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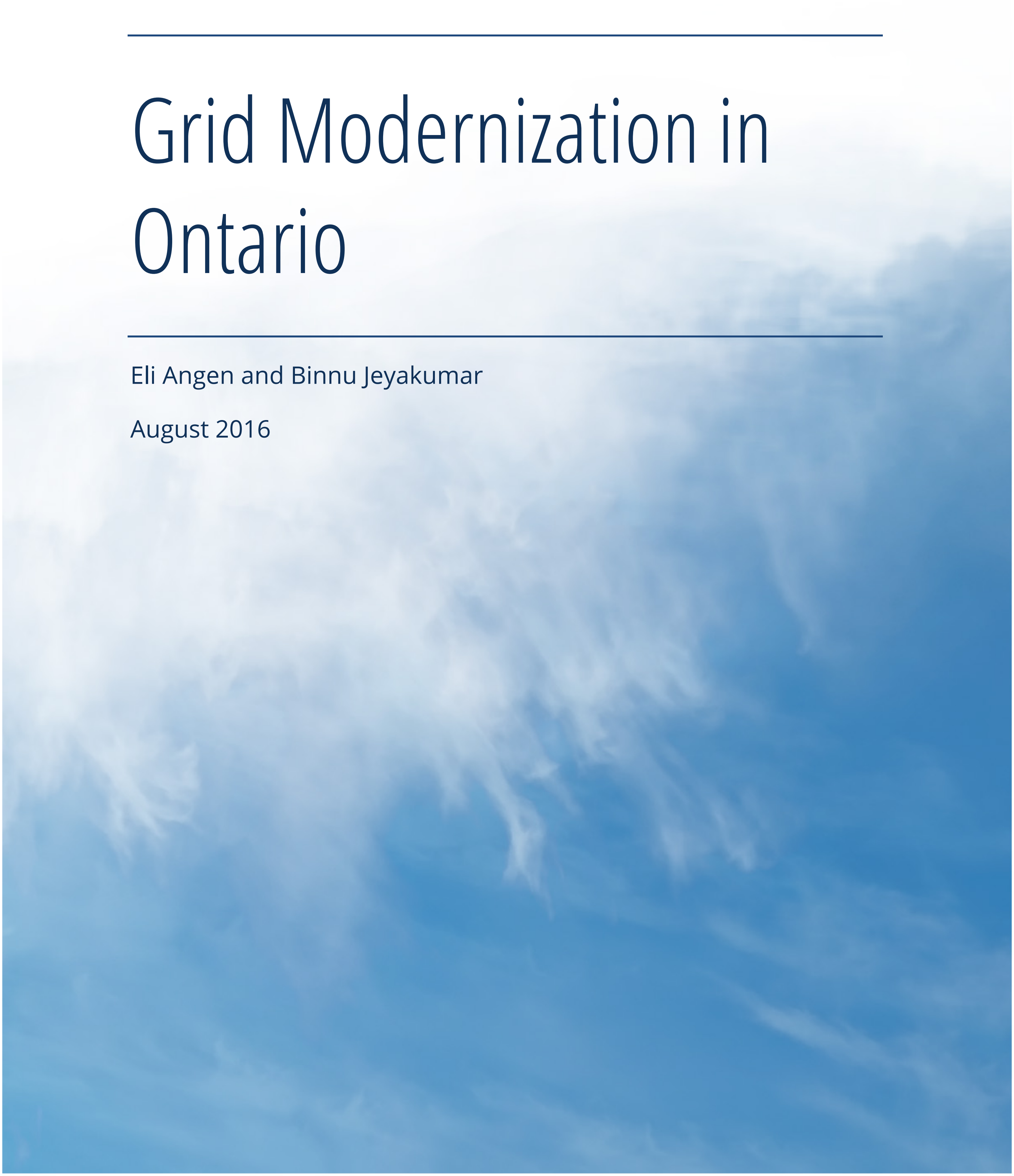

Grid Modernization in Ontario

Eli Angen and Binnu Jeyakumar

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The Pembina Foundation is working to solve today's greatest energy challenges — reducing the harmful impacts of fossil fuels while supporting the transition to an energy system that is clean, safe and sustains a high quality of life. We provide our expertise to industry and government leaders, and we advocate for a strong, science-based approach to policy, regulation, environmental protection and energy development.

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The Pembina Institute is a national non-partisan think tank that advocates for strong, effective policies to support Canada's clean energy transition. We employ multi-faceted and highly collaborative approaches to change. Producing credible, evidence-based research and analysis, we consult directly with organizations to design and implement clean energy solutions, and convene diverse sets of stakeholders to identify and move toward common solutions.

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Grid Modernization in Ontario

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Introduction

In the mid-20th century, our ideas about progress and prosperity were founded on a centralized model. We built big infrastructure and, to keep it running, we put in place hierarchical organizations and rigid regulations. Today's internet-driven world, however, is something more like a network. Distributed technologies, communications tools and access to information have created social and economic relationships of a different sort.

The same could be true of our electricity grid, the very backbone of social and economic life as we know it. In a very near future, grid-connected distributed renewable energy generators could reduce the need for centralized baseload power plants, creating greater resilience in the system. Information technologies could empower system operators and utilities — as well as consumers — to manage generation and demand in realtime, and in a more symbiotic way. Greater flexibility could be provided by new kinds of energy storage, both on the grid and behind the meter.

These transformations will prove to be critical in order for system operators and utilities to meet growing demands on the part of both governments and consumers to ensure that our electrical grid and related services are reliable, resilient, environmentally responsible and affordable. That's not all: such innovations will present new opportunities for efficiency and profitability. Yet, in most jurisdictions, including Ontario, our approach to energy planning operates on the assumption that we'll still be plugging into a centralized, unidirectional electrical grid in five, ten, or twenty years.

In 2013, the Government of Ontario released the current version of the Long-Term Energy Plan (LTEP). The Plan identifies a number of interesting measures, such as a commitment to putting "conservation first", expanding the role of renewables in our electricity mix, and encouraging community and First Nations participation in transmission and generation. However, when we consider current trends, available technologies and precedents from other jurisdictions, these measures look more like tweaks than deep innovation. Thankfully, the LTEP is under review this year and there is an opportunity to better align our future plans with the coming reality.

Across North America and Europe, system operators and utilities are tackling the coming changes head on, but such innovations remain the exception. In Ontario, we can dream bigger about what a modern grid can do for operators, utilities, consumers and the environment. In this paper, we begin to chart the course for a deeper modernization of the grid.

