ELECTRIC UTILITY INNOVATION

TOWARD VISION 2050

Canadian Electricity Association | Association canadienne de l'électricité

WHY NEW IDEAS ARE NEEDED IN CANADA'S ELECTRICITY SECTOR— AND WHY THE TIME TO PURSUE THEM IS NOW

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1 EXECUTIVE SUMMARY

AltaLink's Bowmanton to Whitla Transmission Project—a 240 kV transmission line from east of Medicine Hat to South of Whitla—was built on screw pile foundations. *Photo courtesy of AltaLink.*

ACROSS CANADA, THE ROLE OF ELECTRIC UTILITIES IS CHANGING. IT'S NO LONGER ENOUGH TO SIMPLY DELIVER ELECTRICITY AS A COMMODITY.

Today, utilities are being asked to provide a broad range of *energy services* through a data-driven, customer-centric system operations platform capable of managing responsive loads, electric vehicles, storage devices and distributed generation.

Utilities are expected to meet this expanded mandate in a way that encourages environmental, social and economic sustainability. Doing so will require a degree of technological innovation that goes beyond incremental productivity improvements. With funding and support from policymakers, regulators, and private industry, the electricity sector must develop, test and deploy new ideas, devices and processes that will meet the shifting needs and expectations of tomorrow's customers.

Why Innovation is Needed *Now*

Canada's electricity sector is at a critical inflection point. With much of the country's electricity infrastructure nearing the end of its life expectancy, investing in grid renewal and modernization today will be essential to ensuring a reliable, cost-effective and sustainable power supply tomorrow. The costs of doing so will be high—at least $350 billion in capital investments over the next 20 years—but will be necessary to address the deteriorating condition of utility assets.

This unprecedented need for infrastructure investment is driving up electricity rates, with the average retail electricity price expected to be approximately 20 per cent higher in 2035 compared to 2013. Only through a systematic approach to innovation will it be possible to both pilot new technologies to meet rapidly shifting demand and find new efficiencies to mitigate the impact of rising rates.

The Drivers of Innovation

The motivating drivers for grid modernization in Canada reflect society's changing expectations of utility providers with regard to economic, environmental and social sustainability. Four key drivers are currently guiding the service-related decisions being made by utilities: reducing greenhouse gas emissions; increasing system resiliency to climate change and extreme weather events; empowering customers to play a more central role in shaping the electricity system; and containing costs to be able to do more with less.

Key Technology Areas to Focus On

With a once-in-a-generation investment cycle peak comes the opportunity to develop, test and deploy a wide range of leading-edge grid modernization technologies. From the perspective of the Canadian Electricity Association (CEA), five technology areas currently being explored by Canada's utilities show the most promise for shaping the functionality of tomorrow's electricity system: demand response; the facilitation of distributed generation; the facilitation of electric vehicles; the optimization of asset use; and fault detection and mitigation. As a result, these areas should receive immediate support in the form of pilot project funding.

Customer conserves electricity by turning off the lights. *Photo courtesy of BC Hydro and Power Authority.*

RECOMMENDED ACTIONS

TAKING INTO ACCOUNT THE KEY DRIVERS AND TECHNOLOGY AREAS INFLUENCING THE GRID MODERNIZATION OPPORTUNITY IN CANADA, CEA PUTS FORWARD THE FOLLOWING RECOMMENDED ACTIONS THAT CAN BE TAKEN TODAY TO ENSURE UTILITIES HAVE THE MANDATE AND MEANS TO CONTINUE TO INVEST IN INNOVATION GOING FORWARD:

- **Align priorities and goals**
  Through national organizations and strategic forums, provincial regulators, policymakers and utilities can develop common priorities and goals related to the transformation of Canada's electricity infrastructure.

- **Track grid modernization indicators at a national level**
  A national approach to tracking key indicators related to grid modernization benefits and implementation is needed to proactively identify areas that will require near-term technical and regulatory solutions.

- **Look internationally**
  By participating in the International Energy Agency's International Smart Grid Action Network (ISGAN) and other multi-national forums, Canada has the opportunity to learn from other countries also aggressively pursuing electricity innovation.

- **Pool innovation funding to mitigate risk and share rewards**
  Utilities should hold a broad portfolio of innovation projects. Funding for those projects that support provincial or national policy objectives should be fully or partially matched by public funds through organizations such as Sustainable Development Technology Canada.

- **Share lessons learned**
  All stakeholders involved in grid modernization, including regulators, policymakers, utilities and customers, benefit from the sharing of lessons learned emerging from both successful and failed demonstration projects.

- **Lock in knowledge by developing codes and standards**
  As technologies develop and lessons learned are distilled, knowledge should be formalized into codes and standards that guide utility technical planning and operating practices.

- **Keep customers informed and engaged**
  Grid modernization is focused on protecting and improving the value of electricity service—and it will be critical to communicate this to customers early and often. Going forward, utilities, policymakers and regulators will have to broaden the conversation to engage the public in new ways.

2 INTRODUCTION

MOVING TOWARD A MORE SUSTAINABLE MODEL OF ELECTRICITY DISTRIBUTION WILL REQUIRE EXPERIMENTATION AND INNOVATION

Transmission Lines and the skyline. *Photo courtesy of Nalcor Energy.*

TRADITIONALLY, THE UTILITY MANDATE HAS BEEN TO GENERATE, TRANSMIT AND DISTRIBUTE ELECTRICAL ENERGY IN A SAFE, RELIABLE, AND COST-EFFECTIVE WAY.

Equipment exceeding its expected useful life was typically replaced “like for like,” with the suppliers of that equipment focused on incremental improvements to the functionality, longevity or safety of their products. Utility managers, meanwhile, focused primarily on continuous productivity improvement: performing routine electric utility tasks safer, faster and cheaper.

But that mandate is rapidly evolving and with it the very notion of what an electricity distribution utility should be. The modern utility is no longer simply the provider of “poles and wires” and on-demand commodity delivery. It is instead a data-driven, customer-centric system operations platform capable of managing responsive loads, electric vehicles, storage devices and distributed generation in real time.

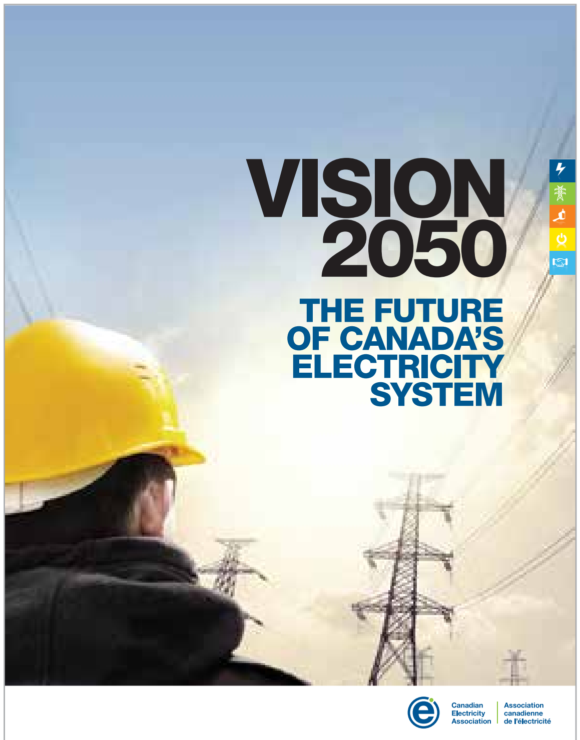
Behind this transformation is a commitment to *sustainable development*, which CEA defines as: pursuing progressive business strategies and activities that meet the needs of the present, while enhancing the environmental, social and economic resources that will be needed in the future.

Moving toward a more sustainable model of electricity distribution will require experimentation and innovation that goes beyond incremental productivity improvements. With the support of policymakers, regulators and private industry, it is imperative that the electricity sector begins to develop, test and deploy new ideas, devices and processes that will meet the needs and expectations of tomorrow’s customers.

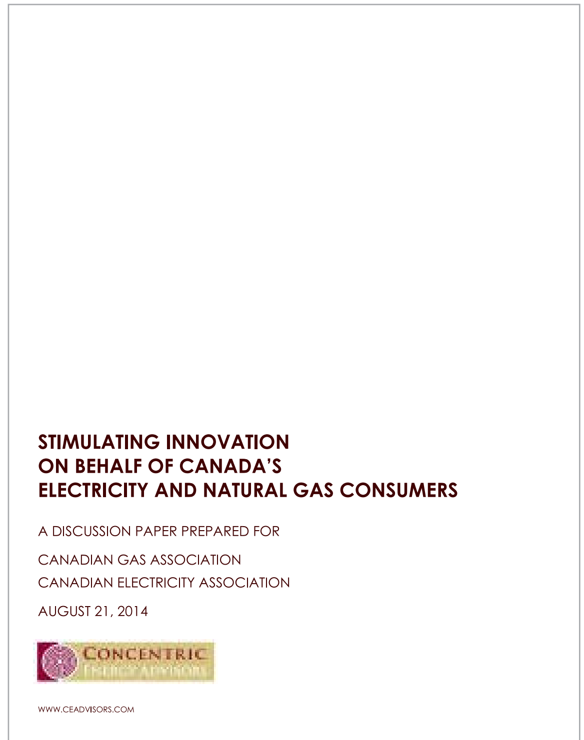
Advancing the Innovation Agenda

This policy paper is intended to give regulators, policymakers and other key stakeholders the necessary information and context to support the electricity innovation agenda.

