SMART FROM SUNRISE TO SUNSET

A **Primer** on Ontario's Evolving Electricity Grid

Environmental Commissioner of Ontario

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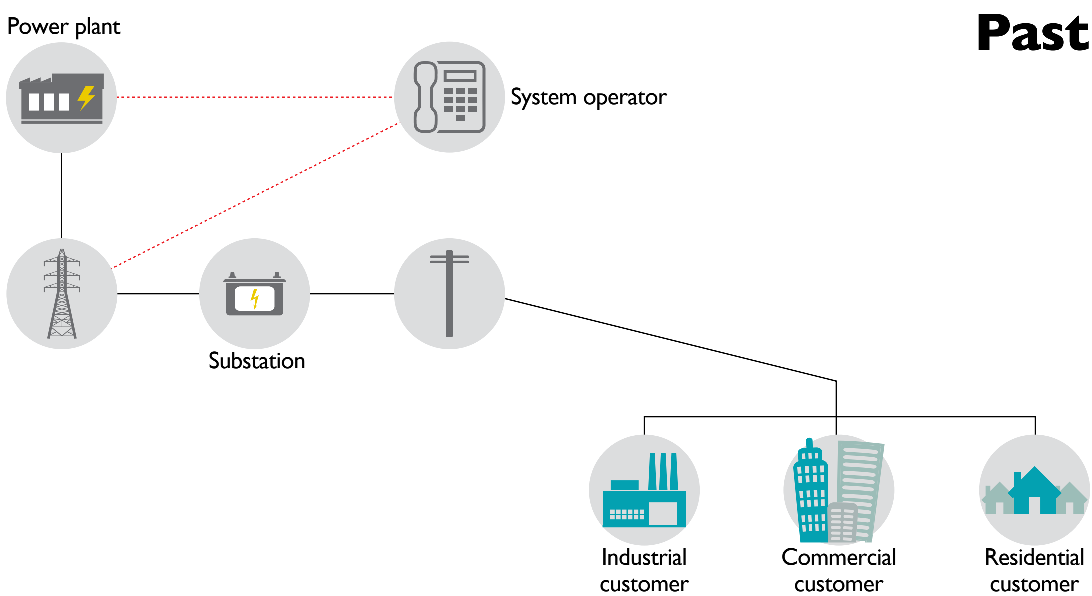
The Environmental Commissioner of Ontario (ECO) believes many aspects of energy literacy in our province are low, and that the concept of a smart grid is unfamiliar. Most Ontarians are by now aware of smart meters but these are only one element of Ontario's smart grid. This report is intended to help legislators and the general public to become familiar with the concept and the potential of the smart grid. It is not a critical review of specific government policy actions to date.

In this primer, we demonstrate some of the benefits that will arise from the high-tech gadgets, data analytics and unfettered consumer participation that will accompany a smart grid. It is the ECO's view that Ontario's pursuit of a smart grid – with its new meters, improved customer interaction, generators and other infrastructure – is a progressive policy development and a shrewd investment that will benefit both individual consumers of power and society as a whole. Our report highlights how the smart grid will enhance Ontario's ability to:

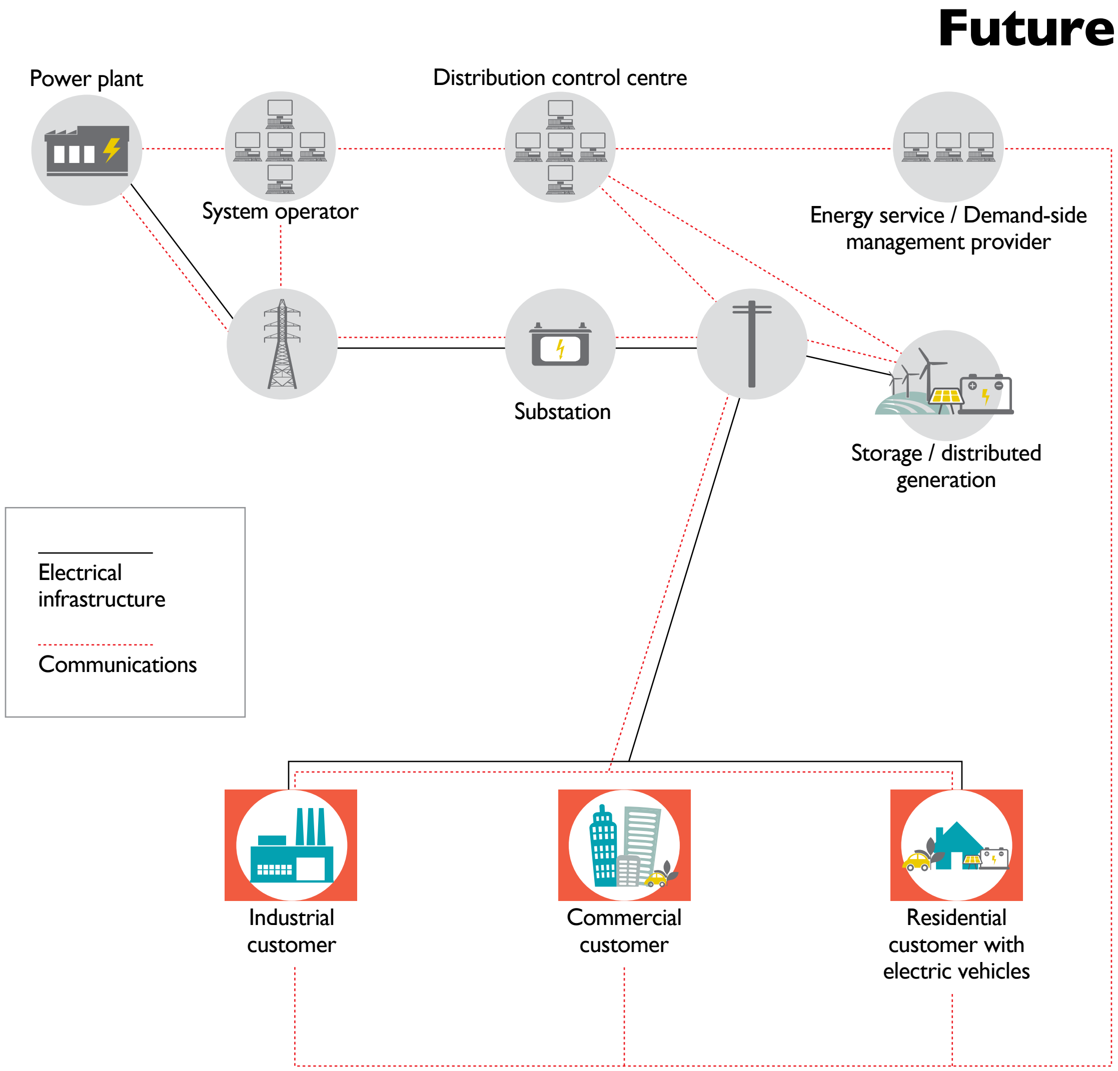
1. Operate low-carbon distributed generation (i.e., smaller-scale decentralized solar, wind and hydro power generators);
2. Use consumption data to conserve electricity with the aid of the next generation of smart appliances and equipment;
3. Charge variable prices and shift consumption patterns to manage peak electricity demand;
4. Improve service reliability and minimize disruption from power outages;
5. Advance the use of electric vehicles and the transition to the electrification of transportation; and
6. Connect electricity storage technology to optimize use of low-carbon generation.

Following a general introduction to the concept of the smart grid and a description of the key players, a stand-alone chapter is devoted to each of these six features. Together, the six chapters cover a hypothetical 'day in the life' of Ontario's smart grid at a point in the near future. Each chapter is divided into four sections:

1. ***The Situation:*** We open each chapter with a description of the electricity grid's operating conditions in a hypothetical day in the near future and situate the smart grid feature within the daily 24-hour cycle, as grid operators follow events: for example, the fluctuations of demand, weather, consumer behaviour and power outages.
2. ***What's Possible:*** We continue the hypothetical scenario, illustrating how a fully functioning smart grid of the future, together with its operators and power consumers, would respond to changing conditions and events during the daily 24-hour cycle.



3. ***How the Smart Grid Works:*** In non-technical terms, we explain how the technologies and operating systems of the smart grid function. For the most part, these technologies already exist but may not yet be fully integrated into Ontario's electricity system.
4. ***Status in Ontario, 2014:*** Finally, we close each chapter with a thumbnail sketch of the feature's current status in Ontario and describe how close we are to achieving the full-fledged smart grid ideal.



I

INTRODUCTION

ONTARIO'S EMERGING SMART GRID

Ontario's smart grid is not an abstract concept to be realized in some distant future. It has already begun to affect our lives in concrete ways. Elements that are available now in the province include: smart meters; in-home electricity displays; thermostats connected to home area networks; time-of-use prices; utility programs that reward customers who conserve power at peak hours of use; plug-in vehicles and chargers; smart appliances; solar panels and wind turbines; sensors that detect faults at distribution sub-stations; and devices that control power flow along transmission lines.

WHY IS IT HAPPENING?

Ontario is building a smart grid because the way society produces and consumes electricity is changing. Ontario's current electricity system relies mainly on large centralized generating stations connected to high-voltage transmission lines that are, in turn, joined to low-voltage distribution wires that deliver power to homes, businesses and institutions.

When this network was designed, the use of electricity at home and work was simpler. For example, few of our electronic devices were so sensitive they might be damaged by a power surge, no business information technology networks existed, and there were only a few small-scale renewable power sources scattered across the province. Now these are commonplace and have increased the technical demands on the electricity system to maintain power quality, reliability and environmental sustainability.

Energy analysts often characterize the smart grid as a "paradigm shift" that will produce disruptive but beneficial change and profoundly transform the electricity industry. The existing grid is portrayed as a "dumb" network that is largely unresponsive to changing customer needs or grid conditions. It pushes electrons out in one direction from a central location and provides only low-quality, after-the-fact information to a passive end-user. In contrast, once transformed, the smart grid will be an intelligent web with a two-way flow of electricity and information. The flow of information will empower grid technicians and consumers to change their patterns of electricity production, delivery and consumption.

The availability of new technology enables policy makers and grid controllers to respond with intelligent grid solutions. The vision of the ideal smart grid is one that offers numerous benefits to our lifestyle and the environment. Tech-savvy, informed ratepayers will manage their bills by conserving electricity or shifting the timing of their electricity use in response to price incentives. This will reduce peak demand and help avoid the need to build new generators. Grid planners will easily accommodate low-carbon generation, such as wind and solar, and will add energy storage technologies to further minimize environmental impacts. Households and businesses will themselves become small-scale generators of such clean electricity, and grid controllers will gain experience with these decentralized power plants. Grid operation will improve as the frequency and duration of power outages is reduced through better monitoring. All of this strengthens the grid's flexibility, efficiency and reliability while reducing the environmental impacts of electricity use.

WHAT IS THE DEFINITION OF A SMART GRID?

There is no universal commonly accepted definition of a smart grid, and the term may elude a precise description. Some definitions refer to the technologies that comprise the smart grid, others its desired attributes. In broad terms though, a smart grid is typically portrayed as an electricity delivery network whose traditional functions have been enhanced by adding new technology. The term is used to succinctly encapsulate the changes made to the multiple devices that are part of the electricity infrastructure. These include the meters, monitors, wires, switches, as well as the technical standards and operating practices that all work together as components of a smart grid.

To give a vivid sense of the nature and significance of these changes, the development of a smart grid is often likened to the recent transformation of telecommunications. This transition saw the replacement of rotary dial telephones, which used mechanical switching technology to send simple signals along wires, by today's portable sophisticated handsets that use cellphone towers to wirelessly transmit large amounts of digital media.

The incorporation of information and communications technology is central to the concept of smart grid, and is the core addition that creates an intelligent power grid. The addition of information and communications technology improves the efficiency and resilience of the system, while also reducing the environmental impact of the use of electricity. The ECO uses the following definition.

> A ***smart grid*** is the application of information technology to improve the functioning of the electricity system and optimize the use of natural resources to provide electricity.

This definition is similar to the description of the smart grid contained in the ***Electricity Act, 1998***, although we more explicitly emphasize the smart grid's mitigation of the environmental impact of electricity use. In the Act, the smart grid and its objectives are set out as the information exchange systems and equipment used together to improve the flexibility, security, reliability, efficiency and safety of the power system, particularly for the purposes of: increasing renewable generation; expanding provision of demand response, load control and price information to electricity customers; and, enabling innovative energy-saving technologies.

ONTARIO IS *NOT* AN ISLAND – IT IS ONE OF MANY PLACES PURSUING THE SMART GRID

About a decade ago, Ontario introduced **smart meters** (that measure electricity use in hourly intervals) as the first element of its smart grid. Ontario was not unique in this pursuit; a number of jurisdictions around the world started developing smart grids about the same time, including Italy, the Netherlands, California, New York, Texas and New Zealand.

Like other Canadian jurisdictions, Ontario has established transmission interconnections with neighbouring provinces and American states. For many decades, these have been used for reliability purposes and for importing or exporting power. Interconnections mean that Ontario's grid is not an island and we must keep pace with leading developments, such as smart grid technology, particularly for reliability purposes.