In Section 1, we look at how system operators can modernize their infrastructure and operations, using new technologies and approaches to manage generation, load, and other components such as storage, transmission and distribution. We also look at some key principles to inform the discussion around grid modernization, including reliability, resiliency, innovation, affordability and environmental responsibility.

In Section 2, we look at how utilities can innovate, including through investment in clean technology and distributed generation, information and system management and service provision. We also explore the drivers of this innovation, the conditions for success and the challenges that limit the transformation.

Finally, in Section 3, we examine storage as a cross-cutting element that will support most or all of the changes identified in the report.

1. System operation

In leading electricity jurisdictions such as Germany and California, the conversation around grid modernization and integrating more renewables has moved beyond a question of whether or not to do it, to a question of how to do it. While the technologies and capacities to manage and operate the modern grid are widely available, system operators in many jurisdictions are still working to understand these and to integrate them into a holistic grid management system.

1.1 Principles of a modern grid

In any discussion of grid modernization it is important to keep in mind the performance expectations of the modern grid, in order to understand how best to invest in and manage it.

Reliable

This has been the primary expectation of electricity grids since they were set up. But now the expectation of reliability goes beyond simply ensuring that the power will be available when needed; the power delivered has to meet the quality needed by consumer devices and industrial processes, as end user needs are more sophisticated than they were a hundred years ago.

Resilient

The increasing risks to the physical and digital security of the grid need to be managed, along with the impacts of unforeseeable events such as extreme weather and natural disasters. A resilient grid is able to prevent damage to the system as much as possible, recover rapidly from any incidents, and may need to be self-healing, automatically detecting and correcting errors. In addition, it needs to maintain some basic level of functionality in the event of a failure.

Environmentally responsible

The urgency of climate change and the stress our energy system is creating on ecological systems demand an electricity grid that is low in emissions and has minimal ecological and health impacts. This means integrating more low- or zero-emission electricity sources into the system. Some of these, such as wind and solar, require more flexibility in the operation of the electricity grid.

Economic, efficient, and affordable

The investments made in the grid need to be economically viable in the long term while also maintaining affordability, particularly for vulnerable populations. Part of being economically viable requires the grid to be operated in a manner that optimizes the use of its assets.

Engages the consumer

Today's consumers often demand sophisticated benefits from the electricity system, such as being able to operate their energy-intensive appliances when prices are low, charging their electric cars and selling stored electricity back to the grid. They are also interested in producing their own electricity. A modern grid must have a flexible platform that allows consumers as well as technological innovators to participate in it.

Enables innovation

A modern grid must have the flexibility and openness to allow innovators to effectively participate. This includes integrating storage technologies (see Section 3), new ways of pricing services to the grid, and considering adopting grid neutrality guidelines.

Grid neutrality

Grid neutrality is being promoted in the U.S. as an electricity system that is fit for the future needs of the producers and consumers. It emphasizes a broad approach to a fair and open electricity network, with the following core principles:

- empowering consumers while maintaining universal access to safe, reliable electricity at reasonable cost
- demarcating and protecting the commons
- aligning risks and rewards across the industry
- creating a transparent and level playing field
- fostering open access to the grid

1.2 Coordinating generation

One of the primary roles of the grid operator is to manage and coordinate generation in a cost-effective manner that is reliable and responsive to the load on the grid. This includes enabling and managing a growing number of decentralized generation sources and increasing connections between different jurisdictions.

A key pathway to implement the principles in the previous section is to diversify generation sources and include renewables. Renewables help reduce greenhouse gas emissions, can make it easier for consumers to participate in generation, provide flexibility, and can reduce the price of electricity.[1] But this diversification adds to the challenges of managing and coordinating generation, as listed below.

Forecasting renewables that are variable

Modern wind and solar power generation are among the most reliable sources of power, with very low maintenance requirements compared to fossil fuel generation. However, their output of power varies depending on weather and time of day. So operators with grids that have high penetration of renewables are seeking to improve their forecasting abilities.

One-day-ahead forecasting has become very accurate over the last few years, and has reached the point where experienced system operators are better able to predict wind and solar output, then they are able to forecast load.[2] Figure 1 below, the one-day ahead forecast of the French system operator, shows how closely the forecast matches the actual national wind power generation.

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[1] U.S. Energy Information Administration, "Levelized Cost and Levelized Avoided Cost of New Generation Resources in the Annual Energy Outlook 2015", June 3, 2015. https://www.eia.gov/forecasts/aeo/electricity_generation.cfm. Table 1 shows the total cost of electricity over the price of different power plants in the US (USD/MWh), with conventional coal at 95.1, advanced nuclear at 95.2, wind at 73.6, and hydro at 83.5.

[2] Amory Levins, "Amory's Angle: Ramping Up Renewable Electricity," *Solutions Journal, Winter 2014, Vol. 1 No.1,* Rocky Mountain Institute, http://www.rmi.org/winter_2014_esj_ramping_up_renewable_electricity

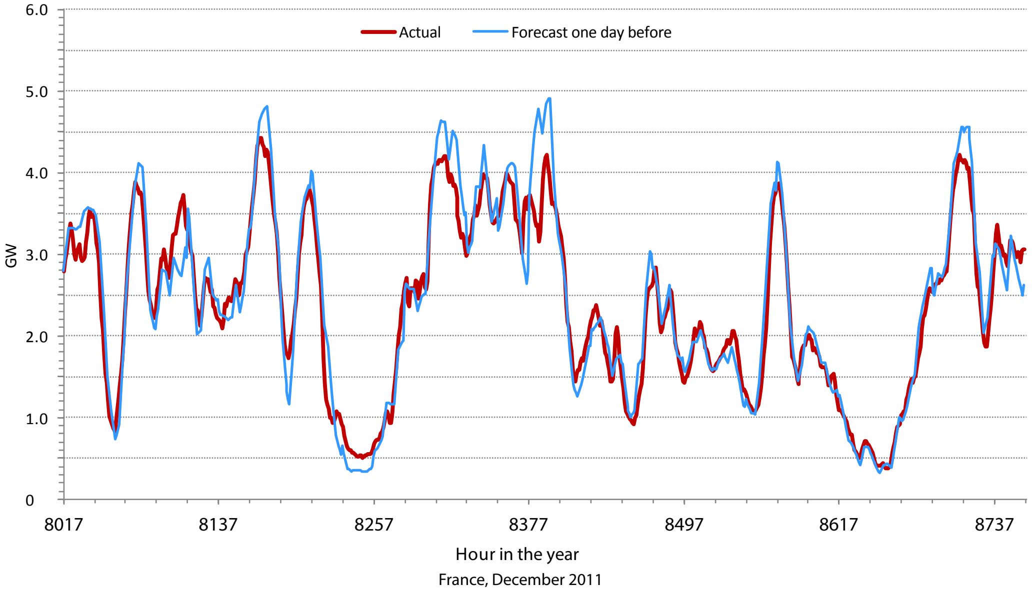

Figure 1. Hourly actual versus forecasted wind generation

Source: Adapted from Chabot[3]