First, the paper examines the current drivers of Canadian electric utility innovation, showing why the sector is at a critical inflection point. It then reviews the key technology areas that are shaping the functionality of tomorrow’s electricity system (and therefore represent considerable opportunities for innovation): demand response; facilitation of distributed generation; facilitation of electric vehicles; optimization of asset use; and fault detection and mitigation. Finally, the paper offers seven recommendations that will help regulators, policymakers and utilities continue to push the innovation agenda forward.



CEA's *Vision 2050: The Future of Canada's Electricity System* cover.



Stimulating Innovation on Behalf of Canada's Electricity and Natural Gas Consumers cover.

While this paper draws on numerous sources for information and inspiration, it attempts to build on the framework established by two papers in particular.

The first is CEA's *Vision 2050: The Future of Canada's Electricity System*.[1] Published in March 2014, it maps out a vision for the future of electricity in Canada—and offers ideas on how to achieve that vision. Specifically, *Vision 2050* recommends the acceleration of electric utility innovation through active support from policymakers and regulators combined with prudent investment decisions made by utilities that focus on key principles such as reliability, equity, integration, efficiency, and growth.

The second is *Stimulating Innovation on Behalf of Canada's Electricity and Natural Gas Consumers*.[2] Published in August 2014 by Concentric Energy Advisors for CEA and the Canadian Gas Association, this paper proposes a gold standard model that Canadian utilities and regulators can adopt to promote and fund innovation. It puts forward recommended guidelines related to funding levels, regulatory oversight, program management and opportunities for collaboration. Informed by global practices, the paper's recommendations are backed by examples of successful innovation approaches already in place across Canada, the United States, and Europe.

With this paper, CEA adds to the innovation conversation with an overview of the specific areas that require action today, as well as a series of recommendations that will help ensure the full value of any innovation investments made in Canada's electricity sector is realized.

1 Canadian Electricity Association. "Vision 2050: The Future of Canada's Electricity System," 2014. Available from http://powerforthefuture.ca/wp-content/uploads/2014/04/Vision2050.pdf.

2 Stephen Caldwell, Robert Yardley, Jr, and James Coyne, 2014. "Stimulating Innovation on Behalf of Canada's Electricity and Natural Gas Consumers." Available from http://www.electricity.ca/media/ReportsPublications/StimulatingInnovation2014.pdf.

SaskPower lineman looks at plans at a substation. *Photo courtesy of SaskPower.*

Power line technician ensure power reliability.
Photo courtesy of Maritime Electric Company Limited.

WITH THIS PAPER, CEA ADDS TO THE INNOVATION CONVERSATION WITH AN OVERVIEW OF THE SPECIFIC AREAS THAT REQUIRE ACTION TODAY, AS WELL AS A SERIES OF RECOMMENDATIONS THAT WILL HELP ENSURE THE FULL VALUE OF ANY INNOVATION INVESTMENTS MADE IN CANADA'S ELECTRICITY SECTOR IS REALIZED.

3 ECONOMIC PRESSURE AND AGING INFRASTRUCTURE

WHY INNOVATION IS NEEDED NOW

Power line technician, Jessica Hadfield safely repairing a line. *Photo courtesy of Manitoba Hydro.*

TWO DOMINANT THEMES ARE RE-SHAPING THE LANDSCAPE IN WHICH CANADIAN ELECTRICITY UTILITIES OPERATE: THE UNPRECEDENTED INFRASTRUCTURE INVESTMENT THAT WILL BE REQUIRED OVER THE NEXT 20 YEARS TO MAINTAIN AND EXPAND THE ELECTRICITY NETWORK, AND THE ACCELERATED PACE OF CHANGE RELATED TO SUSTAINABILITY AND SERVICE EXPECTATIONS.

The need for massive infrastructure investment is driving up electricity rates across Canada. This has led to pressure from regulators, politicians, and consumer groups to find efficiencies and manage costs in the short term. The productivity imperative often seems incompatible with developing and piloting new processes and technologies to keep up with the ever increasing pace of change. In other words, to spend both time and money on innovations that, while fruitful over the longer term, rarely deliver same-year payback.

Utilities are finding ways to address both through a commitment to individual and collaborative innovation. As pressures build to cut costs now, a more systematic, structured approach to innovation will be required if the electricity sector is to successfully bridge the gap between productivity today versus innovation for the future.

Slowed Economic Growth

The cost pressures facing Canada's electricity utilities are exacerbated by a macroeconomic landscape that is markedly different than it was during the last major infrastructure investment campaign about 40 years ago. At that time, the country's real GDP was growing by about five per cent per year[3]. As industrial, commercial and residential customers adopted a broad range of new electric-powered appliances, utility sales increased by five to 11 per cent each year between 1965 and 1974—for a cumulative increase of 94 per cent over the 10 year period.[4]

Comparing the economic boom of the 1970s to today's low-growth reality is sobering. The National Energy Board predicts that Canada's real GDP will grow at an average rate of just two per cent per year until 2035.[5] Growth in electricity generation capacity over that same period will remain relatively flat at about one per cent per year, primarily due to efforts to reduce the energy intensity of the Canadian economy.[6]

3 Statistics Canada. Table 380-0501 – "Gross domestic product (GDP), expenditure-based, 1968 System of National Accounts (SNA), quarterly (dollars)." From CANSIM database accessed: 2014-12-22.

4 Statistics Canada. "Series Q92-96 – Production and trade in electrical energy, 1919 to 1975, CVS document." From StatsCan website http://www5.statcan.gc.ca/access_acces/archive.action?l=eng&loc=Q92_96-eng.csv.

5 National Energy Board, 2013. "Canada's Energy Future 2013: Energy Supply and Demand Projections to 2035." Available from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2013/2013nrgftr-eng.pdf.

6 Ibid, 63.

Canada's Infrastructure Deficit

Much of Canada's generation, transmission and distribution infrastructure is nearing the end of its life expectancy. Toronto Hydro Corporation, for example, estimates that approximately one-third of its electricity distribution assets are currently past their expected useful life.[7] Similarly, BC Hydro and Power Authority (BC Hydro) acknowledges that many assets were built before 1970 and their aging and deteriorating state must be addressed.[8]

It is clear that investing in infrastructure renewal and modernization will be essential to ensuring a reliable, cost-effective and sustainable supply of electricity. It will also be essential for preparing Canada's electricity system for the year 2050 and a world of engaged customers, variable energy resources, electric vehicles, energy storage, advanced asset analytics and responsive outage management systems.

Getting there, however, will require utilities to carefully evaluate the most efficient path forward. Which assets should be replaced "like for like" with more of the same? Which should be replaced with something new? And which may not need to be replaced at all?

Regardless of the approach taken, the cost to maintain and modernize Canada's grid will be high. According to a 2012 Conference Board of Canada (CBoC) report, renewing Canada's electricity infrastructure will cost nearly $350 billion over the next 20 years. And this is likely to be the lower bound: the CBoC notes, for example, that "transmission investments identified in [the] report are likely to be underestimated."[9] Given that caveat, the Canadian electricity sector is likely facing a period of sustained capital investment of about $20 billion per year for 20 years—for a total required investment of approximately $400 billion.

Capital expenditures on new and refurbished infrastructure are increasing each year as utilities begin to chip away at this infrastructure deficit. Among CEA Corporate Utility Members, transmission and distribution infrastructure spending increased from $5.6 billion in 2011 to $7.6 billion in 2012 and then to $9.0 billion in 2013, a three-year increase of 61 per cent.[10] Including generating assets, total infrastructure investment rose to $14 billion in 2013, an increase of 17.7 per cent over 2012.[11]

Fortunately, the investments being made by utilities across Canada are providing a much needed short-term boost to the economy through economic stimulus and job creation. Working from its anticipated infrastructure spend of $350 billion, the CBoC estimates that these investments will contribute $10.9 billion to Canada's real GDP—as well as an average of 156,000 jobs—every year.[12]

THE CANADIAN ELECTRICITY SECTOR IS LIKELY FACING A PERIOD OF SUSTAINED CAPITAL INVESTMENT OF ABOUT $20 BILLION PER YEAR FOR 20 YEARS—FOR A TOTAL REQUIRED INVESTMENT OF APPROXIMATELY $400 BILLION.