When Ontario announced provincial installation targets for smart meters in 2004, it was clearly a global leader. Installation of the meters proceeded rapidly until the end of the decade. However, some short-sighted decisions were made:

- The province did not require smart meters to employ enhanced communication capabilities that would enable greater conservation.
- There were delays before consumers could actually use their smart meter data.
- Work on smart grid initiatives other than smart meters was more measured.

Nevertheless, the province continues to move in the right direction. Early this decade, the province has also: introduced an energy storage target; increased predictability by enabling the system operator to control variable generators, such as wind turbines; and issued regulatory guidance on utility smart grid investment. Although the introduction of smart meters may have had a higher public profile, these are all important initiatives.

ONTARIO'S SMART GRID POLICY ISSUES

The smart grid offers short- and long-term benefits, at both an individual and societal level, but its development raises many of the perennial questions that typically afflict all electricity policy, including:

- Cost – How much should be spent?
- Benefits – How do we quantify them?
- Equity – Who pays, who benefits, and should the costs be allocated in proportion to those benefits?
- Choice – Is participation voluntary or obligatory?
- Ethical Values – Is a common value, such as environmental sustainability, a compelling rationale for action?

- Risk – How should capital be invested in a field where rapid advances in technology increase the risk of financial loss from stranded assets?
- Ownership – Which is the appropriate entity to own the technology (a utility, private company, consumer)?
- Leadership – Should government, the grid operator, the regulator and/or a multi-stakeholder agency develop the vision?

Ontario must decide to what degree the smart grid should be shaped by government policy and how much by the private sector, including customers and the market economy. Moreover, for the part of the grid that is under public oversight, there is the further issue of who is best suited to control development: the Ministry of Energy through its directives and legislation; the Ontario Energy Board by means of its decisions and orders; the Independent Electricity System Operator as a result of its operation of the grid; or some combination of these? If the current approach is maintained, the government will retain a fair degree of responsibility for the pace of smart grid development and the Ontario Energy Board, through its financial control, will have significant influence on the scope of infrastructure that is added.

THE PARTICIPANTS

MINISTRY OF ENERGY

The Ministry of Energy develops energy legislation and policy, including smart grid policy, while administering the ***Electricity Act, 1998*** and other legislation. Section 53.0.1 of the ***Electricity Act, 1998*** gives the government authority to issue regulations governing implementation of the smart grid, including the timeframe for its development, the roles and responsibilities for its implementation, and communications and other operational standards.

The ministry also issues direction to energy agencies on the operation of the electricity sector. For example, the Minister of Energy has directed the Ontario Energy Board to implement aspects of the smart grid. In November 2010, the Minister issued a directive to the Board that described in broad terms the government's vision and the principles of a regulatory framework for the smart grid.

The ministry also administers a smart grid research and development fund that finances the commercialization of new smart grid technologies.

ONTARIO ENERGY BOARD

The Ontario Energy Board (OEB) is a quasi-judicial agency that regulates many aspects of Ontario's electricity industry, as well as other energy sectors. In response to the Minister of Energy's 2010 Directive to implement the smart grid, the Board consulted (case EB-2011-0004) and made recommendations on several technical issues. The OEB established the Smart Grid Working Group – a diverse multi-stakeholder committee – to advise it on its tasks and responsibilities. This function has now been taken over by the Smart Grid Advisory Committee.

Following consultation, the Board issued its ***Supplemental Report on Smart Grid*** to provide guidance to transmitters, distributors and agencies proposing to undertake smart grid activities, outlining how the Board will evaluate their plans and allow cost recovery. The OEB is responsible for reviewing capital spending for smart grid infrastructure by transmission and distribution utilities and determining if utilities can recover these costs from ratepayers.

INDEPENDENT ELECTRICITY SYSTEM OPERATOR

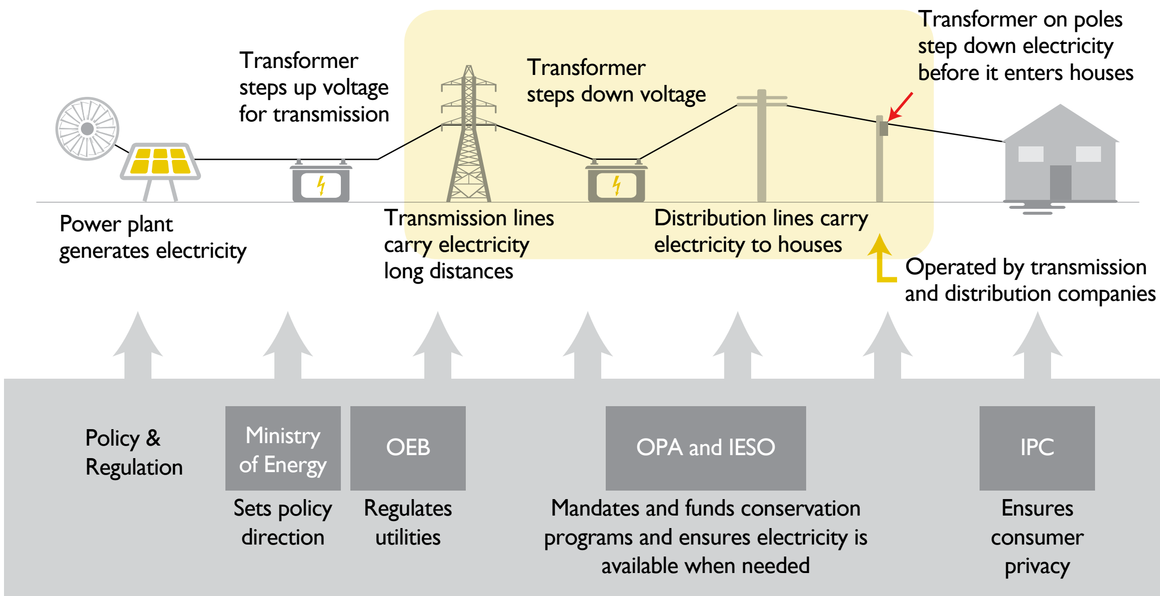
The Independent Electricity System Operator (IESO) is a not-for-profit corporation established by the ***Electricity Act, 1998***, responsible for balancing supply and demand on the electricity grid. It operates Ontario's electricity market by which generators are paid to inject power into the grid and customers (e.g., distribution utilities and large industries) pay to withdraw power from the grid. The IESO is also responsible for the technical implementation of electricity storage systems (e.g., batteries, flywheels, etc.), as well as developing rules for integrating renewable generation and demand response (i.e., load shifting) on the grid.

The IESO chairs the Smart Grid Forum, which is a collaborative group of utilities, agencies, companies, research and academic institutions that produce insightful reports on smart grid development.

The IESO is designated by regulation as the Smart Metering Entity. In this capacity, the IESO operates software and the Meter Data Management and Repository database, which processes smart meter time-of-use consumption data needed by distribution utilities to bill customers.

TRANSMISSION UTILITIES

Hydro One Networks, Great Lakes Transmission, Canadian Niagara Power and other companies transmit electricity at high voltages over long distances to distribution utilities and large industries that are connected to the high-voltage transmission grid. For several years now, these **transmission utilities** have used smart grid technologies to monitor and control power flow on their wires, and they are continually assessing additional smart grid opportunities. Sometimes, lessons learned from the high-voltage smart network are applied to the low-voltage smart distribution grid. These lessons may involve: monitoring technologies; forecasting and balancing renewable generation; and responding to outages.



LOCAL DISTRIBUTION COMPANIES

Local Distribution Companies (LDCs), also known as **distribution utilities** or **distributors**, deliver power along a network of low-voltage wires that they own and operate. LDCs operate the advanced metering infrastructure (the smart meters and communications technologies used to transmit meter data) and customer information systems (the call centres, websites and other means used to respond to service inquiries). LDCs also seek the OEB's regulatory approval to install smart grid infrastructure and to recover these costs. Finally, LDCs participate in pilot demonstration programs related to the smart grid (e.g., electricity storage, time-of-use pricing and the charging of electric vehicles).

INFORMATION AND PRIVACY COMMISSIONER

Ontario's Information and Privacy Commissioner (IPC) protects Ontarians' personal privacy. The development of a smart grid can only occur by providing access to information, such as smart meter data, to analyze demand patterns and customer behaviour. Such data is the property of electricity customers; consequently, there is a need to ensure that their privacy is protected. The IPC's reports have advocated embedding former-Commissioner Ann Cavoukian's concept, called Privacy-by-Design, into the technologies and practices of the smart grid to protect personal information.

Privacy and cyber-security are important to the continued development of Ontario's smart grid and are being addressed by several of the organizations mentioned above, but are not covered further in this report.

COMPANIES THAT SUPPLY THE "INTERNET OF THINGS"

The "Internet of Things" is a term coined to describe a situation in the near future when physical objects used in our everyday lives will be connected to and interact with each other, sending and receiving data through the Internet. For example, a household appliance could receive instructions via a homeowner's smart phone to turn off or cycle down. The creators and manufacturers of these 'things' will be important participants in the development and shaping of the smart grid. They will include appliance and equipment manufacturers, automakers, home builders, telecom companies and software designers that create computer "apps" (applications).

ONTARIO'S ELECTRICITY CUSTOMERS

Through their demand for new and improved electricity services – clean energy, reliability, power quality for sensitive electronic equipment, lower costs and energy literacy – customers will help shape the evolution and implementation of the smart grid. Customers will express their preferences both directly through the products and services they purchase and indirectly through their demand for customer service from distribution utilities. In turn, both private companies and public utilities will need to understand and respond to consumers when making smart grid investments.

AN ELECTRICITY GRID WITH GREATER POSSIBILITIES

In order to demonstrate the value of Ontario's future smart grid, this primer illustrates how the smart grid could benefit an average Ontario resident. Each of the following chapters outlines a hypothetical situation or circumstance, and then proceeds to explain how a future smart grid could increase the electricity grid's resiliency. They also provide some technical detail on different smart grid technologies and a status update on where different technologies stand in Ontario as of 2014.

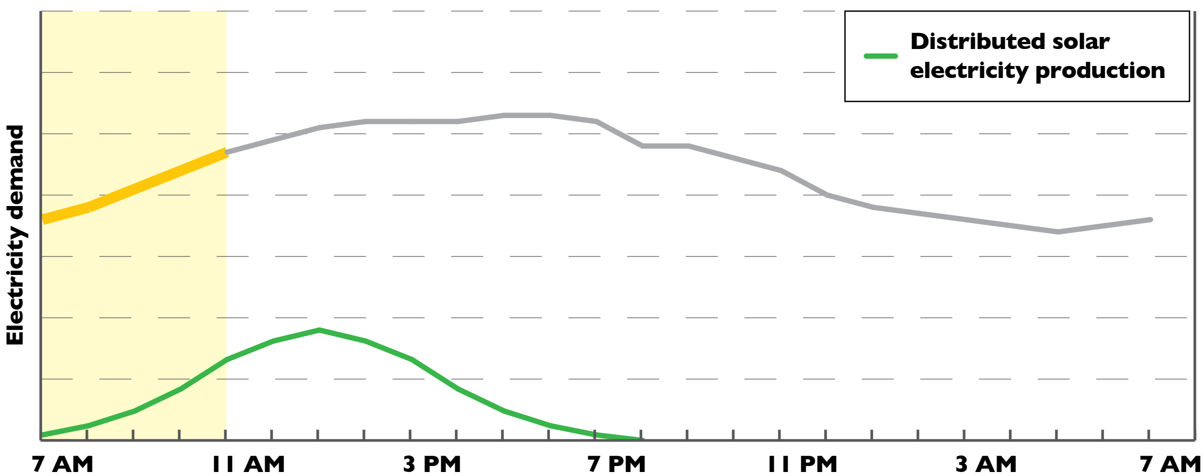
This province already has a strong foundation upon which to build a smart grid. The ECO believes that the electricity sector and its participants should be able to transition readily from the current electricity grid into a smarter system that offers greater possibilities.

2

ENABLING DISTRIBUTED RENEWABLE ENERGY GENERATION

THE SITUATION: 7 A.M. – 11 A.M.

A bright, clear day has dawned and the sun begins to rise in the sky. Electricity use increases as people begin their workdays. At the same time, power production from thousands of solar generators ramps up. Most solar power comes from small units located on the roofs of homes, warehouses, schools and stores across the province. Instead of being connected to the high-voltage transmission grid, these generators inject electricity directly into low-voltage power lines close to customers. This is referred to as **distributed generation**.