Sub-hourly dispatching

Grids traditionally dispatch generation on an hourly basis. But many generation sources now can be ramped up and down quickly, and there is a greater integration of storage devices that can be dispatched rapidly. So grid operators are now looking at dispatch time frames of five to 15 minutes. This allows them greater flexibility in coordinating generation to follow the demand for power.

Incentivizing and managing ancillary services

The grid requires a wide range of support services to maintain reliability and stability. These include maintaining the frequency, having generation capacity available to come online on short notice, and maintaining voltage within certain limits. Different generation sources have different abilities to provide these services. For example, wind power facilities can deliver fast regulation of frequency if they are managed for that purpose. These ancillary services could be incentivized through different schemes including market mechanisms.[4]

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[3] Bernard Chabot, *A case study of harnessing generous natural renewable resources available along hours, days and seasons: wind power production in Germany in 2012.*, 4. http://www.renewablesinternational.net/files/smfiledata/2/2/4/5/4/4/V1WindG2012.pdf

[4] PJM is a leading jurisdiction for creating markets for ancillary services. PJM, "Ancillary Services Market," https://learn.pjm.com/three-priorities/buying-and-selling-energy/ancillary-services-market.aspx

Integrating with other grids

By connecting with other grids, an operator can take advantage of a larger variety of generation sources, as well as geographical variations in renewable resources, to improve system reliability, responsiveness, and cost-effectiveness. This is why more interties are currently being built to connect eastern and central Canada with the U.S. This potential is as yet untapped in the western provinces.

Diversifying the location of the renewable source can also help address their variability. For example, when wind stops blowing in one region, it might pick up in another region. Interconnection ties across time zones can also enable the use of generation sources in one zone to address the peak demand times in another.

Encouraging distributed generation

Distributed sources provide increased flexibility and reliability. It is less likely that a thousand 100-kW systems will simultaneously go offline than that a single 100-MW centralized power generator will. Distributed generation also enables the consumers of electricity to participate in the system as producers.

In distributed generation, power must be able to flow — and be metered — in and out of any customer’s site. This requires investment in distribution infrastructure and technologies such as smart meters. In Canada, smart meter technology has been deployed in B.C., Ontario and Quebec.

1.3 Managing load

While the traditional role of the systems operator has been to manage and coordinate generation in order to meet the demands of the system load, the modern grid enables the system operator to manage load as well. This can reduce or delay the need for more generation and transmission infrastructure by enabling more efficient management of the existing assets. The two basic ways to achieve this are by reducing the absolute demand, or by shifting the demand from peak times to off-peak times.

Improved forecasting and monitoring of load

There are many emerging technologies (some already commercial and in use) for more accurate monitoring of load as well as better models for forecasting load. Both of these equip the system operator with better information with which to make generation and load management decisions. An example is the upgrade in Ontario from traditional meters that have to be read and recorded manually to smart meters that digitally communicate electricity consumption to the system operator. This increases the frequency and accuracy of monitoring, which in turn can help the operators better forecast load patterns.

Incentivizing customer management of load

Customers can be directly incentivized to curtail their energy use during peak demand times. Typical methods involve differentiating the price of electricity based on time — providing cheaper rates during off-peak times or higher rates during critical peak times, or a combination of both. Ontario's time-of-use pricing is an attempt at doing this, and has highlighted the need for effective price differentials.[5]

Increasing system control over load

The system operator has several methods to optimize load. For example, they may offer an incentive or compensation to large commercial or industrial clients in return for the flexibility to curtail that load when needed. In some jurisdictions, utilities provide customers with appliances such as water heaters that can be controlled by the system operator to manage load. The heaters have two heating mechanisms: one allows the system operator to heat it when demand for power is low, and the other allows the user to control the heat and use the hot water at any time of the day.

Integrating different forms of energy with electricity

The above example of managing load by controlling the water heater, is also an example of how system operators can use different forms of energy to manage electricity load. This requires the operator to consider the energy system more holistically. An emerging example is the use of hydrogen to store electricity. Once the electricity is converted to hydrogen, it can be converted back to electricity and fed in to the grid, used as hydrogen for transportation fuel or industrial uses, or pumped into the natural gas system and used to help reduce the emissions profile of natural gas.

The baseload myth

Baseload is a term used to describe the minimum level of demand in an electricity system. Traditional thinking has been that to meet baseload demand, one needs

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[5] Power Advisory LLC, for Ontario Energy Board, *Jurisdictional Review of Dynamic Pricing of Electricity*,(2014).

continuous power from certain baseload generators, typically coal, nuclear and large hydropower facilities.

Countries like Germany and Denmark that are integrating significant amounts of renewables in their grid are finding that this is not necessary. They are able to meet their baseload requirements by looking at the whole system and managing their renewables and electricity exports and imports more effectively. According to Amory Lovins from the Rocky Mountain Institute, the grid operators in these jurisdictions manage the grid like a conductor leads a symphony orchestra: No instrument plays all the time, while the ensemble continuously produces harmonious music.[6]

Baseload generators are also assumed to be 100% available and reliable. However, all electricity generators have both planned and unplanned shutdowns, so no facility is available 100% of the time. And when a 300 MW coal plant or a 1000 MW nuclear plant shuts down, it is much harder to deal with than when a single wind turbine or solar panel goes offline.

So from a system reliability and efficiency point of view, a grid might be better off with a variety of renewables and interconnections that are managed well than with a few large centralized generating stations.

1.4 Managing other components

In addition to managing generation and load in the electricity system, the operators also have to adopt to emerging technologies in other components of the grid: energy storage devices and the transmission and distribution infrastructure.