7 Toronto Hydro Corporation, 2013. "2012 Annual Report: The Measure of Our Commitment, 2013." Available from https://www.torontohydro.com/sites/corporate/InvestorRelations/FinancialReports/Documents/Financial%20Reports/2012%20Interactive/pdf/TOHY%202012AR_eReport.pdf.

8 BC Hydro and Power Authority, 2013. "Annual Report 2012" Available from http://www.bchydro.com/content/dam/hydro/medialib/internet/documents/annual_report/2012_BCH_AnnualReport.pdf.

9 Len Coad, Todd A. Crawford and Alicia Macdonald, 2012. "Shedding Light on the Economic Impact of Investing in Electricity Infrastructure." Conference Board of Canada, available from http://www.conferenceboard.ca/e-library/abstract.aspx?DID=4673.

10 Canadian Electricity Association, 2014. "2014 Sustainable Electricity Annual Report: Engaged for a Sustainable Future." Available from http://sustainableelectricity.ca/wp-content/uploads/2014/09/EngagedforaSustainableFuture2014.pdf.

11 Ibid.

12 Len Coad, Todd A. Crawford and Alicia Macdonald, 2012. "Shedding Light on the Economic Impact of Investing in Electricity Infrastructure." Conference Board of Canada, available from http://www.conferenceboard.ca/e-library/abstract.aspx?DID=4673.

Rising Electricity Rates

Infrastructure investments bring about a number of economic benefits, but they can also cause electricity rates to rise for all Canadians. This is nothing new: even in the booming economy of the 1970s, BC Hydro's last major cycle of infrastructure investment led to a 113 per cent cumulative bill increase from 1973 to 1982.[13] While energy efficiency and conservation programs have helped soften the bottom-line impact to customers, rate increases are inevitable.

What kind of rate increases should Canadians expect in the coming years? In its report titled *Canada's Energy Future 2013*, the National Energy Board projects that the average retail electricity price (including residential, commercial and industrial prices) will be approximately 20 per cent higher in 2035 compared to 2013.[14] The Government of Ontario's Long Term Energy Plan, predicts that rates will increase by 2.8 per cent annually over the next 20 years—resulting in a 42 per cent increase by 2018 and a 68 per cent increase by 2032.[15] (It should be noted that these numbers are actually *lower* than the province's 2010 projections, which forecasted an increase of 3.5 per cent per year until 2030; this decrease is largely due to the success of Ontario's aggressive conservation targets.)[16]

In British Columbia, the cumulative rate increase has been capped by the provincial government at 28 per cent from 2014 to 2019[17]. Beyond that, increases will be determined by the BC Utilities Commission; however, it is expected that investments in BC Hydro's Power Smart Program, lower operating costs and a reduced dividend paid to the province will lead to more modest increases beyond 2019. While not all provinces publish long-term rate forecasts, most jurisdictions will follow the national rate increase trend-line.

POWER FOR THE FUTURE.ca

CEA'S WWW.POWERFORTHEFUTURE.CA WEBSITE PROVIDES A FOUNDATIONAL RESOURCE FOR STARTING THIS CONVERSATION WITH ELECTRICITY CUSTOMERS ACROSS CANADA.

Besides drastically increasing debt, utilities have three broad ways to mitigate the rate impacts resulting from increased capital and operational costs. The first is to increase sales volume for traditional end-uses so they can spread fixed network costs over a greater volume of kilowatt-hours sold. This is an unlikely proposition given the current economic conditions and the ongoing push for energy conservation.

The second option is to change the *perceived* value of electricity service by explaining the need for infrastructure investments to customers directly. If the messages gain traction, it will soften the impact of rising rates because customers will understand why they are necessary.

The third option is to improve the *actual* (rather than perceived) value of electricity service delivered to customers by providing a platform that seamlessly integrates new end-use applications and responds instantly to individual preference. From an operations perspective this is the preferred option—and it is also the option that will require the greatest focus on new innovation to make feasible.

13 Bill Bennett, "10 Year Plan for BC Hydro," Presentation by the Minister of Energy and Mines, November 26, 2013. http://www.newsroom.gov.bc.ca/downloads/Presentation.pdf.

14 National Energy Board, 2013. "Canada's Energy Future 2013: Energy Supply and Demand Projections to 2035." Available from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2013/2013nrgftr-eng.pdf.

15 Ontario Ministry of Energy, 2013. "Achieving Balance: Ontario's Long Term Energy Plan." Available from http://powerauthority.on.ca/sites/default/files/planning/LTEP_2013_English_WEB.pdf.

16 Ontario Ministry of Energy, 2010. "Building Our Clean Energy Future: Ontario's Long Term Energy Plan," Available from http://www.powerauthority.on.ca/sites/default/files/page/MEI_LTEP_en_0.pdf.

17 "10 Year Plan Means Predictable Rates as BC Hydro Invests in System." BC Government news release on November 26, 2013 on the BC Government website http://www2.news.gov.bc.ca/news_releases_2013-2017/2013MEM0023-001774.pdf.

4 WHAT'S DRIVING UTILITIES TO INNOVATE?

UTILITIES ARE REACTING TO AND ADAPTING TO A CHANGING ELECTRICITY CLIMATE

TO UNDERSTAND THE PUSH FOR (AND URGENCY OF) GRID MODERNIZATION IN CANADA, IT IS USEFUL TO CONSIDER TWO TYPES OF DRIVERS: MOTIVATING DRIVERS AND ENABLING DRIVERS.

Motivating drivers reflect society's changing expectations of what Canada's electricity sector should deliver in terms of economic, environmental and social sustainability; and

Enabling drivers are the market and technological forces that, if harnessed properly, will allow utilities to deliver on their evolving mandate.

This section focuses on the following motivating drivers that are currently guiding the service decisions being made by utilities across Canada (and in later sections, the technological opportunities available to address them):

- Reducing greenhouse gas emissions;
- Increasing resiliency;
- Empowering customers; and
- Containing costs.

For additional context, this section also touches on one of the major enabling drivers that will allow utilities to better meet increased expectations and realize CEA's *Vision 2050*: the emergence of Big Data.

Reducing Greenhouse Gas Emissions

Canada boasts one of the greenest electricity systems in the world, with about 80 per cent of the electricity generated coming from sources that do not emit greenhouse gases. In 2013, hydro dams accounted for 63.4 per cent of electricity generation in Canada, followed by fossil fuels (19.2 per cent), nuclear (15.9 per cent), wind (1.5 per cent) and solar (0.04 per cent).[18]

The electricity sector is the only major industrial sector in Canada expected to reduce total greenhouse gas emissions by 2020; relative to 2005 levels, it is expected to cut its emissions by 25 per cent.[19] Real progress is being made: from 2012 to 2013, CEA Corporate Utility Members lowered CO2eq emissions by 3.6 per cent, bringing the total decrease to an impressive 16.6 per cent drop from 2009 levels.[20] CEA's 2014 Sustainable Electricity™ annual report credits this to reduced coal use and the increased integration of renewable and distributed generation.

Still, there is continued pressure to decarbonize Canada's economy. Distributed generation comprises one element of a broader strategy to do so affordably.

18 Statistics Canada. Table 127-0007 – Electric power generation, by class of electricity producer, annual (megawatt hour)." From CANSIM (database) accessed: 2014-12-22.

19 National Round Table on the Environment and the Economy, 2012. "Reality Check: The State of Climate Progress in Canada." Available from http://publications.gc.ca/collections/collection_2012/trnee-nrtee/En134-57-2012-eng.pdf.

20 Canadian Electricity Association, 2014. "Sustainable Electricity Annual Report: Engaged for a Sustainable Future, 2014." Available from http://sustainableelectricity.ca/wp-content/uploads/2014/09/EngagedforaSustainableFuture2014.pdf.

An Emergency Management exercises was held at our System Control Center.
Photo courtesy of Newfoundland Power Inc.

Storm related damage caused by freezing rain in Newfoundland.
Photo courtesy of Newfoundland Power Inc.

Increasing Resiliency

In the past two years, many utilities have experienced severe weather events that have impacted their ability to deliver power. One example of such an event was the Toronto ice storm of December 2013, which left nearly 300,000 customers in the dark over the holiday season. Climate change (and the increasing severity and frequency of extreme weather events that come with it) will continue to have a profound impact on the reliability of Canada's electricity generation, transmission and distribution system. To combat this challenge utilities must make appropriate investment decisions now to increase the resiliency of the power grid.