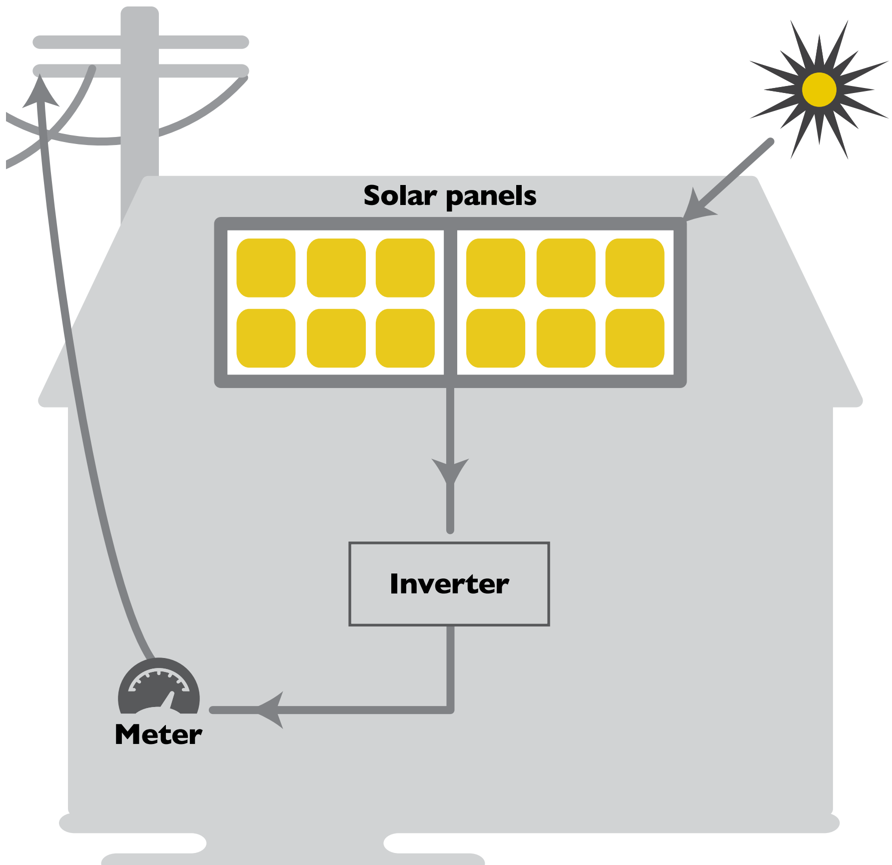


WHAT'S POSSIBLE: A FUTURE SMART GRID RESPONSE

Starting at nearly zero in the mid-2000s, the number of distributed generation facilities has grown each year. In this near future scenario, distributed generation (predominantly renewable energy, such as solar and wind) provides a significant portion of each distribution utility's electricity supply. Utilities have invested in smart grid communications technology to integrate large amounts of distributed generation into their networks, without compromising on the reliability of service. The smart grid is able to use these clean sources of electricity while maintaining and even improving power quality. Sensors on utility wires monitor power conditions at different points on the grid in order to maintain customer voltages within appropriate ranges, despite variations in power production from distributed generators.

From a control centre, each utility monitors the amount of power produced and injected into different parts of the grid by small solar and wind generators, and tracks how electricity production changes in response to atmospheric conditions, such as cloud cover, sun angle, air density and wind speed.

On days when electricity demand is very low and production from distributed generation is high, utilities can remotely reduce power production from solar or wind generators if needed. However, this is not necessary on this day – quite the opposite in fact. Renewable power produced close to the point-of-use reduces the amount of electricity that the local distribution company (LDC) needs to bring in from Ontario's high-voltage transmission system. This maximizes the use of clean, locally-produced energy and reduces the amount of energy wasted when electricity travels long distances across the wires.



HOW THE SMART GRID WORKS

The smart grid is one way to make distributed generation a reality.

The low-voltage distribution network was originally designed only to bring power generated elsewhere (at central stations connected to the high-voltage transmission network) to final consumers. It was not designed to accommodate generation connected directly to the low-voltage wires or to facilitate two-way electricity flow. Therefore, adding large amounts of distributed generation requires grid improvements. Smart grid information technology investments are often a cheaper method of improving the network in order to incorporate distributed generation than are ‘hard’ infrastructure investments, such as transformer station upgrades.

Increasing the amount of distributed generation is a desirable outcome in itself. New small-scale sources of clean electricity located close to customers will reduce energy losses and greenhouse gas emissions, enable more individuals and communities to participate in power production, and potentially avoid some of the siting conflicts that often plague larger centralized generation projects that are connected to the transmission grid. Once in place, distributed generation units become an asset that can be used as part of the smart grid, helping balance supply and demand, and improving power quality and reliability.

Balancing supply and demand through remote monitoring and control: As the amount of distributed generation on the network increases, utilities place more importance on remotely monitoring the power produced at each location, and turning units on or off if necessary, through automated communication between generators and utility grid control centres. Often, distributed generation will improve the supply-demand balance in the distributor’s service area, meaning that the utility will need to bring in less power from the transmission system to serve its customers. However, when available production exceeds demand, utilities may need to shut off distributed generation units to prevent power from flowing back on to the transmission system, as this reverse power flow can damage utility equipment. Energy storage and demand management (discussed in Chapters 7 and 3) also play critical roles in helping to balance electricity supply and demand on both the transmission and distribution systems and better managing the variable production from renewable sources.

Maintaining power quality: Utilities are required to provide power to customers within a certain voltage range. Outside of this range, customer equipment may malfunction or be damaged. Changes in the power produced by distributed generation units can affect voltage levels. LDCs use smart grid technologies to constantly monitor voltage at points along their network to ensure that voltage stays within the acceptable range. The electronic components in solar systems are an asset that utilities can use to improve voltage control, complementing the similar function performed by utility-owned equipment.

Ensuring safety and reliability: Distributed generation can enhance the resilience of the grid in the event of a large scale loss of power on the transmission system. **Microgrids** powered by distributed generation can allow parts of the electricity network, such as buildings that deliver essential services, to remain operating – ‘islands of power’ in a sea of darkness. Site-based backup emergency generators that use non-renewable fuels can be important contributors to microgrids, along with renewable distributed generation and energy storage.

Islanding of parts of the grid should only be done intentionally and under careful utility control. In areas where microgrids cannot be intentionally islanded, distributed generation units must be able to detect large-scale power outages and quickly cease power production to avoid potentially causing injury to the public or utility workers. Further design improvements to distributed generation units (particularly solar generators) can ensure that prompt shut-off is completely reliable under all outage conditions.

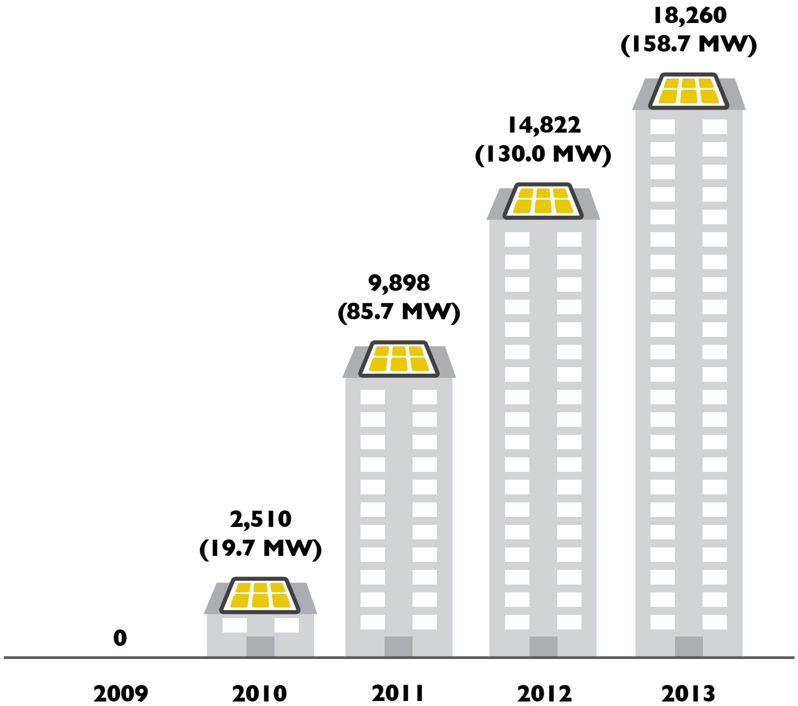
STATUS IN ONTARIO, 2014

Renewable distributed generation was an insignificant part of Ontario's electricity system before 2006 when the Renewable Energy Standard Offer Program was launched. That program and its successor, the Feed-In Tariff (FIT) program, pay renewable power producers a fixed price for power production. Interest in the FIT program remains high, despite the government significantly reducing the prices paid to generators to reflect falling technology costs. A microFIT program exists for smaller projects of 10 kilowatts in size or less. Related provisions in the ***Green Energy Act, 2009*** were also designed to spur small-scale renewable generation. These included a fast-track process for connecting smaller renewable projects to the distribution grid and a requirement that utilities plan to upgrade their distribution networks to enable the connection of renewable generation projects.

These policies diversified Ontario's electricity supply mix beyond the traditional nuclear, hydro and fossil fuel generators. They led to a large addition of both transmission-connected renewable generation and smaller scale renewable distributed generation. By the end of 2012, almost 3,000 megawatts (MW) of renewable distributed generation was in service or under development. Once completed, these projects will account for nearly 10 per cent of Ontario's electricity capacity.

Going forward, the province's long-term energy plan targets an additional 50 MW (roughly 5,000 units) of microFIT projects and 150 MW of medium-size FIT projects to be connected to the distribution system annually. Most will likely be solar systems. This is actually a slower rate of adding renewable generation than we have seen in the past five years. However, the rate at which renewables are installed could increase again, particularly if the continuing reduction in the upfront costs of solar systems makes these systems attractive even without a FIT contract.

Number of MicroFIT Solar Projects In-Service



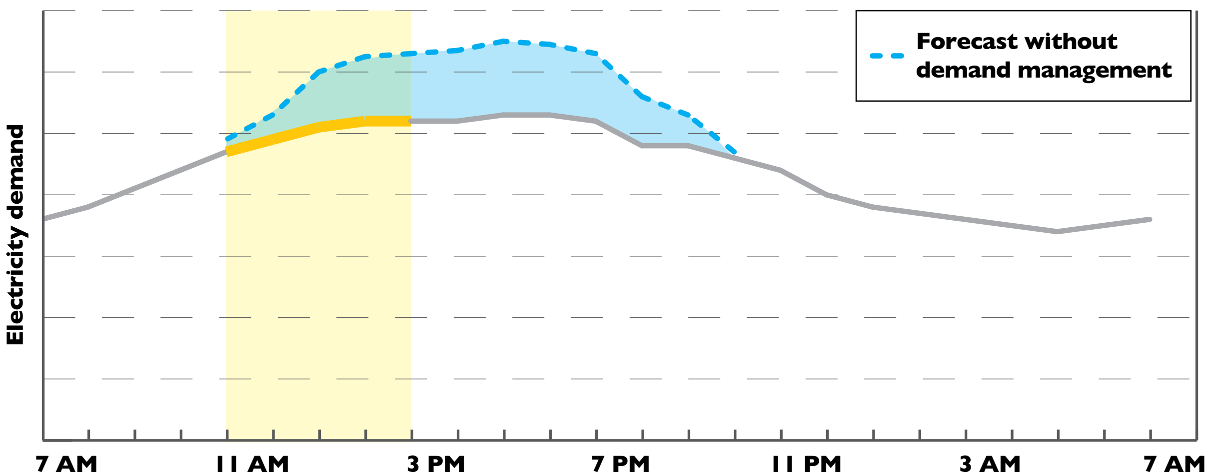
Despite the impressive growth of renewable distributed generation, grid infrastructure issues (including utility requirements designed to protect against unintentional islanding) have restricted installations in many areas of the province. Policy direction from the Minister of Energy and the Ontario Energy Board could lead to further smart grid investments that will facilitate distributed generation. Recent actions in grid operation are also encouraging. The Independent Electricity System Operator can now monitor and control the power output from large renewable generators connected to the transmission grid. Distributors are beginning to add the same functionality in order to remotely monitor and control smaller units connected to their distribution networks. In addition, some utilities are monitoring power lines to track the impact of distributed generation on voltage conditions across the distribution grid. Ontario is still in the early days of learning to use smart grid technology to accommodate renewable distributed generation.

3

MANAGING CONSUMER DEMAND

THE SITUATION: 11 A.M. – 3 P.M.

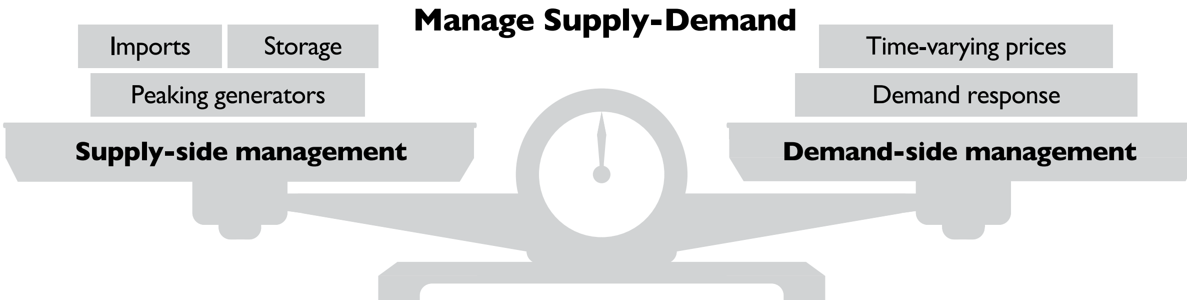
Afternoon is approaching and electricity demand continues to increase as the temperature rises and machines, computers, fans and air conditioners are turned on. Without intervention, demand will continue to increase and remain high until about 7 p.m. The cost to generate enough electricity to meet this high demand will become very expensive. However, if supply and demand are not matched, grid reliability may be compromised and, in the extreme, could lead to brownouts.



WHAT'S POSSIBLE: A FUTURE SMART GRID RESPONSE

In the future, the smart grid will recognize that the addition of more supply is not always the most efficient, environmentally friendly or cost-effective solution to match supply and demand. Instead, the smart grid's preferred solutions are demand-side options – achieved primarily through electricity pricing and demand response programs – to decrease the system's peak demand.