Storage

Storage technologies are loads as well as generators, depending on whether they are drawing energy from the grid to store or discharging energy into the grid. They can also turn on and off much faster than traditional fossil fuel plants. Technologies already exist to take advantage of these benefits. But for systems that have traditionally been operated on an hour-by-hour basis and shaped by the characteristics of fossil fuel generation, there is a learning curve for using storage to optimize system operation. There are also open questions on how storage fits into the system, such as whether it

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[6] Fuchs, Richard, *Germany's Energiewende goes global* (April 4, 2016). http://www.dw.com/en/germanys-energiewende-goes-global/a-19140910

should be managed by grid operators or should be treated as behind-the-meter. See Section 3 for a further exploration of storage issues.

Transmission and distribution

New technologies are already being put to use to enable better monitoring of grid characteristics such as frequency. For example, phasor measurement units sample voltage and current many times per second at a given location, providing a snapshot of the power system at work. There are also automatic response technologies that can make decisions such as transferring load from one line to another or shedding load in case of an impending overload of a line. These allow the operator to use existing transmission and distribution networks more effectively without requiring new construction to meet growing energy demands or reliability needs.

2. Utility operation

As noted in Section 1, the modern grid will be dynamic, finely balancing generation, load and storage, with more distributed components and higher responsiveness. There will be far greater access to information and data for generators, systems managers, energy managers and customers — allowing all actors to be more aware of and better able to manage their energy use.

The modern grid will fundamentally change how consumers, producers and service providers interact — bringing more entities into the game, enhancing their capacity and blurring the lines between them. Its repercussions will extend beyond the realm of technology and into our social and economic behaviors.

This creates boundless opportunities for those willing to embrace it, but it also presents a potentially disruptive challenge for everyone involved, particularly large institutions.

Some utilities are already working to seize this opportunity. They have started providing or are implementing services that both enable and carve the path to the modern grid. This section provides several examples, from electric vehicle (EV) charging to residential solar-storage technology.

Utilities across the continent are beginning to ask themselves what role they want to play in a more distributed and modernized grid.

2.1 Drivers of innovation

A constellation of factors is coming to the forefront right now, forcing utilities to innovate and modernize.

Technological change

Whether it's renewables achieving grid parity, storage technology, or the newest in smart grid technologies, it is abundantly clear that the way we generate, store and monitor electricity is changing. Some of these innovations present opportunities, while others, like rapid penetration of rooftop solar, present a more existential threat to the future of traditional utilities.

Changing customer expectations

As electricity consumers get better access to information, they are demanding more options and flexibility. Many are taking on the role of “prosumers” by producing some of their own electricity, and want the ability to control their electricity storage and usage. Customer expectations are also expanding beyond simply wanting affordability and reliability to include environmental responsibility and responsiveness.

Government and community mandate

Some jurisdictions have their own principles, priorities and visions for energy efficiency, clean energy, greenhouse gas reductions and distributed generation. Some of these are regulated changes that will force utilities to change, while others are simply local ambitions and aspirations that utilities have the opportunity to embrace.

Aging infrastructure

Over the next few decades, many of the existing electricity network components will reach their end of life. At the same time, capacity in the system is oversized to deal with peak demand. All of this creates an incentive to improve asset management and reconsider some of the traditional operating philosophies.

Risk of reduced role in future markets

If utilities don’t adapt to the changing electricity system, they risk the diminishment of their market share and role over time. Non-utility actors are joining markets to provide services such as solar panel installation, applications for monitoring energy usage and energy efficiency technologies.

2.2 Innovative services and business models

There are several opportunities for diversifying and modernizing the services that utilities provide. The opportunities for innovation fall into three broad categories: clean technology and distributed generation; information and system management; and service provision.

2.2.1 Clean technology and distributed generation

Micro-generation

This can include some or all of the engineering, installation and maintenance of rooftop solar panels, micro-hydropower units, virtual net-metering, small-scale wind facilities and geo-exchange systems. These systems could be owned and installed by the utility, private sector entities, or by the consumers. Utilities can also invest in enabling technologies such as multi-metering for condos to allow individual condo owners to invest in solar panels and manage their own consumption.

Oakville geo-exchange projects

Through its affiliate, Sandpiper Geo-Exchange, Oakville is now offering turnkey projects for new homes to install customized metering, a geo-exchange unit for heating, and solar panels for electricity. They are able to leverage their existing expertise in metering and electrical connections along with new technologies to offer customers comprehensive and sustainable home comfort packages.

Electric vehicle charging infrastructure

As electric vehicles grow in popularity, the demand for charging facilities is also going up, both within households as well as in public. In response to this demand, the Ontario government recently announced a $20 million investment into building more public charging stations. There is also room to innovate in terms of vehicle-to-grid and vehicle-to-house technologies, where EVs can be used as storage for the grid and the household.

Energy storage

While energy storage is just hitting commercial viability for both customers and grid-level application, it creates a host of opportunities to stabilize the grid as more variable and distributed electricity generation comes online. In addition, it can support more efficient use of existing infrastructure by enabling load shifting and relieving bottle necks. Utilities could play a role in developing large-scale as well as small-scale (residential or sub-municipal level) storage. See Section 3 for more details.

Energy efficiency

Whether this means municipalities installing LED street lights or customers adopting energy efficient appliances, conservation measures are a growing focus for utilities.

2.2.2 Information and system management

The potential of improved information and system management is slowly being realized as utilities increase their sophistication in collecting and using data from and for their customers. This capacity is critical in understanding and influencing change in energy consumption behaviour.

Data access

The rapidly increasing availability of data from all parts of the electricity system (including smart meters) presents an opportunity for utilities to not only rapidly expand the amount of information they have, but to improve engagement with their customer base. Using the Green Button standard (open source platform to access and share electricity data in a standardized, secure manner) helps set up utilities and other actors to take advantage of this data and continue to innovate on its application and usability.

London Hydro's digital transformation

London Hydro has adopted a digital strategy for customer engagement by promoting energy management self-service. London Hydro's digital transformation includes moving to the cloud, choosing mobile first and embracing the Green Button Standard.

Fault detection and mitigation

Faster-responding and higher-sensitivity technologies are being developed for fault detection and repair of grid components. As many network components reach their end of life in the next couple of decades, these detection and mitigation technologies can help with asset management as well as improve grid reliability. In addition, new transmission infrastructure for new renewable generators can be equipped with sensors and other communications and data processing equipment.

Demand response

Traditionally, the supply of power has been dictated by the demand on the system. But now, technologies are available to allow utilities to adjust generation and demand. This can include aggregating control of loads at the customer level such as water heaters and refrigerators, or, working with and incentivizing large industrial users to curtail demand.