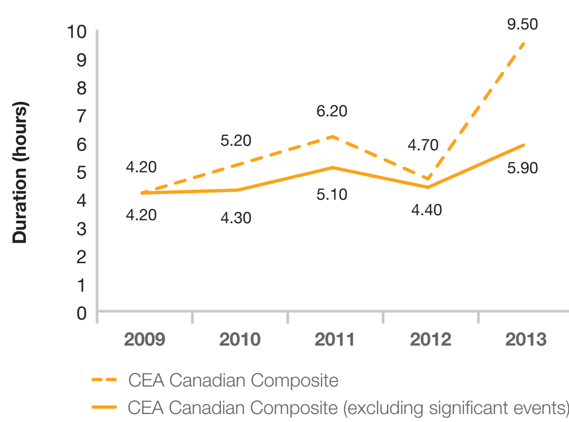
An AltaLink transmission line in Canmore, Alberta during the 2013 flood.
Photo courtesy of AltaLink.

Storm Response

According to the Insurance Bureau of Canada, insurance payouts due to property damage caused by severe weather have doubled every five to 10 years since the 1980s.[21] When property is damaged, electricity infrastructure is likely to be damaged as well. **Figure 1,** right, illustrates how electricity reliability has been affected in recent years by severe weather events.

Public perception is that utilities should be doing more to protect customers from prolonged outages and the expectation is that they will take proactive steps to do so. Improving grid resiliency is just one aspect of a broader push to continuously improve the reliability and quality of electric power service, and this mandate must be delivered with performance and cost finely balanced.

Figure 1. Increases in the System Average Interruption Duration Index (SAIDI) caused by severe weather



21 Insurance Bureau of Canada, 2012. "Telling the Weather Story." Available from http://assets.ibc.ca/Documents/Studies/McBean_Report.pdf.

Manitoba Hydro crews install new equipment in a vault beneath Graham Avenue in downtown Winnipeg as part of the utility's infrastructure renewal efforts.
Photo courtesy of Manitoba Hydro.

For example, while utilities can engineer a distribution system that would deliver very high levels of reliability in the face of ice storms and hurricanes, it would come at a very high cost, especially if such hardening included undergrounding a significant percentage of the distribution system.[22]

As a case in point, Finland has recently set time limits for the longest allowed interruptions due to storms or snow—six hours in cities and 36 hours in all other areas—that must be met by the end of 2028. If the time limits are exceeded, compensation will be paid directly to the customer, up to a maximum of €2,000 per year.[23] The Finnish government expects this policy will encourage greater use of underground cables, and has acknowledged and accepted the associated costs, which are forecast to be significant.

Climate Adaptation

According to Natural Resources Canada, adaptation to climate change can either be reactive (i.e., occurring in response to observed impacts) or anticipatory (i.e., occurring before the impacts of climate change are observed)—and in most circumstances, anticipatory adaptations will result in lower long-term costs and be more effective than reactive ones.[24] Utilities must therefore be given the licence to test anticipatory solutions today.

The challenge will be in understanding appropriate regional system design requirements. Overbuilding leads to charges of the utility investing in "gold-plated" systems simply to maximize its capital expenditures; underbuilding leaves society as a whole vulnerable to severe weather and climate variability. Finding the right balance will require the completion of climate modelling and system vulnerability analyses. Proposed grid-hardening solutions should be tested on a small scale before being rolled out across a full service territory.

22 William P. Zaraka, Philip Q Hanser, and Kent Diep. "Rates, Reliability and Region: Customer Satisfaction and Electric Utilities." Public Utilities Fortnightly, Jan. 2013. Available from http://www.brattle.com/system/publications/pdfs/000/003/981/original/Rates_Reliability_and_Region_Zarakas_Hanser_Diep_PUF_Jan_2013.pdf?1379360894.

23 International Energy Agency, 2013. "Energy Policy Highlights, 2013." Available from http://www.iea.org/publications/freepublications/publication/energy_policy_highlights_2013.pdf.

24 Natural Resources Canada, 2010. "Adapting to Climate Change: An Introduction for Canadian Municipalities." Available from http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/earthsciences/pdf/mun/pdf/mun_e.pdf.

TODAY'S CUSTOMERS, WHO ARE MORE ENGAGED THAN EVER BEFORE, EXPECT A NEW KIND OF RELATIONSHIP WITH THEIR UTILITY.

Empowering Customers

Over the 100-year history of the electric utility in Canada, the successful customer relationship has been characterized by a minimum of contact. Traditional mechanical meters are read six times per year and bills are mailed out shortly thereafter. Customers pick up the phone to call their utility rarely, usually to dispute a bill, report an outage, or arrange a connection or disconnection of service.

In the digital age, where information is abundant and cheap, this model has quickly become outdated. Today's customers, who are more engaged than ever before, expect a new kind of relationship with their utility.

CEA's *Vision 2050* notes that "changing technologies have shifted the role of the customer, increasing the impact of consumers in shaping the electricity system. Fortunately, the same technologies that give the customer a more central role also create opportunities to better manage the new complexities as the system evolves. Customization to meet consumer need will become a key attribute of our electricity system, allowing for efficiencies from production to end use."[25]

In addition to giving utilities new tools to drive grid-side efficiencies, empowering the customer also helps to:

- Contain costs on the grid side, reducing the magnitude of required rate increases;
- Provide customers with the tools to better control their own costs (i.e., conservation, off-peak usage);
- Increase their value through better customer service or the development of new services; and
- Open a two-way dialogue through which utilities can communicate the benefits of technology changes and consumers can communicate their service preferences.

Customer empowerment can yield great benefits to electric utilities if done well, or result in an erosion of public support if done poorly. Either way, it remains a significant driver of utility evolution.

CUSTOMIZATION TO MEET CONSUMER NEED WILL BECOME A KEY ATTRIBUTE OF OUR ELECTRICITY SYSTEM, ALLOWING FOR EFFICIENCIES FROM PRODUCTION TO END USE.

25 Canadian Electricity Association, 2014. "Vision 2050: The Future of Canada's Electricity System." Available from http://powerforthefuture.ca/wp-content/uploads/2014/04/Vision2050.pdf.

Containing Costs

As noted earlier in this paper, the increased investment required to address Canada's infrastructure deficit will also result in rate hikes for utility customers. Yet that doesn't change the fact that Canadian utilities are under continuous pressure to maintain competitive rates and maximize productivity while maintaining the highest possible level of service. Accordingly, utilities are always looking to do more with less.

Grid modernization can help. According to a 2012 Ernst & Young (EY) report (which itself builds on the framework that emerged from the United Kingdom's Smart Grid Forum, an initiative co-created by Britain's national electricity regulator and the Department of Energy and Climate Change), the baseline distribution network infrastructure investment requirement in the UK is about £46 billion by 2050.[26] However, if British distribution utilities embrace smart grid technologies, the required investment may be as little as £27 billion, a total savings of £19 billion.[27]

While it acknowledges EY's work, the UK Department of Energy and Climate Change notes in a 2014 report that while smart grids do not remove the need for conventional reinforcement of networks, they can minimize or defer the need for infrastructure investment by helping utilities reduce costs and incorporate low-carbon technologies at a faster rate.[28]

To put this into a Canadian context, Gaëtan Thomas, President and Chief Executive Officer of New Brunswick Power Holding Corporation, made the business case for his company's pursuit of grid modernization as follows: "By engaging our customers, we can avoid more than $1.3 billion net present value over 25 years on our system by deferring the requirement for new generation or refurbishment by seven to 10 years."[29]

Toronto Hydro Corporation has converted 99.7 per cent of its meter population to Smart or Interval Meters. *Photo courtesy of Toronto Hydro Corporation.*

26 Ernst & Young, 2012. "Great Britain: Unlocking the Potential of the Smart Grid." Available from http://www.ey.com/Publication/vwLUAssets/EY_-_Great_Britain_-_unlocking_the_potential_of_smart_grid/$FILE/EY-Plug-In-Great-Britain-unlocking-the-potential-of-smart-grid-v1.pdf.

27 Ibid.

28 UK Department of Energy and Climate Change, 2014. "Smart Grid Vision and Routemap." Available from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/285417/Smart_Grid_Vision_and_RoutemapFINAL.pdf.

29 Junior Isles, "Special Project Supplement: Realising a smart vision." Dec. 2013. Available from http://www.anderson.ucla.edu/rosenfeld-library/citing-business-sources#journals.

The Emergence of Big Data

Utilities are reacting to and benefiting from the same technological advances that have affected every other sector of the Canadian economy. Health care, media, retail and countless other sectors have been transformed by the falling costs of collecting, storing and sharing data. Utilities are simply riding the same wave of automation—and Big Data underpins the opportunity to move beyond the traditional ways of delivering electricity and toward CEA's *Vision 2050*.

The Utility Analytics Institute has predicted that spending on Big Data software, hardware and services by North American utilities will increase to about $2 billion in 2016, up from $1.3 billion in 2013[30] and $511 million in 2011.[31] At the same time, data-related costs are continuously decreasing. Over the past 30 years, the cost to store data has been cut in half every 14 months or so. In 1995, storing a gigabyte of data cost about $11,200; by 2000 it was $11 and today costs a mere three cents.[32]

Affordable data storage is critical to grid modernization. Smart meters provide a good example to highlight why this is.