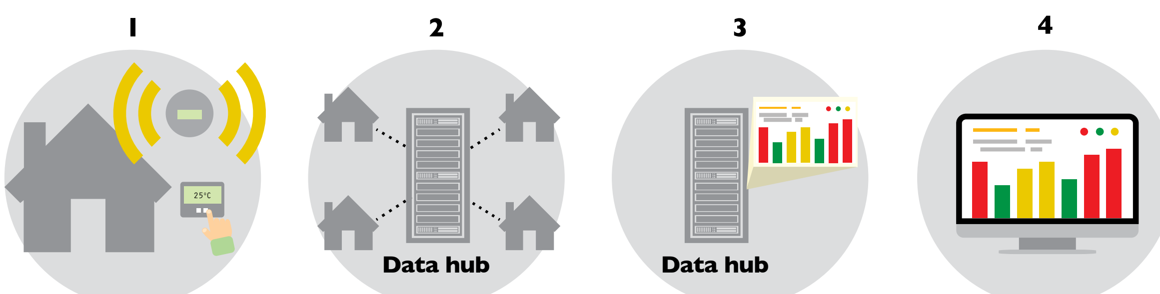
As demand climbs through mid-day, electricity prices rise – jumping to five times their regular level – to reflect the increased cost of producing electricity with more expensive forms of power generation, such as that supplied by natural gas-fired "peaker plants." Residential, commercial and industrial customers are alerted to the high prices and make use of improved electricity data and software (see Chapter 4: Facilitating Customer Use of Electricity Data) to reduce their electricity consumption and shift non-essential uses of electricity to lower-priced times.



Electricity pricing reduces some of this peak demand but, alone, is not enough to keep demand and supply balanced on this hot summer day. Ontario's grid operator turns to another tool at its disposal – **demand response** programs – to further reduce demand. These smart grid enabled programs automatically reduce the electricity consumption of specific equipment within homes and businesses by amounts pre-agreed in contracts. Regional demand response events are activated by the system operator in areas of the province where transmission wires are particularly congested to ensure grid reliability is not compromised.

HOW THE SMART GRID WORKS

Smart grid technologies provide consumers with the opportunity to actively manage their electricity usage by being aware of and responding to electricity price signals, and by participating in demand response programs.



ELECTRICITY PRICING

Time-varying electricity prices are usually set based on expected supply-demand conditions. The conservation effect of time-varying prices relies on customers responding on their own, perhaps with the aid of smart technology, (see Chapter 4: Facilitating Customer Use of Electricity Data) to these price signals by changing their consumption patterns to help manage their bills.

Time-varying prices are enabled by **smart meters** and **interval meters** (a more sophisticated smart meter used by large industries), which record electricity consumption data in set time intervals (e.g., every hour) and transmit this to utilities. By time-stamping electricity consumption, utilities determine the amount, time and price of the electricity that was used and bill consumers accordingly.

There are many ways to implement time-varying pricing, including **time-of-use** (TOU) and **critical peak pricing**. Each influences customer behaviour slightly differently, but the common goal is to deter peak consumption. TOU rates reflect the daily variation in peak and off-peak energy costs by dividing the day into two or more time periods with corresponding prices for peak hours and off-peak hours. Critical peak pricing sets an extremely high electricity price for a short time during instances when the system is under particular stress (e.g., mid-afternoon on the hottest summer day) to reflect the very high cost to produce power during critical system peaks. The short-lived, very high prices signal that although critical system peaks occur for only a few hours a year, they require building expensive electricity infrastructure, such as natural gas peaker plants, to meet just these few hours of demand. Jurisdictions have implemented one or both of these variable price designs (as well as others) to reflect the fact that raising peak capacity is expensive and peak consumption must be shifted.

DEMAND RESPONSE

In addition to the conservation-promoting effect of time-varying prices, the utility or system operator can activate demand response programs to directly control household customer equipment (e.g., air conditioners and water heaters), or in the case of large industrial, commercial and institutional customers, direct them to shut down production processes or operations and reduce demand. These programs are usually voluntary and customers receive incentive payments for participation. Once enrolled, participants must follow the instructions of the program operator.

Customers will pre-determine exactly what equipment will be controlled so that impacts on businesses or homes are minimized. Utilities may activate demand response programs through technologically advanced electricity meters or through a separate communications channel, such as radio or the Internet. The hourly electricity data collected can be used by demand response providers to verify their program performance.

Both time-varying prices and demand response programs can provide environmental and financial benefits by reducing reliance on existing power plants and possibly avoiding the need to build new fossil-fuelled plants.

STATUS IN ONTARIO, 2014

Ontario's electricity pricing policies currently include several mechanisms to influence the electricity consumption of both large and small consumers.

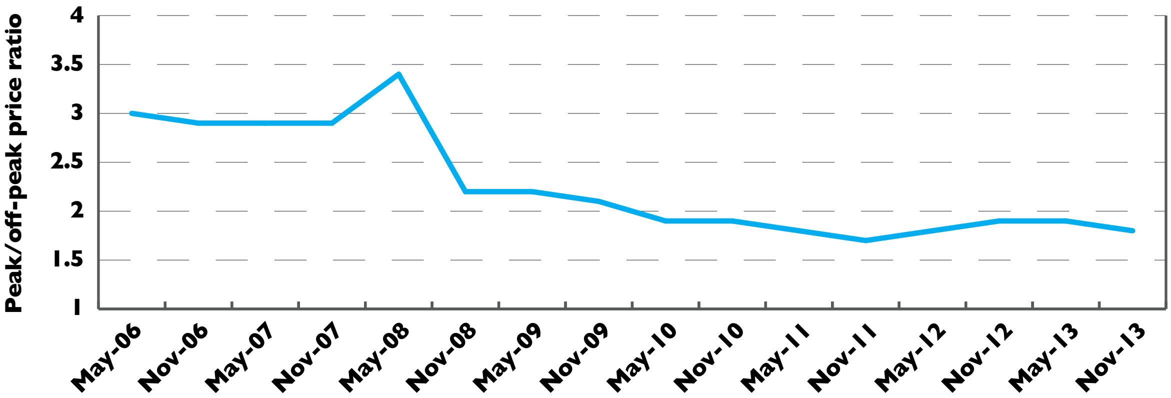
Very large electricity consumers – those with an average demand of 5 or more megawatts (MW) – can avoid paying higher power prices by reducing power use during periods of high demand. A portion of the bills of these consumers is based on their share of total provincial demand during the five highest peak demand hours in a year. Since it can't be predicted on which five hours the highest demand will occur, companies have an incentive to reduce demand during most times of high demand. This pricing mechanism is believed to have lowered Ontario's peak demand by several hundred megawatts.

Smaller consumers – like businesses using more than 250 megawatt-hours (MWh) of electricity per year – pay the market price for a portion of their electricity costs. This price varies hourly and is based on market conditions (e.g., with high demand and tight supply forcing prices up), so price fluctuations provide an incentive for companies to strategically manage when and how they use electricity.

For customers who consume less than 250 MWh of electricity per year, including all residential customers and many small businesses, electricity prices are determined by a Regulated Price Plan developed by the Ontario Energy Board. The Board forecasts the cost of electricity used by consumers to ensure that, on average, regulated electricity prices reflect and are sufficient to recover the cost of generating power, although there is no guarantee that the price in any given hour exactly matches the real-time cost of generation.

In Ontario, nearly 4.8 million customers have smart meters and, in May 2006, Ontario became the first North American jurisdiction to require TOU pricing for all residential and small business customers. TOU rates provide a financial incentive for customers to shift some of their electricity use from on-peak to off-peak times. TOU rates require experimentation and fine-tuning of the peak to off-peak ratio to nudge customer power consumption patterns toward an optimal demand response.

Through the regulated price plan, the Board sets TOU rates and adjusts them, if necessary, every six months. Ontario's peak to off-peak ratio has narrowed substantially since its inception. A report prepared for the Board estimates that TOU rates have resulted in a 3.3 per cent reduction in residential consumption during summer peak hours. Pricing structures in other jurisdictions indicate that peak demand reductions of 10 per cent or more are possible with a strong enough price signal (i.e., a large difference between peak and off-peak prices).



In addition to pricing, several demand response programs have been implemented in Ontario. Most are triggered by system needs (e.g., capacity and reliability requirements).

- Through the Demand Response 3 program, companies agree to conserve electricity when demand is high in exchange for an incentive payment.
- Certain smaller consumers can manage demand by working with demand response "aggregators" – companies that combine capacity from multiple small consumers to collectively reduce demand without requiring each consumer to manually manage their own consumption.
- Ontario's ***peaksaver*** PLUS program allows residential and small business customers to permit utilities to cycle down home air conditioners, water heaters and swimming pool pumps when necessary.

Ontario's current demand response programs are expected to evolve in the near future. In Ontario's 2013 Long-Term Energy Plan, the government announced that the Independent Electricity System Operator (IESO) will manage and update Ontario's existing demand response programs. The IESO will provide demand response programs in a way that puts this resource on par with generation resources (i.e., system needs will be met by the most cost-effective resource(s), either supply-side or demand-side). The smart grid makes possible and enhances this flexibility in grid operation and response.

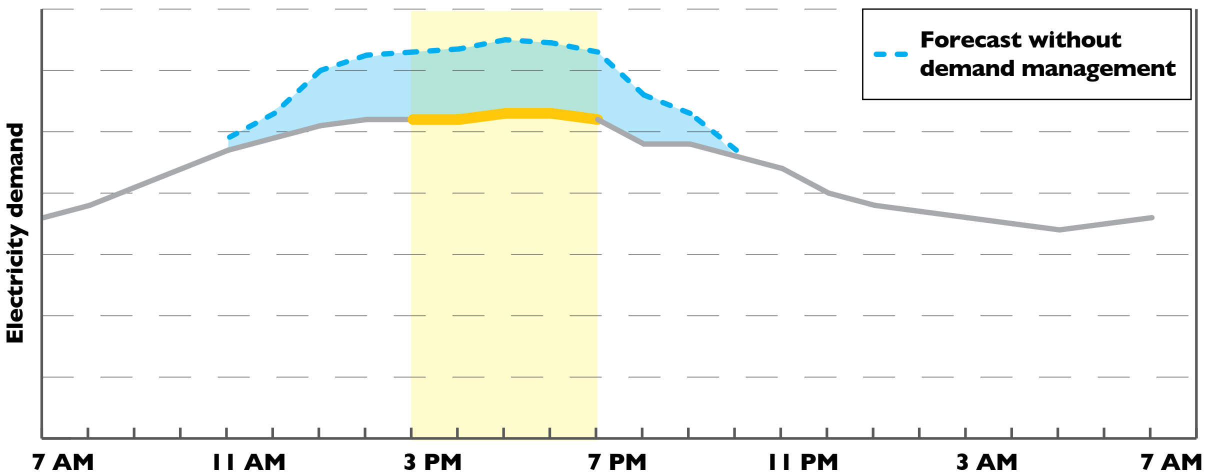
Another demand response opportunity is arising. More residential consumers are purchasing appliances and products with programmable technology (e.g., fridges, programmable thermostats, and "smart plugs" to control plugged-in devices) that can automatically respond to electricity market conditions based on user preferences. This represents an untapped demand response resource for system operators and will allow more customers to participate in demand response programs in the future smart grid. Technology standards must be established for response and control equipment to ensure that demand response can be fully automated across a wide variety of devices.

4

FACILITATING CUSTOMER USE OF ELECTRICITY DATA

THE SITUATION: 3 P.M. – 7 P.M.

Temperatures have continued to rise on a hot and humid afternoon. Electricity demand is high as commercial and residential air conditioners are in full swing. Electricity prices are high for both residential customers on time-of-use rates and business customers paying the market price.

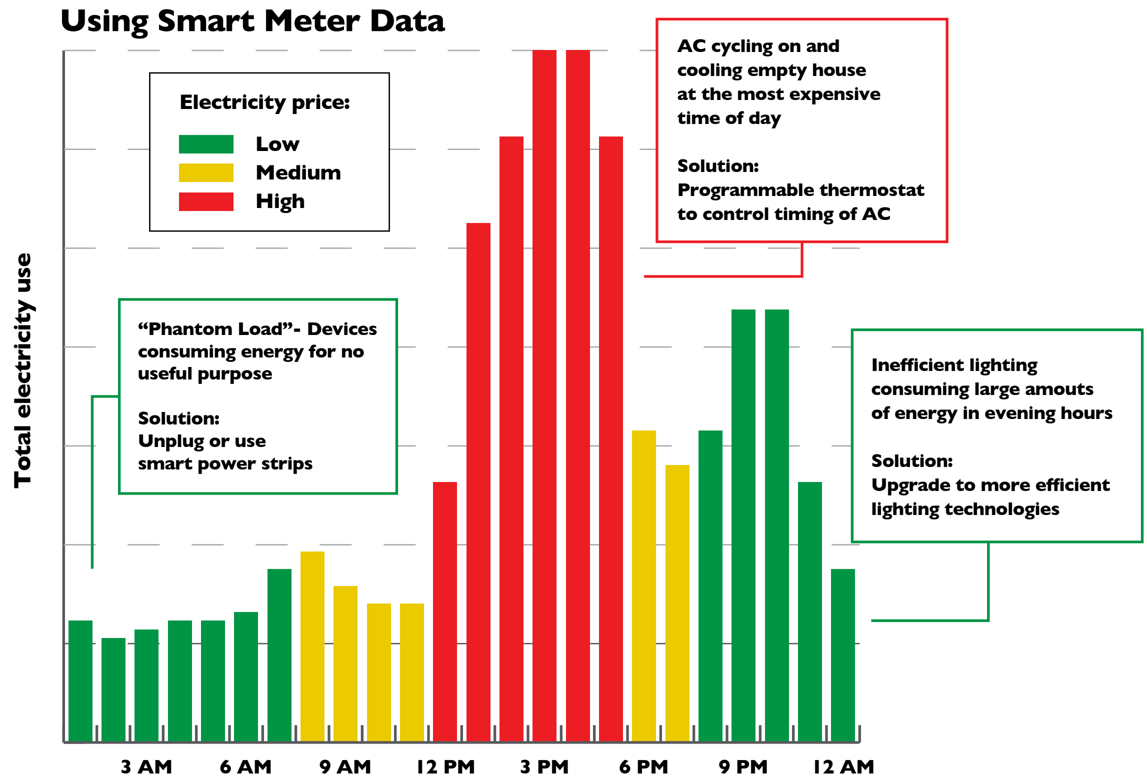


WHAT'S POSSIBLE: A FUTURE SMART GRID RESPONSE

In the near future, advances in electricity metering, communications, and smart software applications have enabled Ontario business and residential customers to readily access real-time information on their electricity use patterns and changes in electricity prices. Customers use this information to reduce their consumption and control their electricity costs, by improving energy efficiency or shifting some energy use to cheaper off-peak hours.