2.2.3 Service provision

Utilities service commercial entities, individual homeowners and municipalities, as well as other utilities. Innovation is happening in two ways: in how the utilities interact with their stakeholders, and how they operate internally.

Providing enabling services

Utilities are exploring what types of value-add services they can provide that enable other actors. For example, some are developing innovative billing services that they can provide not just to their direct customers but also to other utilities. Many of these data-related projects enable different programs such as energy efficiency initiatives.

ERTH Corp's Utility 2.0 journey

Two-thirds of ERTH Corp's revenue is generated in its unregulated businesses, offering services such as billing and customer care, retailer settlements, traffic control and LED street lighting, high voltage construction, and installation and maintenance of renewable generation. ERTH is active across Ontario, as well as in other provinces, the U.S. and Australia.

Engaging customers in pilot projects

Some utilities are engaging their customers in pilot programs that result in learnings for both the customer and the utility. This strategy also enables the utility to manage risks when considering adding a new service or program.

Different asset ownership and capital investment models

There is room to further redesign the relationship between the actors in the local distribution system. For example, utilities traditionally have had complete ownership of their generating assets, but now they can also share equity or ownership with co-operatives or individual customers. At a larger scale, municipalities could attract capital investment from private service-provider companies for infrastructure projects in return for long-term service contracts.

Greater Sudbury Utilities' 10-year plan

GSU is working with a business transformation consultant to develop and implement a 10-year plan that has identified several programs and activities. The long-term horizon allows them to consider aspirational ideas such as self-healing grids. They are also trying to match their plans with Sudbury's Community Energy Plan.

2.3 Pre-conditions and enablers

There are several internal characteristics and behaviours that are common across the utilities leading the way on this path to innovation.

Compelling vision and long-term planning

Given the operational horizon of their assets, utilities have both the need and opportunity to engage in long-term planning. This can build the foundation for a clear and compelling vision for the organization, or the region it is operating in, to help focus on strategies for change.

Entrepreneurial leadership

Innovation requires an increased tolerance for risk and the ability to identify opportunities that others might not see. This requires a shift away from the traditional mode of operation for utilities, which is more risk-averse and primarily concerned with ensuring reliable service provision. Organizations that are able to attract competent, creative and entrepreneurial people to their workforce can better position their leadership to innovate and address emerging opportunities.

Holistic functions for departments

Nimble organizations ensure that all departments are connected to the core mission as well as being committed to innovation. For example, the IT department should be expanding its function beyond maintaining the company's hardware and software to include managing information for the company and the customers, and strategizing on the best ways to improve the access, currency, security, reliability, flow, and utilization of information.

PowerStream's microgrid demonstration project

In partnership with the Korea Electric Power Corporation, PowerStream is implementing a microgrid initiative covering 400 customers. PowerStream also has a microgrid demonstration project at its Vaughan office that integrates EV-to-home technology — the EV acts as battery storage and supplies power to the building when needed.

Developing strategic partnerships

Another way to attract the new knowledge, skills and attitudes needed for a transition is to partner with the right external organizations that can bring this expertise.

Leveraging reputation

Most utilities have a long history with their customers. This can provide a loyal customer base, and reputation for reliability. This better enables them to recruit customers for new programs, while a new entrant to the market might find this more difficult.

2.4 Challenges

There are a few challenges and barriers that make innovation harder and at times prevent utilities from modernizing their services.

Misaligned incentives

Even when a utility is interested in pursuing innovations, the incentives that are built into the regulatory framework can be a barrier. Generating assets bring direct returns that are easy to quantify. Improvements and new initiatives in customer service, for example, may be harder to quantify, and potentially more difficult for the OEB to approve.

Lack of clarity on what is permissible

As a regulated utility there are limits on what kinds of activities can be undertaken, but there is currently a lack of clarity on precisely what those limits are. Some utilities have focused on their unregulated groups to push forward with innovative ideas, while others have done that from within their regulated business. This lack of clarity holds many utilities back from taking on new initiatives. There is also uncertainty on whether some of the new programs that utilities are trying will continue to be permissible in the future.

Integrating different types of businesses

Utilities typically encompass a wide range of business units and cultures, including regulated and unregulated divisions, unionized and non-unionized workforce, local and international/national services. This inevitably leads to challenges in communication, isolation of departments and groups from each other, and conflicts in mandate. These can all hinder the ability to change and adapt the organization.

Cost to customers

Many of the innovations outlined previously require an initial capital investment — sometimes by the utility, and sometimes by the customer. This can conflict with the customer expectation of cheap power, and it can be complicated for a utility to articulate the benefits that accrue throughout the system from these innovations.

Changing risk tolerance

Utilities are traditionally risk-averse, but many of the investments in grid modernization involve higher levels of risks and uncertainties in their initial adoption. The board, senior leadership, and their investors must be willing to embrace higher risk and do the work of sound risk analysis and decision-making.

Extended timelines to create sustainable change

Developing the right knowledge base, competencies and attitudes as an organization and as individuals takes time. Particularly, the mindset shift and new organizational structures and functions need to have complete buy-in of the employees.

3. Storage

In the traditional electricity system, every time you turn on a light, a generator has to ensure that additional power is generated. Conversely, every kilowatt-hour of electricity that is produced has to find a consumer. Energy storage, however, throws this requirement out the window.

By storing energy when it is abundant and releasing energy when it is needed, storage systems can improve several aspects of the grid including its reliability, cost effectiveness and ability to integrate cleaner sources of energy. The Ontario government has already recognized the potential of energy storage and has recently procured an additional 50 MW[7] of storage on top of an initial 10 MW[8] secured under a pilot program in 2012.

This section summarizes the benefits of investing in storage, the different mechanisms to incentivize storage, and the best practices that are applicable to the Ontario grid.

3.1 Types of storage

There are countless articles[9] on the different storage technologies that currently exist and that are being developed. These technologies can all be classified based on some basic characteristics (see Figure 2).

3.1.1 Characteristics of storage technologies

Location

Generation- or transmission-level technologies work at higher voltages and are usually located at central generating stations, transmission lines, and transmission substations.