According to the Canadian Electricity and Gas Inspection Regulations, utilities are required to keep "for each billing period, the metering information used by the owner in establishing a charge […] for a period of at least 12 months after the date the meter ceased to be used."[33]

Individual electricity meters typically have an expected useful life of about 30 years. Even for large utilities, storing bi-monthly meter reads logged with pencil on paper has never required more than a few large filing cabinets as each meter has a maximum of 180 reads over the course of its life. Contrast that with the current practice in Ontario, which captures and stores five-minute interval demand data for any customer who is forecast by the distributor to have a monthly average peak demand of more than 50 kilowatts during a calendar year. That works out to 105,120 records per year—and 3,153,600 records over the 30-year life of the meter.

Toronto Power line technician Pete Patton installs an automated meter.
Photo courtesy of FortisAlberta Inc.

Fortunately, the falling costs of data storage have made the transition to real-time data collection economically feasible, but it is not the end of the story. As information technology systems evolve, old data must be pulled along with it in a way that maintains accuracy and protects security and privacy. The need to protect the integrity of historical data will be one area that will require continuous attention and innovation over the long term.

CEA is confident that the grid operators of 2050 will look back and be amazed that meter reads were performed once every other month *in person*! Also, outages were not known by the utility until customers called in to complain about a lack of power. Advanced metering infrastructure, workforce management, distribution automation, smart homes… Big Data is the tool that enables it all. The next step, of course, is to turn cheap data into valuable information that grid operators and customers can use to make better decisions—and that requires ongoing innovation.

30 Jonathan Berr, "Utility Grid Barons Warm to Big Data's Power," *CNBC*, July 14, 2014. http://www.cnbc.com/id/101823030#.

31 Utility Analytics Institute, "Annual Market Outlook and Forecast: Summary Report, 2012." Available from http://www.energycentral.com/marketing/UAI/2011_UAI_Market_Report_Summary.pdf.

32 Statistic Brain, 2013. "Average Cost of Hard Drive Storage." Available from http://www.statisticbrain.com/average-cost-of-hard-drive-storage.

33 Electricity and Gas Inspections Regulations, SOR/86-131. Available from http://laws-lois.justice.gc.ca/eng/regulations/SOR-86-131.

5 OPPORTUNITIES FOR INNOVATION: KEY TECHNOLOGY AREAS REQUIRING IMMEDIATE SUPPORT

INVESTMENT IN LEADING-EDGE TECHNOLOGIES WILL IMPROVE OPERATIONAL EFFICIENCY AND REDUCE COSTS

EACH PROVINCE AND TERRITORY WEIGHS MOTIVATING AND ENABLING DRIVERS DIFFERENTLY, BASED ON FACTORS SUCH AS THEIR EXISTING INFRASTRUCTURE, NATURAL RESOURCE AVAILABILITY, POLITICAL PRIORITIES AND CUSTOMER PREFERENCES.

There is no one-size-fits-all model for grid modernization. There are, however, some common technological capabilities that can be funded and supported that will help utilities deliver on their expanding mandate.

CEA supports innovation opportunities and technology demonstration projects across three categories:

- Investigating the application of new technologies;
- Developing new methods, procedures or products to carry out work more efficiently or safely; or
- Gaining specific knowledge about the evolving utility environment to enhance design, operations or customer programs.

In practical terms, the interest is in leading-edge technologies that will improve operational efficiency and reduce the cost to transmit electricity: distribution management systems; smart meters; automated switches, transformers and substations; and integrated systems for handling outage management, asset management, geographic information and customer support.

This section takes a closer look at the most promising technology areas currently being explored by Canadian utilities that require immediate support in the form of pilot project funding.

Toronto Hydro's community energy storage system was developed with a lithium-ion battery solution used for distribution grid applications. It consists of batteries, controls, and communication systems that interface with the grid and was made possible through funding in innovation. *Photo courtesy of Toronto Hydro Corporation.*

Demand Response

In the traditional grid context, generation follows load, meaning that as electricity usage increases in a given service territory, power plants are brought online to meet the demand and maintain system balance. Grid modernization provides utilities with the data and controls necessary to allow, and even prompt, load to respond to supply conditions or other signals such as power quality deterioration.

In early demonstrations, demand response initiatives have largely focused on peak shaving, which involves shifting energy demand from one time period to another to smooth consumption patterns. However, increasing attention is being given to shorter timescale applications like frequency regulation, which provide the flexibility to better integrate intermittent renewable energy resources and can also serve as a short-term contingency to mitigate unscheduled loss of supply.

Worldwide revenue from residential demand response is expected to grow from $322 million in 2014 to $2.3 billion in 2023.[34] In line with those estimates, Ontario is aiming to use demand response to meet 10 per cent of its peak demand by 2025, equivalent to approximately 2,400 megawatts under forecast conditions.

A December 2013 report from the U.S. Department of Energy's National Renewable Energy Laboratory found that a modest demand response resource of 45.4 megawatts added to a testing scenario could provide up to 113 megawatts of capacity (roughly two per cent of peak load) and shift 135 gigawatt-hours of energy. It can also meet about 33 per cent of the need for frequency regulation, 19 per cent of spinning contingency reserve and 85 per cent of flexibility reserve.[35] Without getting into the details on each of these, suffice it to say that this translates into better grid performance and can significantly reduce necessary infrastructure investment.

In the United States, demand response is currently being challenged by some traditional wholesale generators who feel that paying customers to curtail demand, thus getting paid for negative watts or "negawatts", will ultimately undermine the energy market and starve out traditional utilities.

Table 1. The Impact of Motivating Drivers on Demand Response

Driver	Challenge/Opportunity
Reduce emissions	Most peaker plants burn natural gas to generate electricity, because of the fast ramp rate. Demand response can help alleviate the need for these plants.
Increase resiliency	Demand response reduces pressure on the system during times of peak demand and can provide short-term cover for emergency downtime at traditional power plants.
Empower customers	Demand response is a tool for utility operators to control electricity consumption at times of peak demand; it also includes efforts by customers to respond to real-time price signals. By shifting to off-peak consumption, customers can reduce their bills.
Contain costs	Demand response can help avoid expensive upstream solutions to a "peaky" system, while extending the life of downstream assets by alleviating system congestion.

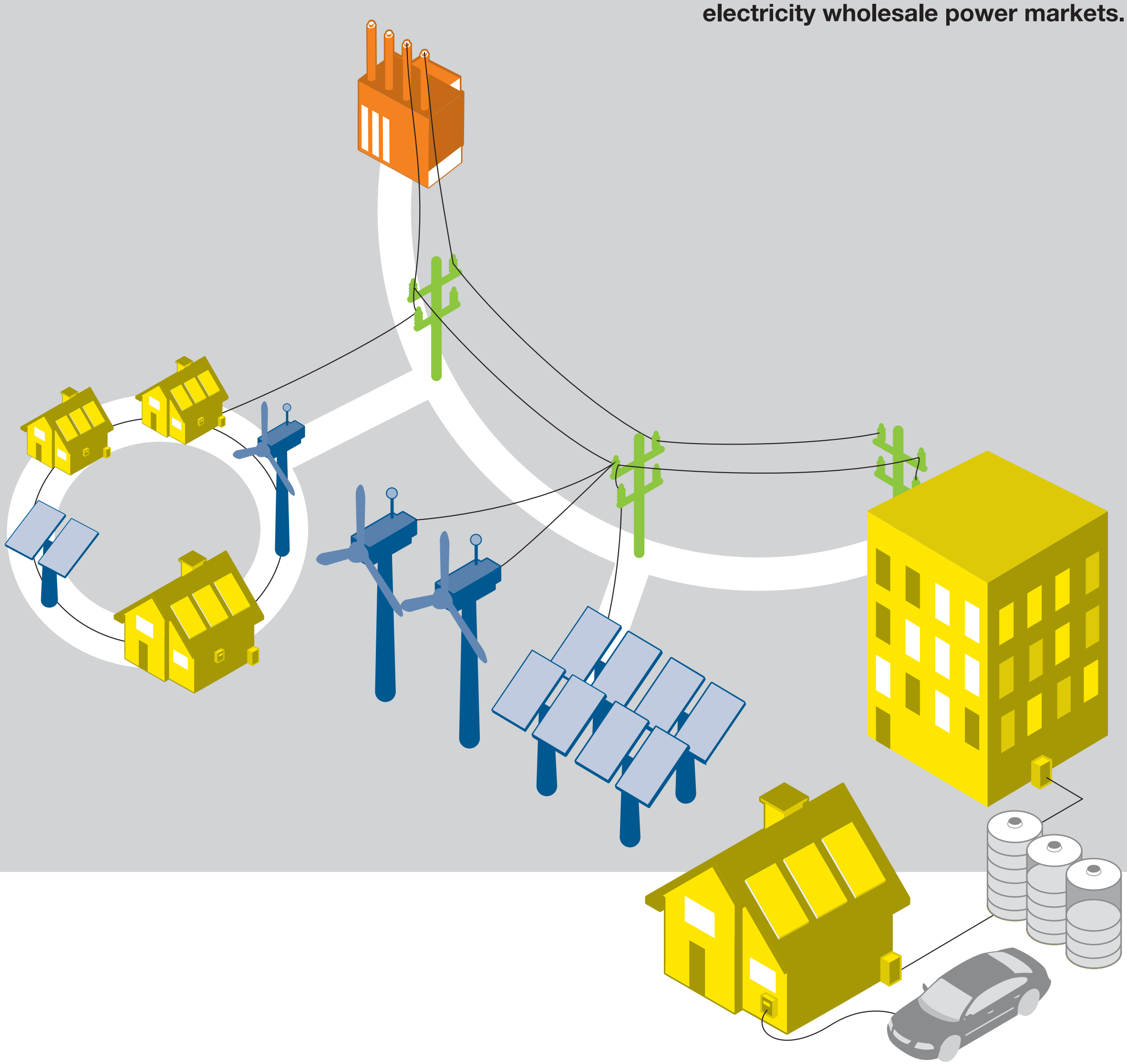
34 Navigant Research, 2014. "Residential Demand Response." Available from http://www.navigantresearch.com/research/residential-demand-response.