Some of these actions are done consciously by consumers, who use their smart phones or computers to remotely turn down or shut off appliances in their homes. However, there has been an evolution towards automated control, by smart appliances and energy management systems that interpret the raw energy and price data and take action to adjust energy use based on customer preferences. Household appliances are now embedded with technology that automatically responds to price signals by shifting non-essential demand to lower-priced times of the day. Automated building systems in office towers and condominiums respond in similar fashion to programmed set points.

As a consequence, even on the hottest summer days, Ontario's peak electricity demand never again approaches the all-time high reached back in the summer of 2006. All these years later, Ontario's electricity system can supply enough electricity to meet the province's needs, without experiencing brownouts or requiring other emergency control measures.



HOW THE SMART GRID WORKS

Enabling customers to change their patterns of energy use in response to data inputs requires technological improvements in several areas.

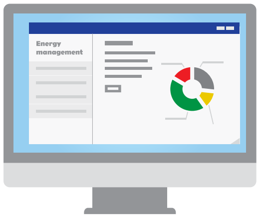
Improving customer use of electricity data is a three-step process.

Data Collection

Data collection gathers the source information needed to understand energy use and, subsequently, drive action. The most important data are a continuous record of the amount of electricity consumed in each time interval (collected through the meter) and electricity prices over the same time period. Some customers will also be motivated to take action by a third signal: the environmental impact (most notably the greenhouse gas emissions) associated with their electricity consumption. This will vary depending on the types of electricity generators running and the amount of electricity they are supplying to the grid. Other data of interest may include weather conditions and any messages sent by the electric utility.

Telecommunications

Telecommunications transmit the data to electricity consumers. There are several possible pathways. Utilities and other information providers can make the information available on the Internet, which customers can access using their computers or mobile devices. Alternatively, each customer's electricity meter can serve as a direct communications gateway into the home or business, passing real-time electricity consumption information (and possibly other information, such as critical peak pricing alerts – see Chapter 3: Managing Consumer Demand) directly to consumers and their compatible devices, such as smart appliances. For this to work, the utility meter must "speak the same language" (communications protocol) as the customers' devices.



Energy Management Software

Applications software programs make sense of the raw data and enable consumers to convert information into action. In-home energy displays can show users the information in an easy-to-understand format. More advanced control technologies can interpret the data and take action on their own. For example, smart electric vehicle chargers could track battery charge levels, electricity prices and user preferences to determine when to charge (see Chapter 6: Fuelling Electric Vehicles). And at a still more sophisticated level, commercial building automation systems can assess many inputs (e.g., price, external temperature, occupancy, amount of daylighting) and make continuous adjustments to run the building's heating, cooling, and lighting systems at a low cost and environmental impact.

Thanks to improved data access, customers can save energy while reducing their peak electricity demand. How much they save will depend on such factors as timeliness (e.g., real-time feedback versus next-day data), the quality of the applications software, and the degree to which data access is complemented by incentives to adjust electricity consumption patterns, such as time-varying pricing or demand response programs (see Chapter 3: Managing Consumer Demand).

Improving access to data will involve the efforts of both distribution utilities and the private sector. For example, manufacturers are building "smart" appliances that can track appliance energy consumption directly and be remotely controlled by the customer via Wi-Fi. Telecommunications companies are providing smart home monitoring that includes energy controls, although the products and services offered are still at an early stage. Ideally, the information gathered by distribution utilities and the electricity system operator (e.g., electricity price, metered consumption, greenhouse gas emissions and reliability conditions) will be communicated to the energy-using devices that are under customer or third-party control. As these technologies mature and become more user-friendly, they will be used by a wider segment of the population and will become embedded in our daily lives.

STATUS IN ONTARIO, 2014

Ontario has been a North American leader in converting almost all residential and small business customers to smart meters. Smart meters record electricity use in hourly intervals and send this data back to distribution utilities. Many utilities have completed the data link to customers by developing web portals that allow customers to view or download their data, comparing their energy use on an hourly, daily, monthly or yearly basis, as well as against time-of-use prices. Since smart meter data from all Ontario utilities is stored in a central database, eventually utilities or third parties could mine the smart meter data records (with confidential information removed) for planning, research and customer benchmarking applications.

Ontario has taken an important step to produce more customer value from smart meter data through the "Green Button" initiative, which establishes a standard, open data format for energy information. Software developers can use the Green Button standard to develop useful applications for customers that combine smart meter data with other features to help customers manage their energy costs or reduce their environmental impact. The "Energy Apps for Ontario Challenge" encouraged the development of innovative new software programs that use smart meter data in the Green Button format, and some Ontario electricity utilities will be pilot testing the best of these "apps" (software applications) with their customers. Customers will choose which apps to use and grant permission to these programs to access their utility data. Ontario's Smart Grid Fund has also provided financial support for some developers of energy management software.

Data Access for Ontario Business and Institutional Customers: Surprisingly, it can be more difficult in Ontario for large businesses to access their electricity data than for residential and small business customers, even though the potential energy and cost savings are greater. Smart meters will not be in place for all large customers until 2020. Even large business customers with smart meters may find it difficult to access price and consumption data from their utility in a timely and useful format (e.g., online), as the initial focus of "Green Button" applications has been on residential customers. Some large electricity users with motivation and resources have implemented finer-scale metering and energy management technologies on their own.

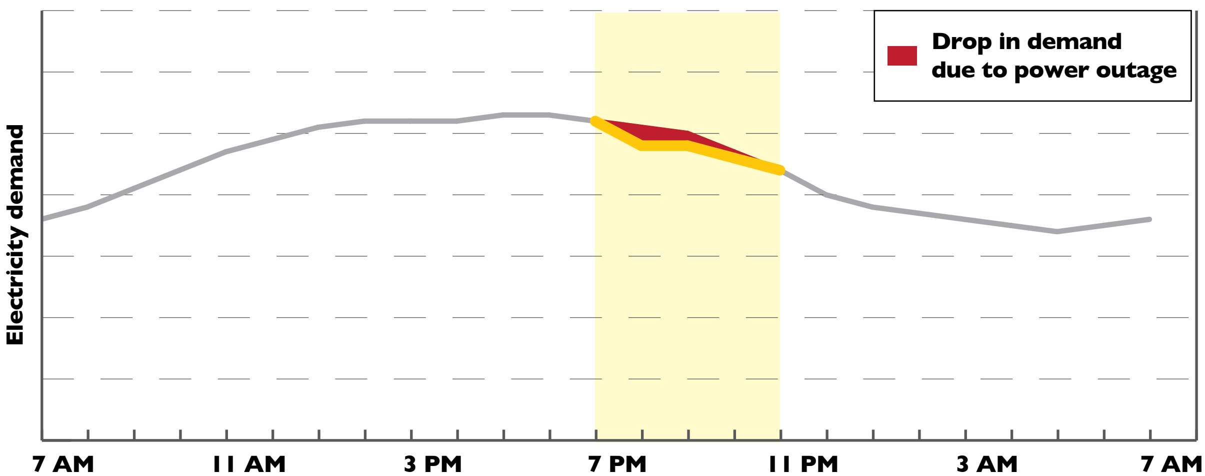
Role of the Ontario Energy Board: Further actions to improve access to data will partly depend on decisions of the Ontario Energy Board, which must approve the economic prudence and rate impact of any proposed technology upgrades by utilities. For example, customer access to smart meter energy data is not yet available in real time (the data is usually available the next day). Enabling real-time smart meter data access and communication between meters and customer appliances and Home Area Networks would require meter upgrades in most cases and the Board would weigh the cost versus the benefits of enhancing meter capabilities.

5

IMPROVING RELIABILITY

THE SITUATION: 7 P.M. – 11 P.M.

Weather conditions have taken a turn for the worse as a major windstorm has swept through parts of Ontario, the remnants of an Atlantic Ocean hurricane. High winds have caused major tree damage. Generating stations and the high-voltage transmission system are largely unaffected, so there is enough electricity supply to meet demand. However, downed trees in dozens of locations have caused physical damage to the distribution system. Thousands of customers have lost power.



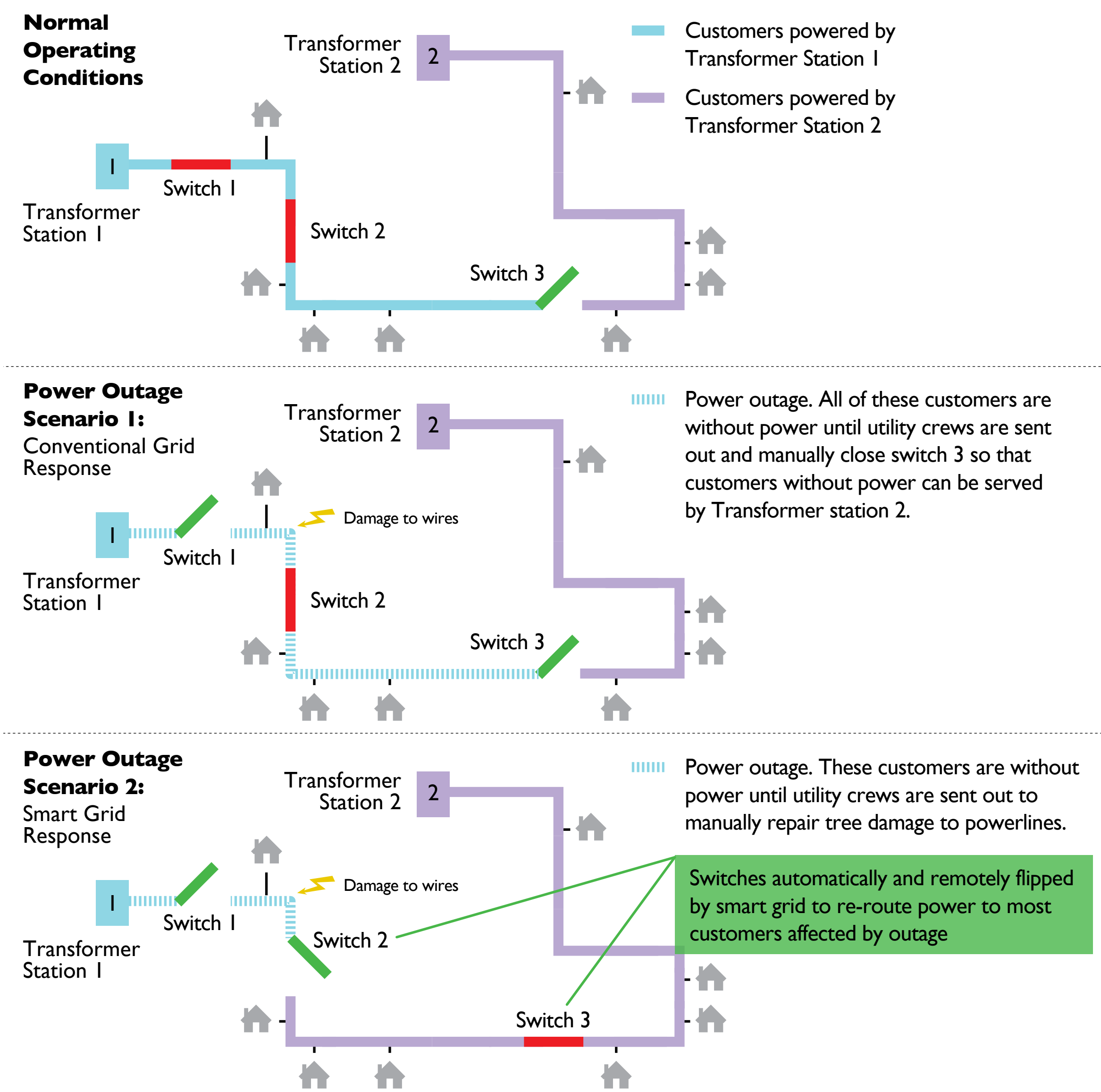
WHAT'S POSSIBLE: A FUTURE SMART GRID RESPONSE

Under our future scenario, several years of smart grid investments mean that many local electricity distribution utilities are able to respond more quickly to extreme weather events than they were in the past.