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[7] Independent Electricity System Operator, "Energy Storage Procurement." http://www.ieso.ca/Pages/Participate/Energy-Storage-Procurement/default.aspx

[8] David Beauvais and Jennifer Hiscock, *Smart Grid in Canada: 2012-2013* (Natural Resources Canada, 2014). http://www.nrcan.gc.ca/smart-grid-in-canada-201213

[9] For an overview of energy storage technologies along with a description of their costs and performance, see Sandia National Laboratories, *DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA* (2013), Chapter 2. http://www.sandia.gov/ess/publications/SAND2013-5131.pdf

Distribution-level technologies are located at medium-voltage distribution lines, distribution substations, and commercial/industrial customers.

End user technologies are located at the customer site. They are often on the non-grid side of the meter and controlled by the customer. This includes EVs.

Size of the system

Storage systems can range in size from a few kW to hundreds of MW. Smaller systems are usually located at the distribution level or behind the meter, while larger systems are usually directly connected to the transmission grid. Depending on its size, the storage system can be used to manage different sizes of load and the variability of different types of renewables.

Discharge time

Depending on how fast the storage technology can discharge electricity, it can be used for different purposes (see Figure 2). The range is from seconds to months.

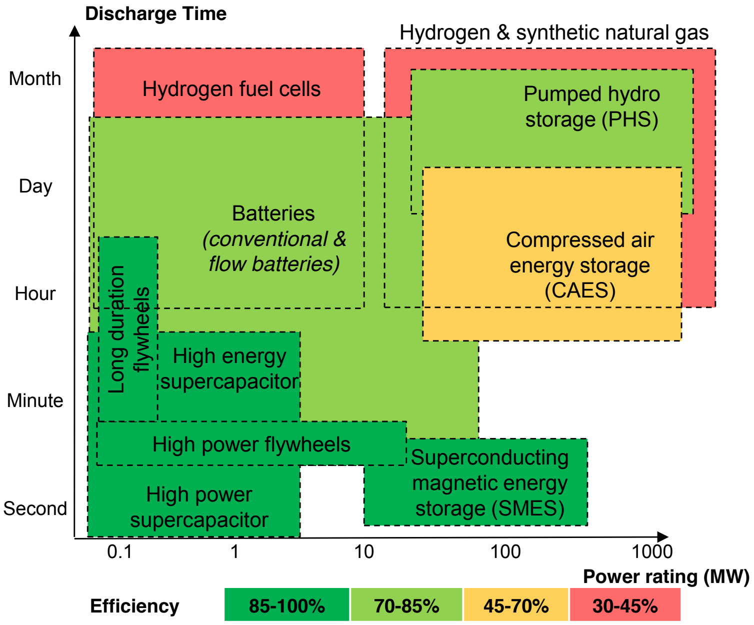

Figure 2. Storage technologies classified by discharge time, size of the system and efficiency

Source: SBC Energy Institute[10]

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[10] SBC Energy Institute, *Leading the Energy Transition: Electricity Storage* (2013), 25. http://www.sbcenergyinstitute.com/_/media/Files/SBC Energy Institute/SBC Energy Institute_Electricity_Storage Factbook_vf1.pdf

3.1.2 Examples of storage technologies

Supercapacitors: Capacitors that can have extremely high power outputs and storage capability compared to conventional capacitors.

Flywheel: A large rotating cylinder that speeds up to store energy. Electricity can be extracted by slowing the cylinder down.

Superconducting magnetic energy storage: Energy is stored in the magnetic field created by flow of electricity in a superconducting coil which is kept at very low temperatures.

Compressed air energy storage: Electricity is used to compress air and store it in a vessel. When needed, the air is mixed with natural gas, burned and used to generate electricity with a gas turbine.

Conventional batteries: These include batteries that use lead acid, lithium ion, nickel cadmium or nickel metal hydride.

Flow batteries: Liquid electrolytes are pumped through an electrochemical cell that can convert electricity to chemical energy and back.

Pumped hydro storage: Water is pumped into a higher elevation reservoir from a lower reservoir, and is then allowed to flow through turbines when needed to generate electricity.

Hydrogen fuel cells: Electricity is used to extract hydrogen from water. The hydrogen can then be converted back into electricity with a fuel cell.

Hydrogen and synthetic natural gas: Electricity is used to extract hydrogen from water. The hydrogen reacts with carbon dioxide to produce methane which can then be combusted to produce electricity.

Pairing storage with other energy systems

Electricity storage can also interact with systems such as heating and transport. For example, there are hot water tanks that can use electricity to store heat during the time of the day when electricity prices are low, and then provide the heat throughout the day. They can also be controlled directly by the utility to reduce load during peak hours.

3.2 Benefits of storage

Storage is an integral part of any grid modernization effort. It enables key elements of the emerging smart electricity grid including integrating renewables and managing demand. It also increases the sophistication of grid operations, improving reliability and optimizing the use of existing assets. Below is a summary of the most significant benefits from storage;[11,12,13] some are also shown in Figure 3.

