity Directly for Fossil Fuel Displacement (Assumes All Surpluses are Used for Water and Space Heating)

Year	Surplus Emission-Free Electricity in TWh(1)	Reduction for Nat. Gas only Mt CO_2
2020	16.3	3.5
2021	11.5	2.5
2022	12.1	2.6
2023	5.8	1.2
2024	13.4	2.9
2025	3.9	0.8
2026	6.6	1.4
2027	6.5	1.4
2028	6.3	1.3
2029	10.1	2.2
2030	6.7	1.4
2031	9.6	2.0
2032	9.9	2.1
2033	13.6	2.9
2034	12.7	2.7
2035	11.8	2.5
16-yr Annual Average	**9.8**	**2.1**
16-year Total	**157.0**	**33.4**

Notes:
1. Includes both curtailed and exported quantities of surplus emission-free electricity.
2. Other uses such as propane and fuel oil heating, electric car charging and hydrogen production can provide greater emission reductions than shown above.

Readers who are interested in reviewing the more detailed analysis and discussion related to retail electricity price reform can access the detailed OSPE report at www.ospe.on.ca

For more information or to book a meeting with OSPE, please contact advocacy@ospe.on.ca

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