In the first few hours of the storm, tree branches falling on wires interrupt the flow of electricity and briefly cause power outages for all customers over a large portion of the distribution network. However, recently installed control switches located at key points along the distribution wires communicate with one another and automatically re-route electricity along alternate paths to restore service for 90 per cent of affected customers. Power is restored for these customers almost instantaneously, without operator involvement.

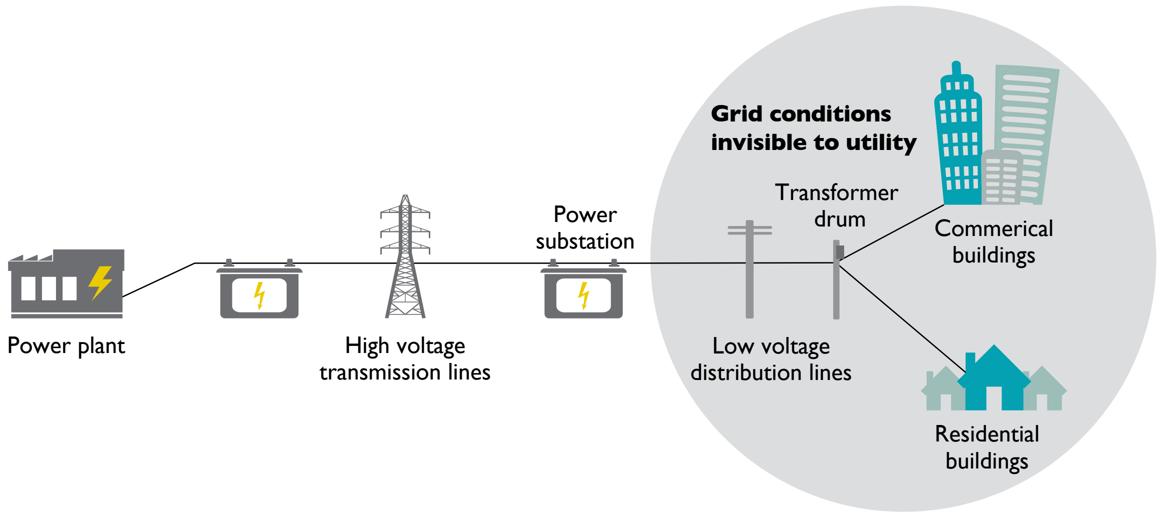
The next task is to restore service for the 10 per cent of customers whose power can only be brought back through manual intervention to clear the lines. Sensors on the distribution wires let the utility know the approximate location of the faults. This information is supplemented by signals from customer smart meters indicating zero power consumption, a likely indicator of loss of service for these customers. The utility processes this information to develop a priority sequence for fault restoration and to dispatch field crews to the areas where power is still out. Crews first tackle faults on major trunk lines serving large numbers of customers, then faults on secondary lines. Flashing indicators on power lines provide visual clues to help utility workers identify exactly where faults occur, speeding up the job of clearing the faults.

The improved monitoring of conditions on the distribution network enables the grid to return to normal operation faster. The average amount of time that customers experience without power each year is much lower than it was five years ago.



HOW THE SMART GRID WORKS

Customer reliability can be improved by filling an information gap in part of the electricity system.



The outer arms of the electricity grid, where power moves along low-voltage wires from sub-stations for delivery to customers, have historically been "invisible" to utilities because there was little or no sensing, control or communications capability along these lines. When weather or equipment failure on these wires caused outages, restoration of service relied on utilities receiving "power out" phone calls from customers and then reactively sending crews out to locate and clear faults, a slow process that was annoying for waiting customers.

This is beginning to change as improved communications technology can make conditions on these wires more visible to utilities. Sensors placed at strategic locations on different parts of the distribution network can monitor the flow of power and communicate this information to the utility's control centre. In some cases, the flow of information is two-way, and wire-mounted devices can be controlled remotely (e.g., utility technicians can open or close a circuit and route the flow of electricity along a new path). The most advanced technologies use intelligent devices distributed across the grid to monitor operating conditions, communicate with one another, and restore the system to an ideal state without human intervention, if possible. This is known as a "self-healing" smart grid.

The information gathered about power flow on the distribution system can also be used to proactively prevent some types of power outages. Many outages are caused by the premature failure of distribution infrastructure, such as pole-mounted "bucket" transformers. Sensors that measure power flow and wire temperature over time can be used by utilities to identify which transformers are being overstressed and to take corrective action before they fail.

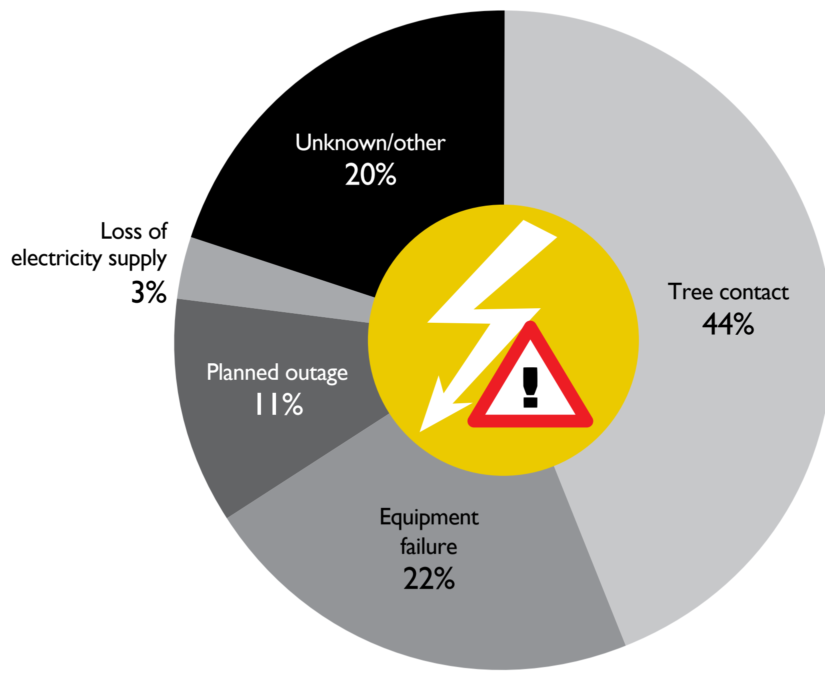
The goal of each of these technologies is to lower the number and duration of power outages, reducing inconvenience for residential customers and saving money for commercial and industrial customers. The opportunity costs of power outages for medium or large businesses in terms of lost production or productivity can easily be thousands of dollars per hour.

Beyond higher reliability, improved monitoring of the distribution network has additional applications, including reducing power theft, lowering customer voltage levels slightly to save energy, and allowing a larger amount of local generation (e.g., solar panels) to connect to the distribution system (see Chapter 2: Enabling Distributed Renewable Energy Generation).

STATUS IN ONTARIO, 2014

In 2012, Ontario electricity customers experienced, on average, two sustained interruptions where power was lost for a total of four hours. The majority of outages each year are due to issues with the low-voltage distribution system; the high-voltage transmission system already features a considerable amount of monitoring, automation and remote control, as well as built-in redundancies to isolate and limit the impacts of equipment failure.

Causes of Power Outages, Hydro One Distribution, 2009–2012



Maintaining reliable service has always been a core function for electric utilities, and this will continue under the smart grid build-out. The Ministry of Energy has established reliability as a fundamental smart grid objective. The Ontario Energy Board uses a scorecard approach to measure distributor performance against several indicators, and the Board will be using reliability statistics as a key metric when evaluating each utility's performance and setting profit rates. Poor reliability could thus impact the bottom line of utilities.

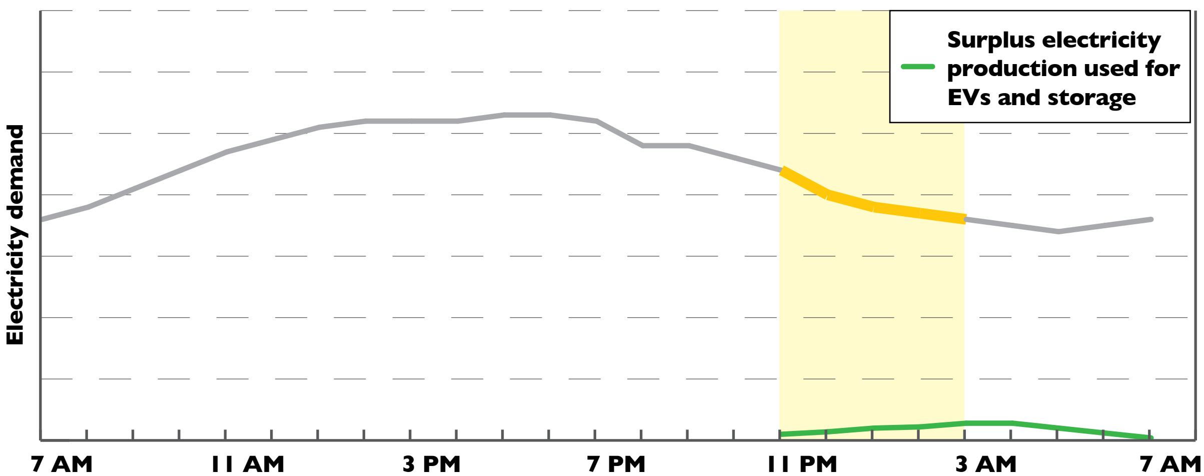
Improvements in reliability will largely depend on the actions of Ontario's local electric distribution companies. Many local distribution companies have already made smart grid investments in reliability, and different technologies will make sense for different utilities. Not all sections of the distribution grid will be smartened immediately. Utilities will likely focus their initial investments on improving grid infrastructure that serves large numbers of customers or has a poor track record of reliability. Utility smart grid reliability projects will need to compete against other capital projects, based on the value that they provide to customers. The regulatory environment in Ontario favours investments in reliability, and much work in this area can be expected.

6

FUELLING ELECTRIC VEHICLES

THE SITUATION: 11 P.M. – 3 A.M.

On a typical summer day, Ontario's electricity demand peaks during the hottest part of the afternoon and remains at relatively high levels until the early evening. Then demand drops by several thousand megawatts overnight because most people are asleep. Even though demand drops during overnight periods, baseload power plants (such as nuclear plants) and intermittent generators (such as wind turbines) typically continue to generate electricity.



WHAT'S POSSIBLE: A FUTURE SMART GRID RESPONSE

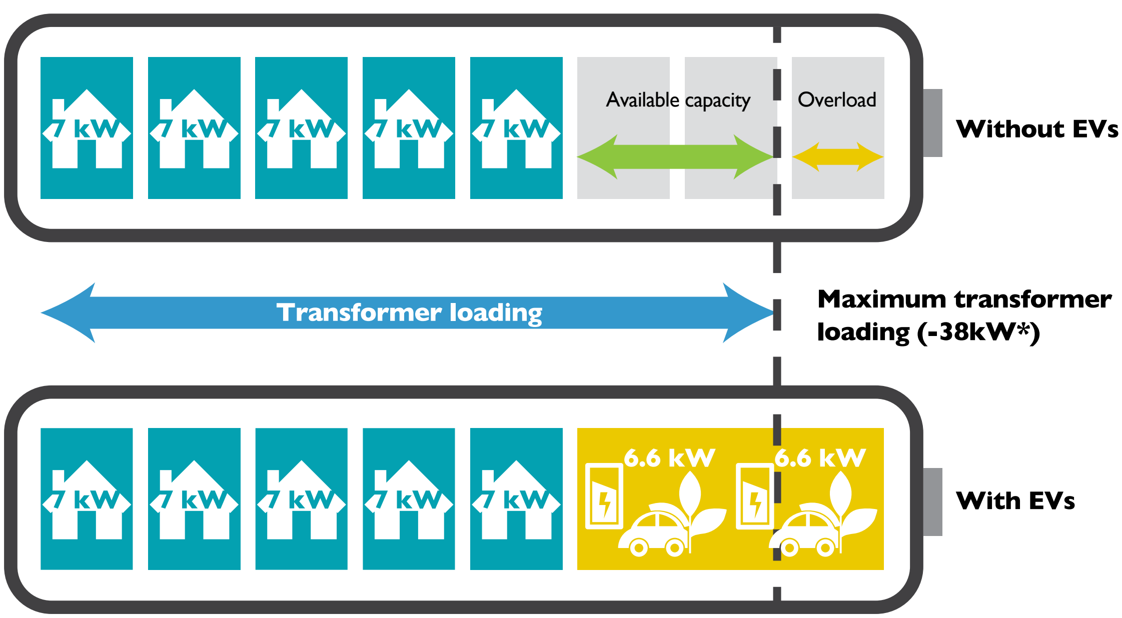
Imagine an evening in the near future where 1 in 20 cars on Ontario's roads are electric vehicles and these cars are regularly plugged in to charge in the evening around 6 p.m. Without control over how or when charging begins, the majority of electric vehicles will start to refuel immediately when they are plugged in – at 6 p.m. – which is also when electricity demand is relatively high. Refuelling Ontario's electric vehicles when demand is high could strain the electricity system.