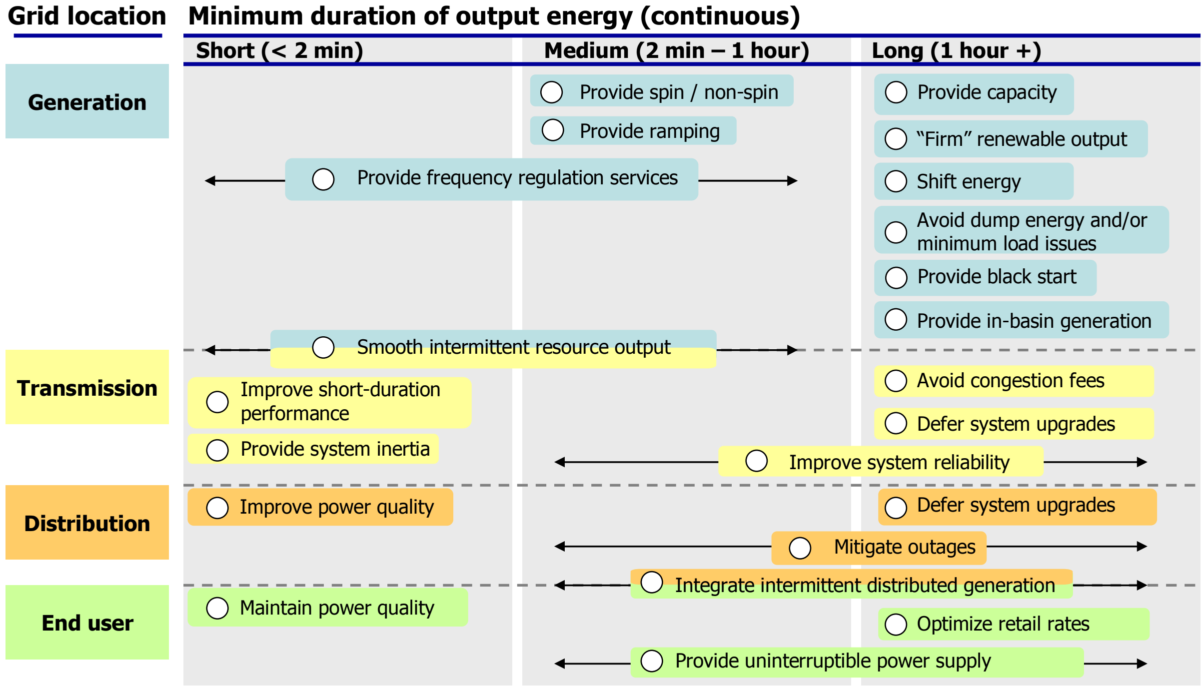

Figure 3. Potential uses and benefits for storage systems

Source: Adapted from Southern California Edison[14]

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[11] Hussein Ibrahim, Rachid Beguenane and Adel Merabet, Wind Energy TechnoCentre, "Technical and Financial Benefits of Electrical Energy Storage," presented at Electrical Power and Energy Conference London, Ontario, October 2012. http://www.ieee.ca/epec12/files/slides/TM04-1569623959.pdf

[12] Rocky Mountain Institute, *The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid* (2015). http://www.rmi.org/Content/Files/RMI-TheEconomicsOfBatteryEnergyStorage-FullReport-FINAL.pdf

[13] *DOE/EPRI 2013 Electricity Storage Handbook*, 29.

[14] Southern California Edison, *Moving Energy Storage from Concept to Reality: Southern California Edison's Approach to Evaluating Energy Storage* (2012). https://www.edison.com/content/dam/eix/documents/innovation/smart-grids/Energy-Storage-Concept-to-Reality-Edison.pdf . For another representation of storage benefits, particularly of battery storage, see *The Economics of Battery Energy Storage*, Figure 2.

3.2.1 Benefits at the system level

Peak shaving/shifting and avoiding building new generation

The system can store excess energy generated at one time, and discharge it at another time when needed. This is particularly useful for shifting demand from peak hours of the day to off-peak hours when the demand is low. Peak demand often drives the building of new generation plants, so reducing these peaks can help avoid those costs.

Purchasing inexpensive energy

Storage can also allow the system operator to purchase inexpensive electricity (e.g., when prices are low during low-demand periods) to charge the storage facility, and use or sell the energy at a later time when the price for electricity is high. This is particularly advantageous for a system like Ontario's that is interconnected with several other electricity grids.

Demand management

While there are many benefits to energy storage, several of them fall under the category of avoided generation or avoided building of new generation. It should be noted that the same benefit can be obtained by managing — and especially reducing — demand. Efficiency measures, which are often the last item in big energy policy announcements, can help reduce load and often have very short payback periods. This is one of the reasons many advocacy groups would like to see Ontario invest more heavily in conservation efforts.

Integrating renewables

The flexibility that storage provides to grid operators also enables the integration of more intermittent sources of energy such as solar and wind.

Ancillary services

Storage can also benefit many of the support services that are needed to keep the grid reliable and stable. These include:

- Frequency regulation — balancing minute-to-minute between generation and consumption by storing and discharging as needed.
- Load following — charging and discharging as needed to ensure supply matches demand. This is similar to frequency regulation, but occurs over longer periods of time, often hours.

- Reserve capacity — providing electricity to the grid in case of an unexpected problem with supply.
- Voltage support — maintaining voltage within specified limits.
- Black start — energizing the grid and providing power to bring power plants back online in the event of a catastrophic grid failure.

3.2.2 Benefits to utilities

Deferring upgrades to transmission and distribution lines

Storage can be used to avoid upgrading a transmission or distribution line when it gets close to peak capacity. This is a particularly cost-effective solution, since often the peak demand that requires an upgrade only occurs for a few days or hours per year. So a small addition of storage capacity can defer/avoid significant capital investments in transmission or distribution.

3.2.3 Benefits to end users

Reliability

Storage can be used to manage power outages for commercial and industrial customers.

Power quality

In addition to power outages, poor quality power (e.g. fluctuating voltage or frequency) can damage or shut down equipment, particularly for commercial and industrial customers. An on-site storage system can monitor the power quality and adjust its operation accordingly to ensure stability.

Retail energy time-shift

From an end user’s perspective the total cost of electricity could be reduced if power can be used from storage rather than purchased from the grid during high price periods.

Off-grid opportunities

Storage can also enable end users to become independent producers and consumers of power. This is particularly significant for remote communities.

3.3 Best practices for energy storage adoption

3.3.1 Financial incentives

Like most emerging technologies, storage requires the help of financial instruments in order to make it viable. [15] Experience in several jurisdictions indicate that all incentive schemes should have a clear end date and a ramp-down schedule. This enables utilities and customers to plan accordingly and creates certainty for investors.

Regional targets and procurement policies

These include separate "carve out" targets for energy storage. Examples include Ontario (50 MW with a pilot 10 MW), California (1.3 GW by 2020), South Korea (154 MW), Japan (30 MW in battery storage), and Italy (75 MW)[16].

California's procurement targets

In 2013, the California Public Utilities Commission (CPUC) passed the first energy storage mandate in the U.S., requiring the state's three largest investor-owned utilities to procure 1.3 GW of energy storage by 2020.[17] It set year-by-year targets for three categories of storage: transmission, distribution, and end-user or customer-facing. The CPUC also has several provisions to ensure greater participation in energy storage systems. It sets a limit on utility ownership of storage projects at 50%, and it requires other electric service providers, including community-based ones, to procure energy storage capabilities of 1% of their annual peak load by 2020.

In February 2016, California developed a new flexible ramping energy product,[18] which included storage, to compensate power sources that can respond quickly to real-time steep increases in demand for a short period of time. This proposal is currently under review by the Federal Energy Regulatory Commission.