35 National Renewable Energy Laboratory, 2013. "Grid Integration of Aggregated Demand Response, Part 2: Modeling Demand Response in a Production Cost Model." Available from http://www.nrel.gov/docs/fy14osti/58492.pdf.

CEA takes a more favourable view. Used properly, demand response replaces only the most marginal, highest cost peaker plants (i.e., plants that run only during times of high demand). That said, market mechanisms must be developed that reward demand response without unduly punishing incumbent utilities. A failure to provide a fair rate of return on capital investments may lead to an underinvestment in generating assets moving forward, which will undermine the long-term sustainability of Canada's electricity system.

IO INNOVATION OPPORTUNITIES: DEMAND RESPONSE

- **Better integrate demand response into network management, including increasing the granularity of control to enable targeted demand response at specific substations or even specific feeders.**
- **Develop the tools and information exchanges that will allow customers to respond to price signals from behind the meter.**
- **Design and test incentive programs that lead to the uptake of grid-side demand response programs.**
- **Evaluate various pricing signals to determine what leads customers to curtail electricity usage during times of peak demand.**
- **Develop and pilot market mechanisms to integrate demand response resources into electricity wholesale power markets.**



Facilitation of Distributed Generation

While renewable electricity generation will continue to grow, it is unclear whether its pace of growth will accelerate or remain relatively modest. Despite this uncertainty, there are clear signals that distributed generation is not a passing trend.

Currently, 1,200 megawatts of solar capacity is connected to Canadian electricity grids—and that amount is growing rapidly each year, increasing by 58 per cent in 2013 alone.[36] The increased solar capacity is being driven by feed-in-tariff contracts, renewable energy standards, environmentally conscious energy consumers and falling costs. According to Natural Resources Canada and the Canadian Solar Industries Association, photovoltaic module prices have declined from $10.70 per watt in 2000 to $0.95 per watt in 2013, falling 17 per cent in 2013 alone.[37]

The wind farm in Prince Township, Ontario is the third largest in Canada.
Photo courtesy of Brookfield Renewable Energy Group.

Canada's wind capacity, meanwhile, is now more than 8,500 megawatts—and it also continues to grow at a rapid pace and in line with international trends. According to the Canadian Wind Energy Association, global wind energy capacity grew by 19 per cent in 2012, with the wind industry installing a record level of 44,711 megawatts of new power.[38] The National Energy Board projects Canadian wind capacity to grow to 16,000 megawatts by 2035, with the largest capacity additions expected to occur in Quebec, Ontario, Alberta, and British Columbia.[39]

Of course, Canadian renewable energy development is not limited to solar and wind: project proponents are adding innovative approaches such as small-scale hydro, biomass, geothermal and marine power to Canada's distributed energy resource portfolio. Taken together, Canada had more than 7,000 megawatts of renewable energy capacity in 2012, accounting for 5.5 per cent of the country's total capacity.[40] As the portfolio expands, distribution utilities will need to develop advanced processes and tools to integrate a greater volume of renewable resources without undermining service reliability.

Germany is widely seen as a world leader in distributed generation; however, the rapid growth of distributed generation in that country has resulted in a situation where policymakers and utilities have had to change interconnection rules, grid expansion plans, connectivity requirements, and wind and solar incentives to better integrate distributed resources.[41] As distributed generation expands in Canada, province-specific solutions to each of these issues will need to be developed, tested and deployed.

36 Y. Poissant and P. Luukkonen, (2013) "National Survey Report of PV Power Applications in Canada, 2014." Prepared by the Canadian Solar Industry Association and Natural Resources Canada, 2013.

37 Ibid.

38 Canadian Wind Energy Association, "Wind Facts". Web. 22 December 2014.

39 National Energy Board, 2013. "Canada's Energy Future 2013: Energy Supply and Demand Projections to 2035." Available from https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2013/2013nrgftr-eng.pdf.

40 Ibid.

41 Electric Power Research Institute, 2013. "The Integrated Grid: Realizing the Full Value of Central and Distributed Energy Resources." Available from http://www.epri.com/abstracts/Pages/ProductAbstract.aspx?ProductId=000000003002002733.

Table 2. The Impact of Motivating Drivers on the Facilitation of Distributed Generation

Driver	Challenge/Opportunity
Reduce emissions	While 80 per cent of Canada's electricity supply comes from non-GHG-emitting sources, there remains an opportunity for distributed renewables to replace retiring coal plants or natural gas peaker plants.[42] There may also be increased export opportunities for renewable energy produced in Canada as environmental regulations tighten in the U.S.
Increase resiliency	If not managed effectively, distributed generation can actually undermine grid reliability and resiliency.
Empower customers	In the U.S., more than 500,000 residential and commercial customers have installed rooftop or ground-mounted solar panels.[43] The market has begun to "pull" toward distributed generation.
Contain costs	At this point, distributed generation is driven more by emissions reductions and customer empowerment than it is by cost reductions for either grid operators or consumers. As distributed generation proliferates, owners who want to maintain a connection to the grid will have to pay their fair share of the fixed infrastructure costs.

Completed in 2010, the Digby Neck Wind Farm supplies up to 10,000 homes.
Photo courtesy of Nova Scotia Power Inc.

42 Statistics Canada, Electric Power and Generation – Annual (CANSIM 127-0007), 2013.

43 Solar Energy Industries Association, 2014. "Solar Market Insight Report 2014 Q2." Available from http://www.seia.org/research-resources/solar-market-insight-report-2014-q2.

INNOVATION OPPORTUNITIES: FACILITATION OF DISTRIBUTED GENERATION

- Develop tools to better integrate distributed generation, including better forecasting methods, more granular feeder operations assessments, and more robust aggregate system impact modelling and controls.
- Further explore the complementary value of energy storage or demand response to distributed generation.
- Implement market and tariff mechanisms that adequately value a "backup" grid connection.
- Establish dispatch controls and "anti-islanding" protection schemes to prevent distributed generation from continuing to supply electricity to a location when power lines are down, thereby reducing risk to utility workers and guaranteeing a high quality of electricity.

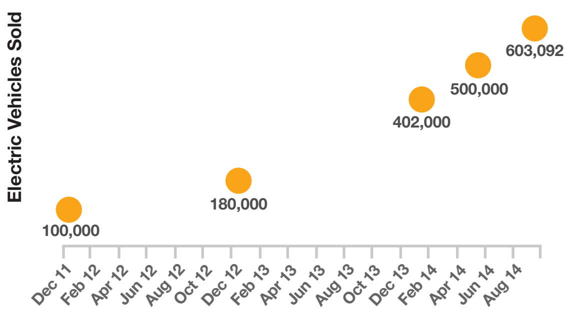
Capital Power Corporation's 105 megawatt Port Dover and Nanticoke Wind project is located in Haldimand and Norfolk Counties, Ontario. The project, which began commercial operations in November 2013, features 58 Vestas V-90 turbines. *Photo courtesy of Capital Power Corporation*.

Facilitation of Electric Vehicles

The transportation sector accounted for almost one-quarter of Canada's total greenhouse gas emissions in 2012.[44] While vehicle emission standards will help bring this number down in the near term, electrifying Canada's light vehicle fleet is the most promising way to drastically reduce the sector's emissions by 2050.