Now, imagine that same evening in the near future where 1 in 20 cars on Ontario's roads are electric vehicles, only this time Ontario has a smart grid. The smart grid will allow each utility to see when and where electric vehicles are plugged in to refuel. Vehicle battery information will flow between those cars, local distribution utilities and the Independent Electricity System Operator (IESO), so utilities can schedule vehicle charging in a way that minimizes costs for participating car owners and maximizes the use of intermittent renewable energy, all without inconveniencing car owners. For example, on this hypothetical future evening, the IESO forecasts unusually strong winds across southern Ontario between 11 p.m. and 3 a.m., and knows that most electric vehicles will be plugged in to charge around 6 p.m. In order to take advantage of the additional wind power, the IESO will send a signal to local utilities that tells them to stagger vehicle charging until after 11 p.m. In this scenario, Ontario will maximize its electricity generation from wind turbines and use this electricity to refuel electric vehicles.

HOW THE SMART GRID WORKS

Electric vehicles are powered by on-board batteries and offer several environmental advantages over gasoline-powered cars: they use fuel three times more efficiently than cars powered by gasoline on a tank-to-wheels basis; and their fuel comes from energy sources that produce minimal greenhouse gas emissions because Ontario has a low-carbon supply of baseload electricity – nuclear, hydro and wind. Given that gasoline-powered passenger vehicles were responsible for almost 20 per cent of total provincial greenhouse gas emissions in 2012, cleaner and more efficient vehicles, including electric vehicles, will be key to helping Ontario reduce emissions from the transportation sector.

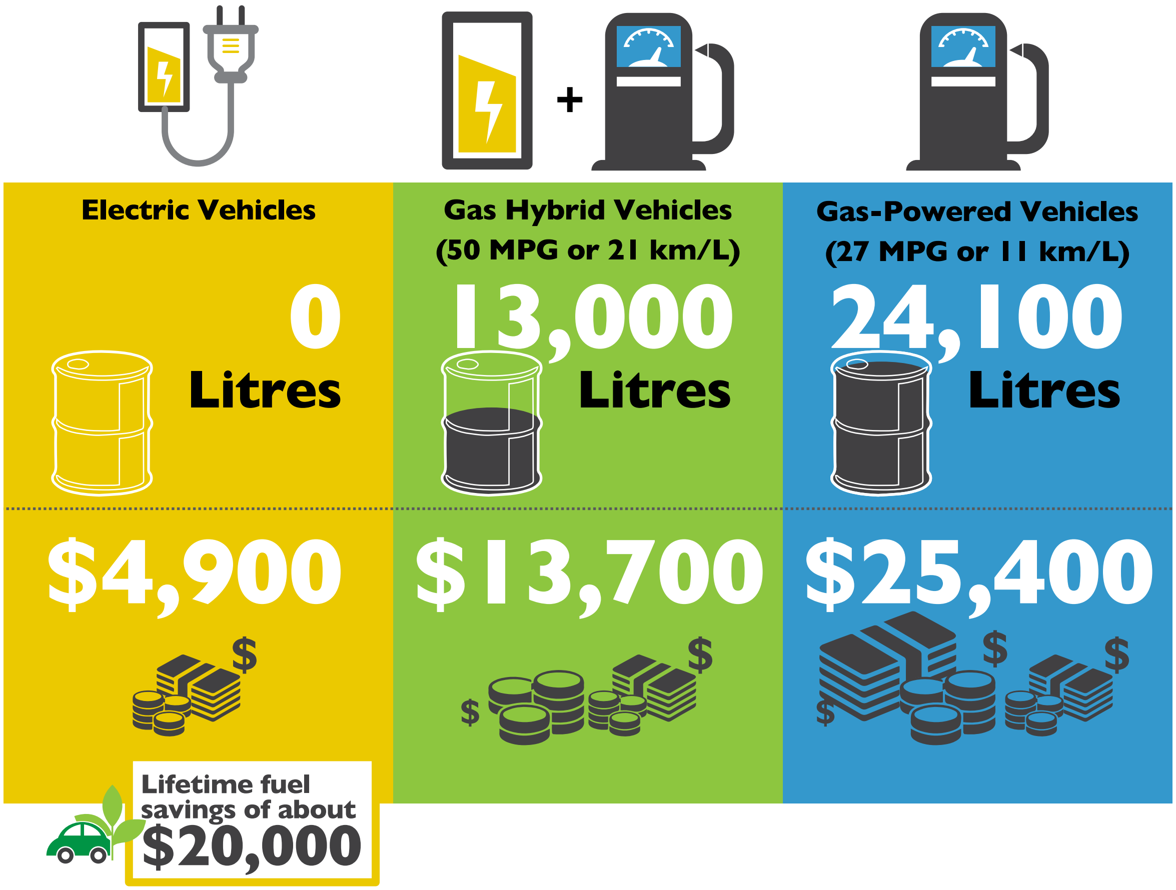
While the widespread adoption of electric vehicles could help reduce Ontario's greenhouse gas emissions and other tailpipe pollutants, it could also greatly affect the province's electricity distribution system. These cars draw a measurable amount of electricity as they refuel; charging even a few vehicles at the same time could overload components of the grid's infrastructure, such as neighbourhood transformers. Fortunately, smart grid technologies can help avoid such problems and can even harness electric vehicles to help manage the electricity system.



*Assuming a transformer rating of 37.5kVA and unity power factor

Note: The current electricity grid infrastructure was not designed to recharge multiple electric vehicles simultaneously. The smart grid's advanced communication network will help avoid overloading electricity equipment by making these cars visible to the grid and co-ordinating vehicle charging.

Here's how it can work: electric vehicle charging stations, which consist of a power plug and a meter that records and communicates information, will make vehicles visible to utilities and system operators (these smart grid elements allow real-time information to flow between electric vehicles and the grid). This information exchange will help utilities or the IESO manage vehicle charging, as well as use electric vehicles to absorb short-term fluctuations in demand and regulate grid frequency. There would be several options for co-ordinating the charging of a large number of electric vehicles on a province-wide scale. For example, predetermined algorithms could stagger when cars start and stop charging, or the grid could automatically adjust the amount of power sent to a specific substation based on real-time vehicle charging and electricity grid information. There may even be a role for third-party software applications to help optimize refuelling schedules.



Note: Assumptions include gasoline cost of 127.0 cents/L, an average electricity price of 10.15 cents/kWh, a discount rate of 3 per cent applied to future savings, cumulative lifetime mileage of 277,000 km, and annual travel that starts at 25,000 km/year and declines 4.5 per cent per year over 15 years. Vehicle efficiencies and fuel consumption estimates are based on published fuel consumption ratings for the Nissan LEAF (electric), Toyota Prius (hybrid), and Honda Accord (gasoline), however, actual fuel consumption varies depending on how, when, and where a vehicle is driven.

If large numbers of electric vehicles were connected to the grid, it could smooth out differences between on- and off-peak electricity demands. Vehicles connected to the grid could strategically charge during off-peak hours and discharge power back to the grid (when needed) in exchange for financial reward to their owners (known as vehicle-to-grid). Battery technology improvements, including higher battery discharge rates and larger on-board battery storage capacities, will help advance vehicle-to-grid integration.

STATUS IN ONTARIO, 2014

While the number of electric vehicles in Ontario continues to increase each year, interest to date has been modest and there are only approximately 1,750 electric vehicles (not including traditional hybrids) on Ontario's roads as of October 2013. This relatively small number means that this province has ample opportunity to address any technical issues/concerns that may arise before the widespread adoption of electric vehicles.

One concern is that public charging systems and their related infrastructure will need to be deployed so that customers can refuel their vehicles while away from their homes. Utilities, regulators and owners of public electric vehicle charging stations must work together to establish business and billing models for this infrastructure. So far, the Ontario Energy Board has indicated that "behind the meter" services (such as electric vehicle charging stations) are non-utility activities that should be left open to market competition in order to best serve customers. Unfortunately, the Ministry of Transportation does not publicly report electric vehicle registrations; access to this information could benefit the electricity and transportation sectors by allowing utilities and/or private sector companies to plan for and install public electric vehicle charging stations in strategic locations.

Nevertheless, there has been some utility and private sector involvement related to electric vehicle charging in Ontario. For example, Toronto Hydro has a pilot program to evaluate the impact of electric vehicle charging on the distribution system, and Sun Country Highway and ChargePoint are two companies that operate electric vehicle charging locations in southern Ontario. There are also several useful resources for Ontarians interested in electric vehicles. Plug'n Drive is a non-profit organization committed to accelerating electric vehicle adoption and it provides educational resources about electric vehicles and home/public charging infrastructure. PlugShare is an open database that identifies public charging stations and home chargers shared by individuals from across the U.S. and Canada.

The Ontario government also supports electric vehicles by: providing financial incentives for the purchase or lease of electric vehicles and home charging stations (scheduled to end March 2015); allowing unrestricted access to High Occupancy Vehicle lanes through green licence plates for electric vehicles (scheduled to end June 2015); and equipping several GO Transit stations with electric vehicle charging stations. To date, several hundred government grants and green licence plates have been issued.

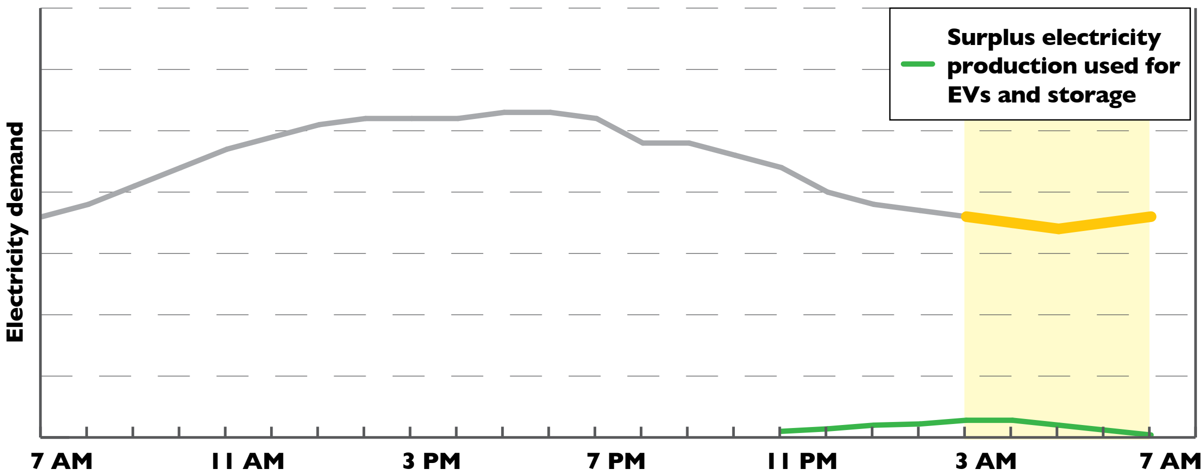
The smart grid and the future of electric vehicles remain closely connected. Smart grid technology will help electric vehicles refuel safely, efficiently and without compromising grid reliability.

7

STORING ELECTRICITY

THE SITUATION: 3 A.M. – 7.A.M.

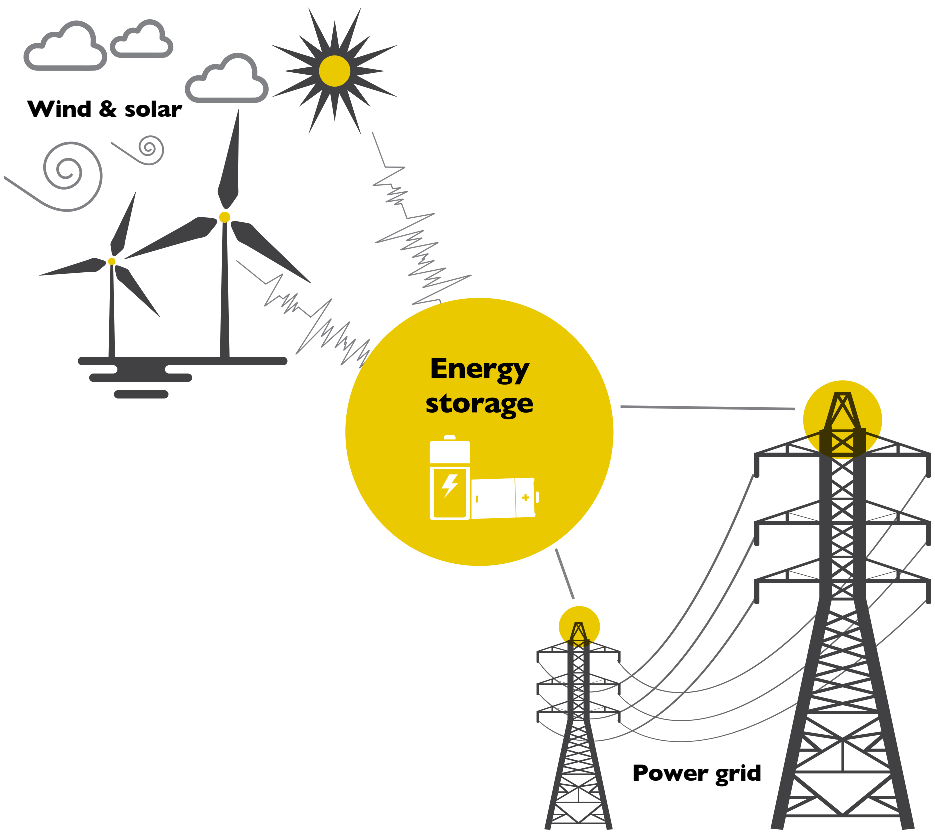
Strong winds are blowing across Ontario on this clear night and wind turbines are at their most productive. More electricity can be generated than is needed, as it is the off-peak period; electricity demand is low as most consumers are asleep.