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[15] International Renewable Energy Association, *Self Consumption of Renewables: The Role of Storage in Revolutionizing Grid Infrastructure*, proceedings of the IRENA Energy Storage Policy and Regulation Workshop, Tokyo, November 2014. http://www.irena.org/documentdownloads/events/2015/Tokyo Energy Storage Proceedings final.pdf

[16] U.S. Department of Energy, *DOE OE Grid Energy Storage Report* (2013). http://www.sandia.gov/ess/docs/other/Grid_Energy_Storage_Dec_2013.pdf

[17] Energy Policy Innovation Council, *California's Energy Storage Procurement Framework and Design Program* (2014). https://energypolicy.asu.edu/wp-content/uploads/2014/03/California-Energy-Storage-Framework-and-Design-Program_Final.pdf

[18] California ISO, "ISO Board approves enhancements to support storage, DR," news release, February 3, 2016. http://www.caiso.com/Documents/ISO_BoardOkaysMarketEnhancementsToSupportStorage_DR.pdf

These policies have placed California as a leading jurisdiction in storage. By the end of 2015, Southern California Edison had contracted out 260 MW of storage, far exceeding its mandated requirements of 50MW.[19] To date, California has successfully already installed a storage capacity of 29.2MW.[20] If the state meets its procurement targets, it is expected to produce savings of around $78 million per year for the grid.[21]

Rebates[22]

Rebates can help investors offset a portion of the purchase price. California's Self-Generation Incentive Program uses rebates to incentivize behind-the-meter storage among other self-generation technologies. The program provides $83 million per year, with a carve-out for energy storage ($1.80/MW[23]) that was for 2 MW in 2012.

Price signals

Most traditional markets provide price incentives for energy generation, and a few select ancillary services like black start capability. But markets are needed for the other grid and utility services summarized above. System operators such as PJM (originally the Pennsylvania, New Jersey, and Maryland power pool) are starting to create parallel markets for these attributes.[24] In regulated markets, compensation for the system services provided by storage may need to be reviewed, recognized, and unbundled to allow the range of technologies to compete effectively.

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[19] California Energy Storage Alliance, "Largest Utility Energy Storage Purchase in History Announced in California," news release, November 5, 2014. http://www.storagealliance.org/sites/default/files/Press Releases/SCE Announces ES Solicitation Winners_FINAL.pdf

[20] Herman K. Trabish, "Storage update: Inside the sector's hot Q1 and what's next for utilities & suppliers," *Utility Dive*, June 11, 2015. http://www.utilitydive.com/news/storage-update-inside-the-sectors-hot-q1-and-whats-next-for-utilities/400204/

[21] California's storage portfolio, when providing energy and operating reserves, reduces the total WECC-wide production costs by $78 million (about $59/kW-year) per year in the 33% renewable portfolio scenario in California. National Renewable Energy Laboratory, *Operational Benefits of Meeting California's Energy Storage Targets* (2015).

[22] Sandia National Laboratories, *Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide* (2010) , 143. http://www.sandia.gov/ess/publications/SAND2010-0815.pdf

[23] Eric Wesoff, "California Approves $415M for Behind-the-Meter Energy Storage, Fuel Cells, Wind and Turbines," *Greentech Media*, June 18, 2014 http://www.greentechmedia.com/articles/read/California-Approves-415M-For-Behind-the-Meter-Storage-Fuel-Cells-Wind-an

[24] Sandia National Laboratories, *Market and Policy Barriers to Energy Storage Deployment* (2013). http://www.sandia.gov/ess/publications/SAND2013-7606.pdf

Tax incentives[25]

Investment in storage could qualify for tax credits. For example, the IRS in the U.S. has a provision for a 30% tax credit for investment in energy. A review[26] is currently underway to determine what new technologies, particularly those related to a smart grid, would qualify for the tax credit. Currently, batteries that are coupled with solar PV systems are included in this program.

3.3.2 Other supports

Grid operations capacity

Investments in modelling capacity are required so systems operators are able to predict grid behaviour and appropriately value storage. Models should provide enough resolution to capture the very short timeframe that some storage technologies operate on (i.e., seconds to minutes), which are often much shorter than those of traditional power plants and system models.

Policies balancing regulation with freedom to innovate

Policies supporting experimentation with storage systems should be promoted. Storage opens up possibilities to optimize grid operations and enable microgrids. In order to tap into this potential, grid operators, storage technology providers and consumers need to have more freedom to try new systems, supported by helpful guidelines and boundaries. An example of such an experiment is the partnership between PJM, BMW, and the University of Delaware that enables a small fleet of EVs to bid services into PJM's market.

PJM's market-based incentives[27]

PJM Interconnection coordinates the movement of electricity through all or parts of several states in the northeastern U.S. PJM is paving the way for recognizing the services provided by energy storage systems and expanding the revenue streams for storage. In particular, it has developed new tools to make better use of fast-responding energy storage products such as batteries, water heaters, and flywheels.

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[25] *Energy Storage for the Electricity Grid*, 143.

[26] http://www.greentechmedia.com/articles/read/the-irs-plans-to-issue-new-regulations-for-the-investment-tax-credit

[27] Energy Storage Update, "PJM Leads the US Fast-Frequency Regulation Market," April 20, 2015. http://analysis.energystorageupdate.com/market-outlook/pjm-leads-us-fast-frequency-regulation-market

In October 2012, PJM restructured its wholesale electricity market to provide additional performance payments for resources that can respond faster, accurately and over a higher range of output power.

The market structure has enabled energy storage providers to increase their revenue generating potential, and as a result PJM captured two-thirds of all storage deployed in the U.S. in 2014. It now has 86 MW of grid-scale batteries in operation, with more than 500 MW in the interconnection queue.

4. Towards the modern grid

While there is a long transitional journey ahead with unforeseen challenges, there is a world of opportunity waiting. To successfully integrate the emerging technologies and characteristics of a modern grid, we need decision-makers and system operators to incorporate more information and make more holistic decisions. They need to move from managing large central generating units to managing distributed and variable generation sources. They need to play a larger role in managing the load in the system, rather than passively reacting to the demand levels being set by consumers.

System operators and decision-makers also need to work more closely with power generators, utilities, retailers, consumers, and technology companies to encourage these entities to participate in grid modernization. In addition, adequate market or price signals are needed to incent behaviour and innovation from the different actors in the system.

All of this needs more than just training. It needs the creation of labs, pilots, and learning systems that enable new competencies to be built as well as to continuously test different ways to improve.

Utilities, in particular, have a strong role to play. They are located at the nexus of generation, consumption, and information — and are therefore in the best position to drive the modernization of the electricity grid. Innovative approaches are already being adopted by jurisdictions across North America and Europe. Ontario should learn from these jurisdictions as we chart our own path through the challenges of grid modernization.