As of early 2015, approximately 10,000 highway-capable plug-in electric vehicles will have been sold in Canada. While this is a long way from having an electric vehicle in every driveway, global sales have now increased to more than 600,000 light duty vehicles over the past 10 years—with the adoption of electric vehicles continuing to accelerate each year (see **Figure 2**).

Figure 2. Total Global Electric Vehicle Sales



Source: http://www.hybridcars.com/global-plug-in-car-sales-now-over-600000

Horizon Utilities' electric vehicle charging station.
Photo courtesy of Horizon Utilities Corporation.

44 Environment Canada, 2014. "Canada's Emission Trends." Available from http://ec.gc.ca/Publications/E998D465-B89F-4E0F-8327-01D5B0D66885/ETR_E-2014.pdf.

Table 3. The Impact of Motivating Drivers on the Facilitation of Electric Vehicles

Driver	Challenge/Opportunity
Reduce emissions	While total emission reductions are ultimately dependent on the supply mix of the electricity used to fuel the vehicle, Canada's electricity mix offers a world-leading opportunity to harness the environmental benefits of switching to electric vehicles.
Increase resiliency	At their current adoption rate, electric vehicles are of no real concern to grid operators. However, if the adoption rate changes significantly over a short period of time, some feeders could be affected. Over the longer term, vehicle-to-grid and vehicle-to-home applications could contribute positively to grid resiliency.
Empower customers	Utilities will not be a roadblock to the adoption of electric vehicles; however, utilities are also not in the best position to directly encourage EV adoption.
Contain costs	Electric vehicles are unlikely to mitigate infrastructure investment needs; however, they do represent a potentially significant new load centre that can help to defray rate impacts.

Horizon Utilities' staff and electric vehicle.
Photo courtesy of Horizon Utilities Corporation.

INNOVATION OPPORTUNITIES: FACILITATION OF ELECTRIC VEHICLES

- **Explore the feasibility of vehicle-to-grid and vehicle-to-home applications.**
- **Develop programming that educates customers about the environmental and operational cost advantages of electric vehicles.**
- **Establish vehicle-charging models that value the natural coordinating role of the distribution utility.**
- **Build operational tools that allow utilities to predict, evaluate and control charging patterns.**
- **Develop programs that support the use of electric vehicles in commercial vehicle fleet.**

Electric vehicle Direct Current fast charging demonstration by BC Hydro. *Photo courtesy of BC Hydro and Power Authority.*

Optimization of Asset Use

Over the next 20 years across Canada, a significant proportion of the following network components will reach or exceed their anticipated end of life. This includes distribution stations, underground cables, manholes, duct lines, padmount transformers, wood poles, overhead conductors, overhead transformers and streetlight standards. Fortunately, Big Data and grid modernization tools such as sensors, integrated distribution communications systems, advanced analytics software and new diagnostic tests allow for increasingly targeted operations and asset management programs, helping utilities maximize asset performance, proactively maintain equipment and optimize replacement strategies.

Advanced monitoring, for example, enables more timely maintenance; more efficient matching of supply and demand from various economic, operational and environmental perspectives; and overload detection of transformers and conductors—all of which help utilities to reduce energy losses, improve dispatch, enhance stability and extend the lifespan of their assets.

A 10-year maintenance of one of our Whitehorse hydro units. *Photo courtesy of Jim Petelski/Yukon Energy Corporation*.

Table 4. The Impact of Motivating Drivers on the Optimization of Asset Uses

Driver	Challenge/Opportunity
Reduce emissions	Optimization of network assets will allow grid operators to integrate an increasing amount of distributed generation without safety or reliability concerns.
Increase resiliency	Maintaining asset health is critical to ensuring Canada's electricity grid continues to operate to a high standard of reliability.
Empower customers	Optimization of asset use is principally focused on grid-side operations.
Contain costs	Optimizing asset monitoring and usage can significantly extend asset lifespan; this results in lower rates to customers than would be the case under age-based asset replacement programs.

INNOVATION OPPORTUNITIES: OPTIMIZATION OF ASSET USE

- **Improve peak load management and energy efficiency through the use of overload detection, phase balancing and volt/VAR control (i.e., managing active power load through voltage controls at the substation level and volt-ampere-reactive [VAR] power load through capacitors at the grid level).**
- **Strengthen distribution system management capabilities such as state estimation, safety management, volt/VAR control, and load forecasting and balancing.**
- **Improve asset health data collection and assessment/ prioritization algorithms.**

Worker makes repairs in residential community. *Photo courtesy of FortisAlberta Inc.*

Fault Detection and Mitigation

While supervisory control and data acquisition (SCADA) and other energy management systems have long been used to monitor transmission systems, visibility into the distribution system has been limited. In fact, many utility customers would probably be surprised to learn of the limited information historically available to grid operators, especially at the distribution level.

As an example, when a blackout occurred customer calls were mapped to define the geographic area affected. This, in turn, allowed utility engineers to determine the lines, transformers and switches involved and what must be done to restore service. On many occasions, a utility's customer care representative would actually ask callers to step outside to visually assess the extent of the power loss in their neighbourhood. It is a testament to the high levels of reliability enjoyed by Canada's electric utility customers that most have never experienced this; however, it is also evidence of an antiquated system.

The end goal is to implement full fault location with isolation and restoration capabilities; however, this will require tying together numerous utility systems—outage management, advanced metering, distribution management, geographical information—and hardening the system so it can withstand more severe weather events.

Fault detection and automated restoration technologies are being developed and are currently being integrated with utility outage management systems; however, they must be piloted by utilities so the potential value of deployment across a full service territory may be assessed.

While storm activity continues to be the biggest threat to service continuity, cyber security threats are on the rise as well. While hackers have traditionally targeted electricity generation and transmission, an automated distribution grid is both a means for grid operators to fix problems and hackers to cause them.

Table 5. The Impact of Motivating Drivers on Fault Detection and Mitigation

Driver	Challenge/Opportunity
Reduce emissions	This driver does not apply in any meaningful way to fault detection and mitigation.
Increase resiliency	While asset optimization will prepare utilities to face extreme weather events, fault detection and mitigation will speed recovery. Resiliency is at this heart of this capability.
Empower customers	Fault detection empowers customers by detecting problems *before* they need to pick up the phone and report them to their utility.
Contain costs	Debate continues as to how much utilities should spend to prepare for extreme weather events. Customers are asked to invest in grid infrastructure as insurance against the significant economic impacts resulting from extended power loss.

INNOVATION OPPORTUNITIES: FAULT DETECTION AND MITIGATION

- Explore ways to better handle call volumes and website traffic during an outage event.
- Improve estimated time to restoration models to better inform customers about outage management and response.
- Improve systems tied to restoration efforts, including field communications, outage management, interactive voice response, SCADA, geographic information systems and distribution automation.

Other Promising Technology Areas

While not as fully featured as the other technology areas discussed in this section, other promising opportunities for innovation include the following:

A view of the interior of BC Hydro and Power Authority's Field energy storage facility.
Photo courtesy of BC Hydro and Power Authority.


A view of the exterior of BC Hydro and Power Authority's Field energy storage facility.
Photo courtesy of BC Hydro and Power Authority.

Storage

Downstream electrical energy storage has often been referred to as the "holy grail" of grid modernization—and for good reason. Energy storage promises to simplify the integration of distributed generation and electric vehicles, mitigate the need for demand response (although overall conservation will remain important), limit periods of asset overload, and keep the lights on when the bulk power system fails. The challenge so far has been to do any of these things economically.

A number of Canadian pilot projects are currently exploring energy storage applications. CanmetENERGY, a department of Natural Resources Canada, has tracked more than $70 million worth of storage projects across the country that are funded in part or in full by various federal and provincial funds.[45] According to CanmetENERGY researchers, the integration of distributed generation, storage and reactive sources that can compensate for fluctuating generation and consumption demand will help produce more robust, cost-saving electricity networks.

While these initial pilot projects are important, now is the time to push energy storage innovation into overdrive across Canada. According to the Brattle Group, the cost of installed electricity storage, which is currently $700–$3,000 per kilowatt-hour, is expected to decline to less than half of that over the next three years.[46] Navigant Research, meanwhile, forecasts that the annual revenue of cell sales for advanced batteries for utility-scale storage applications will grow from $221.8 million in 2014 to $17.8 billion in 2023.[47]

Given these numbers, it is imperative that Canada's electricity utilities and regulators start taking a closer look at the value of specific storage applications in Canada.

45 Natural Resources Canada, 2014. "CanmetENERGY Research Brief: Integrating Electricity Storage Into Smart Grid." Available from http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/canmetenergy/files/pubs/2014-106_EN.pdf.

46 Judy Chang, Johannes Pfiefenberger, Kathleeen Spees, Matthew Davis, Ioanna Karkatsouli, Lauren Regan, James Marshal, 2014. "The Value of Distributed Electricity in Texas: Proposed Policy for Enabling Grid-Integrated Storage Investments." Prepared for Brattle Group, available from http://www.brattle.com/system/news/pdfs/000/000/749/original/The_Value_of_Distributed_Electricity_Storage_in_Texas.pdf.