WHAT'S POSSIBLE: A FUTURE SMART GRID RESPONSE

In our not-too-distant future scenario, energy storage systems have been rapidly integrated into Ontario's smart grid. Now the system operator has a third option, in addition to controlling generator output and customer consumption, to help it match supply and demand on a real-time basis. Energy storage systems capture electricity whenever it is generated – store it for a few seconds, minutes or several hours – and are ready to feed it back to the grid whenever required.

While the wind is blowing during off-peak hours, energy storage systems, such as batteries located on-site at wind farms, are charged up to absorb the surplus electricity being generated. Since off-peak electricity prices are in effect, (see Chapter 3: Managing Consumer Demand) it is much cheaper to charge storage devices now compared to peak times. The lower-cost electricity generated during off-peak hours is stored and later supplied back to the smart grid during peak hours when it can be resold for higher prices. By storing off-peak power generated by wind resources, for example, to use later in the day, peak demand is met without the need to turn on additional fossil-fuelled generators, thus, reducing greenhouse gas emissions from the electricity sector.



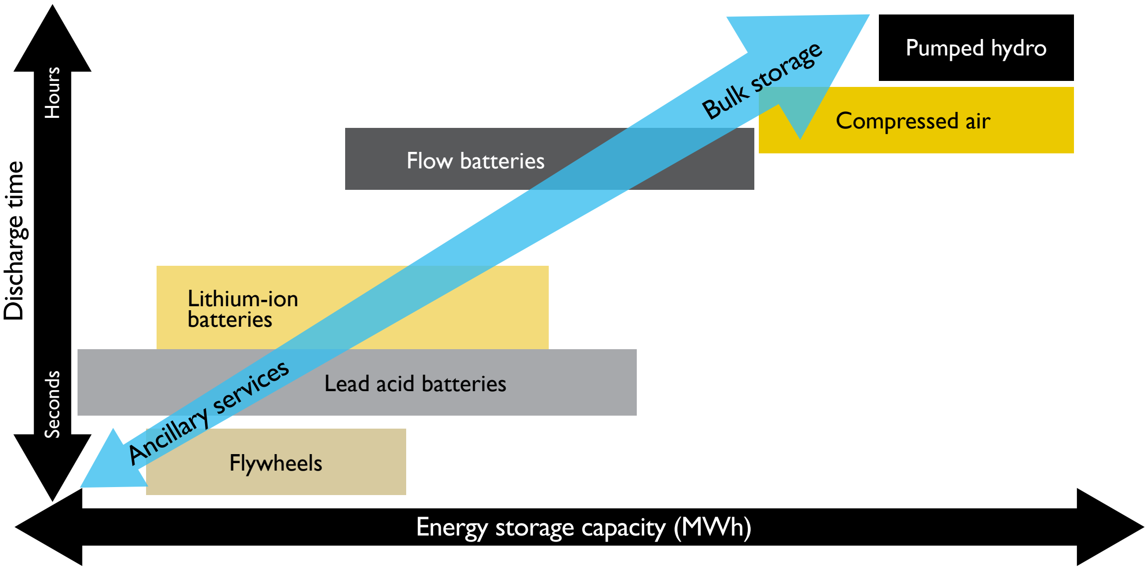
In this future smart grid, 25 per cent of Ontario's power is supplied by renewable wind and solar generators when the wind blows and the sun shines. As the wind speed suddenly changes and clouds pass overhead, brief surges and dips in the amount of electricity generated by wind turbines and solar panels cause small fluctuations in electric voltage and frequency that can affect grid reliability.

Battery and flywheel storage devices provide **ancillary services** that balance these sudden changes in supply and demand by acting as shock absorbers. Energy storage devices located across the smart grid rapidly absorb and inject power to balance these fluctuations and ensure the safe and reliable operation of grid equipment and consumer appliances.

HOW THE SMART GRID WORKS

It is important to understand that electricity is a form of energy that cannot be stored directly. So, storage technologies must convert electricity to other forms of energy (e.g., chemical, potential, kinetic) that can be stored, and convert it back into electrical energy when required later.

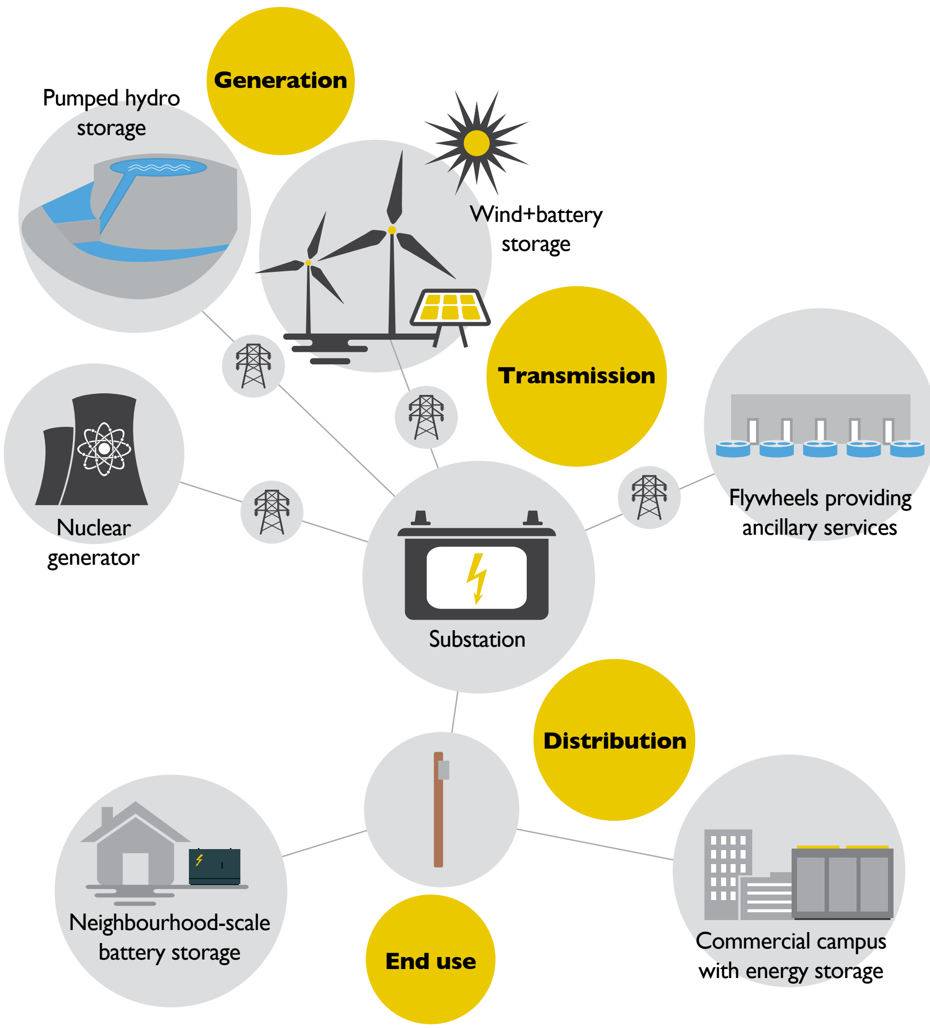
Energy Storage Application by Technology



For example, a battery is a device that stores electricity as chemical energy and directly converts the chemical energy back into electrical energy for use when needed. Pumped water and compressed air are mechanical storage technologies that store electricity as potential energy and later pass this energy through a turbine to generate electricity when required. Flywheels are another mechanical storage technology, which use a spinning rotor to store electricity in the form of kinetic energy and, once connected, to a generator can convert the kinetic energy into electricity as needed.

The role of a specific storage system is based on how much power it can provide to the grid and how quickly. This is known as its energy storage capacity:

Power (Megawatt or MW) * Time (Hours) = Energy Storage Capacity (Megawatt-hour or MWh)



Generally, storage systems with a low energy storage capacity are best suited for providing ancillary services, and those with a high capacity are best suited to bulk storage of electricity to take advantage of price variations.

Energy can be stored within large, grid-scale facilities that are connected to the transmission network, or small-scale devices located closer to end users and connected to the distribution network ("distributed storage"). For example, a large transmission-connected battery storage facility located on-site at a wind farm may be used to balance generation from the turbines and match demand, or quickly supply back-up electricity to the grid during a period of unexpected sharp rise in demand or sudden loss of a generator.

Similarly, on a neighbourhood scale, smaller, distribution-connected battery storage systems located within a residential community may be used to manage local peak demand, improve reliability and accommodate distributed generation (see Chapter 2: Enabling Distributed Renewable Energy Generation).

STATUS IN ONTARIO, 2014

Ontario has long made use of large-scale electricity storage to manage output from generating stations located at Niagara Falls through a nearby "pumped hydro" storage facility. Pumped hydro storage currently provides the vast majority of total energy storage capacity worldwide. However, it relies on a specific topography to pump water from a low-lying reservoir to an elevated reservoir during off-peak hours and release it to generate electricity during peak hours when prices are higher.

With the exception of pumped hydro, the integration of energy storage within Ontario's 2014 electricity grid is currently limited because storage has not been cost-competitive historically. However, this could change as energy storage is expected to play a significant role in facilitating the growth of intermittent renewable resources in Ontario – forecast to reach approximately 13 per cent of Ontario's supply mix by 2032.

Ontario's first energy storage procurement target – 50 megawatts (MW) by the end of 2014 – was laid out in the Ministry of Energy's 2013 Long-Term Energy Plan. To achieve this, the Independent Electricity System Operator (IESO) and Ontario Power Authority will procure 35 MW and 15 MW respectively of energy storage. This will build upon the IESO's 2012 procurement of 6 MW of battery and flywheel storage to provide ancillary services typically provided by generators. Several other energy storage projects are also underway in Ontario, including a 400 MW pumped hydro facility and many smaller thermal, flywheel, battery and compressed air projects ranging from 0.5 MW to 10 MW in size.

Ontario will have to overcome some policy hurdles to increase its energy storage capacity. For example, the current structure of Ontario's electricity market can result in energy storage paying certain market charges twice – once when energy is captured and again when it is released. The Ontario Energy Board's Smart Grid Advisory Committee is working to address the barriers that may hinder the ability of storage to compete in Ontario's electricity market. Furthermore, recent policy changes by the Board require that distribution utilities explore integrating more storage into their distribution systems.

Energy storage offers system-wide benefits (e.g., grid reliability, renewables integration, peak demand management) for several stakeholders, including the system operator, private generators, utilities and consumers. How these benefits are valued, in terms of where investments come from and who benefits from them, is complex. Appropriately valuing storage will encourage the wider adoption of energy storage technologies as a cost-competitive option to help balance Ontario's electricity needs.

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CONCLUSION: A WORLD OF POSSIBILITIES

What will Ontario's electricity grid look like in ten years? As this primer has shown, new features (and others that have yet to be introduced) will transform Ontario's electricity system over the next decade. The impact of the smart grid will reach far beyond smart meters. Smart grid technologies have the potential to improve reliability, reduce system costs, lower the environmental impact of electricity use, and empower customers.

In a recent report on the potential for information and communications technologies to "green" Canadian society, the Council of Canadian Academies observed:

> Society continues to move towards ever increasing connectedness. Everything that can be connected to high-speed broadband has the potential to be smart … information and communication technologies (ICT) … enhanc[e] the ability to adapt and flexibly respond to the uncertainty associated with environmental challenges, social structures, and human-technology interactions. ICT can potentially improve the delivery of services of all kinds and the efficiency with which Canadians use energy, water, and materials, thereby reducing environmental impacts.
>
> ***– Enabling Sustainability in an Interconnected World***

In a world where many of the machines, devices and appliances in people's daily lives will be smart and connected, the Council noted that interconnected information and communication technologies not only have the potential to drive sustainability, by addressing environmental issues, but also to create substantial economic opportunities – a market whose value over the next ten years is estimated in the trillions of dollars.

There is still a gap between the technological potential of the smart grid and how Ontario's grid is currently operated, but efforts are underway to close this gap in all areas. Closing the gap while securing new employment fits well with the Ontario government's 10-year plan to invest and build a modern public infrastructure.

How far we go – and how fast – will depend on informed decisions made in the months and years ahead. Hopefully, this primer will equip Ontarians to make educated choices about the possibilities that a smart grid offers for the future of electricity in Ontario.

A WORLD OF POSSIBILITIES

LIST OF ACRONYMS

ECO – Environmental Commissioner of Ontario

FIT – Feed-in Tariff

IESO – Independent Electricity System Operator

LDC – Local Distribution Company

MW – Megawatt

MWh – Megawatt-hour

OEB – Ontario Energy Board

TOU – Time-of-Use

Certified

Processed Chlorine Free

100% Post-Consumer Waste Fibre

Recyclable Where Facilities Exist

Green Energy Source

Mixed Sources
Product group from well-managed forests, controlled sources and recycled wood or fiber
www.fsc.org Cert no. SW-COC-1811
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Environmental Commissioner of Ontario

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