47 Navigant Research, December 22, 2014. "Advanced Batteries for Utility-Scale Energy Storage." Navigant Research website, available from http://www.navigantresearch.com/research/advanced-batteries-for-utility-scale-energy-storage.

Unmanned Aerial Vehicles

CEA Corporate Utility Members are increasingly interested in using unmanned aerial vehicles (UAVs), or drones, to monitor their assets. Advanced applications allow utilities to map terrain and form an accurate 3D model of the components of their power network and also any surrounding buildings, landscapes and vegetation. Currently, this work is performed predominantly by full-size manned helicopters; UAVs are being touted as a low-cost, safer alternative.

Examples of how UAVs are currently being used by electric utilities include:

- **SaskPower** is testing a $23,000 UAV to survey substations and other assets.[48] Capable of flying for about 25 minutes with a maximum flight path of 1.6 kilometres, the UAV provides SaskPower with visual access to the tops of transformers without having to de-energize them; can fly within six feet of transmission lines, which is close enough for photos to show loose pins and missing bolts; and provides aerial photos during flooding events when some assets may be unreachable by ground travel.
- **San Diego Gas & Electric** was approved by the U.S. Federal Aviation Authority in July 2014 to use UAVs for research, testing and training flights in sparsely populated areas of their service territory.[49] This was the first such approval in the U.S.
- **Iberdola** (Spain) plans to use UAVs to monitor power lines and distributed generation assets such as wind turbines.[50]

Induction Charging

The transformation of the electricity system is often likened to the one experienced by the telecommunications industry, which saw a move from landline telephone systems to cell phones and smart phones. However, while the management of the electricity system and the technologies being powered might change, the physical characteristics of moving power remains the same. Utilities will continue to push electrons through conductive wires from the transmission system into the distribution system.

Induction is the one mainstream technology that can turn this model on its head. Also known as wireless power, induction is the equivalent of replacing the wired Ethernet cable with Wi-Fi—and may eventually allow customers to access electricity "on the go." The current technology is not quite there yet, though. A mobile device charged by induction needs to sit on an induction pad and cannot be used during the charge. Also, charging a device in this way is less efficient than charging by cable, requiring more energy and a longer charge time.

While induction charging is still in its early days, in an increasingly wireless world, it is an area that utilities and regulators simply cannot afford to ignore. Of particular interest is the fact that the market for wireless charging is set to explode over the next few years: revenues from shipments of induction power transmitters and receivers are expected to expand to $8.5 billion in 2018, up from just $216 million in 2013.[51]

48 Mark Melnychuk, "SaskPower Sends in the Drone," Leader-Post, October 15, 2014, available from http://www.leaderpost.com/technology/SaskPower+sends+drone+Video/10289435/story.html.

49 Jeff St. John, "Are Flying Robots the Next Smart Grid Technology Ready to Take Off?" Greentech Media, July 23, 2014, available from http://www.greentechmedia.com/articles/read/flying-robots-for-the-smart-grid.

50 "Iberdola to Use UAVs for Power Lines Monitoring," sUAS News, June 13, 2013. available from http://www.suasnews.com/2013/06/23318/iberdrola-to-use-uavs-for-power-lines-monitoring.

51 Ryan Sanderson, "Wireless Power Report, 2014." IHS Technology. Available from https://technology.ihs.com/438315/wireless-power-2014.

6 APPROACHES FOR FUNDING INNOVATION

REMOVING BARRIERS TO INNOVATION

Employees share their knowledge. *Photo courtesy of Newfoundland Power Inc.*

OVER THE PAST 20 YEARS, CANADA'S ELECTRIC UTILITIES HAVE LARGELY DIVESTED THEMSELVES OF THEIR IN-HOUSE RESEARCH AND DEVELOPMENT (R&D) ARMS. (THERE ARE A FEW EXCEPTIONS, INCLUDING HYDRO-QUÉBEC'S IREQ AND BC HYDRO AND POWER AUTHORITY'S POWERTECH LABS.)

Instead, new technologies are developed by equipment vendors, which are then incorporated into a system managed by utility operators and asset managers. Utilities look to the vendor community for early-stage technological innovation, and then provide controlled grid access to the vendors so their applications can be tested in a real-world environment. Through this relationship, utilities can still help shape the final product to fit a specific need.

Sticking with proven technologies may be the easiest way for Canadian utilities to keep the lights on, but in this new world of grid modernization and increasing customer expectations, "first movers" are required—and they must be incentivized to take on the risk of new technology development, testing and integration.

Collaboration Ecosystems

When done well, collaboration significantly reduces the barriers to innovation. Equipment manufacturers provide the technology, utilities provide the living lab to test the technology, and government partners provide the funding and guidance needed to build a consortium of industry experts to direct the technology's implementation. This kind of collaboration "ecosystem" brings together the broad-based expertise and oversight necessary to ensure project success.

A collaborative approach to innovation sufficiently addresses the lack of in-house R&D capacity as well as the grid access needs of technology developers. It also pools financial and knowledge resources to minimize project risk and spread costs between businesses (both competitive and regulated) and public policy priorities.

The Concentric Model

In August 2014, Concentric Energy Advisors published a discussion paper at the behest of CEA and the Canadian Gas Association.[52] The paper lays out the "gold standard" model for collaborative innovation, which features the following key characteristics:

- **Funding** – The Concentric Model calls for an initial funding level of $3–$5 per customer per year—that is, it is fully ratepayer-funded—with funding authorized for a period of at least three years. Cost recovery is achieved through a dedicated reconciling mechanism (e.g., a variance account).
- **Regulatory oversight and program management** – The majority share of the funding should be spent on collaborative projects, with the minority share spent on internal, utility-specific efforts. Multi-year innovation investment plans need to be subject to regulatory approval and formal stakeholder review, and regulatory guidance should be provided with regard to the criteria used to build the business case justifying innovation activities.
- **Collaborative, innovation-focused entities for gas and electric industries** – A clearinghouse for the key findings and lessons learned emerging out of R&D projects (both successful and unsuccessful) should be established. Regulators and public-interest stakeholders should serve on utilities' Boards of Directors or Advisory Councils to provide substantive direction and oversight.

CEA's mid- to long-term vision is a pooled fund for collaborative innovation demonstration projects. To achieve this vision, however, there will need to be greater alignment between the values and objectives of customers, regulators, policymakers, private industry and regulated utilities. The industry can get started on this today.

52 Stephen Caldwell, Robert Yardley, Jr, and James Coyne. "Stimulating Innovation on Behalf of Canada's Electricity and Natural Gas Consumers, 2014." Available from http://www.electricity.ca/media/ReportsPublications/StimulatingInnovation2014.pdf.

7 RECOMMENDED ACTIONS

ADVANCING THE ELECTRICITY INNOVATION AGENDA IN CANADA

Wind turbines dot the prairie landscape south of Winnipeg. *Photo courtesy of Manitoba Hydro.*

GIVEN THE KEY DRIVERS AND PROMISING TECHNOLOGY AREAS DISCUSSED THROUGHOUT THIS PAPER, CEA PUTS FORWARD FOR CONSIDERATION THE FOLLOWING SEVEN ACTIONS THAT CAN BE TAKEN TODAY TO ENSURE UTILITIES HAVE THE MANDATE AND MEANS TO INVEST IN INNOVATION MOVING FORWARD.

Align Priorities and Goals

While the various drivers and capabilities propelling grid modernization weigh more heavily in some provinces than others, overall there is sufficient commonality that national collaboration is valuable. When it comes to innovation, no one province or country should go it alone.

Provincial regulators can express common priorities and goals through the Canadian Association of Members of Public Utility Tribunals (CAMPUT), and policymakers can do the same through the Council of the Federation's work towards a National Energy Strategy. In both of these forums, CEA hopes participants will advocate for the need to transform Canada's electricity infrastructure, markets and technologies through a long-term, sustained commitment to innovation.

Track Grid Modernization Indicators at a National Level

To support the alignment of key priorities, Canada must have a national approach to tracking key grid modernization indicators such as the amount of distributed generation connected, the number of electric vehicles sold, the number of smart meters in service, and the number of customers engaged in demand response programs. This data will help proactively identify areas that will require technical and regulatory solutions.

CEA has entered into discussions with Natural Resources Canada's CanmetENERGY clean energy research program about conducting a regular smart grid metrics survey for Canadian utilities. Such a project would:

- Create a "dashboard" of national smart grid data;
- Enable data-backed insights and best practices to emerge;
- Inform R&D and demonstration funding; and,
- Provide a useful public reference for discussions with regulators and the public.

CEA and CanmetENERGY continue to explore this initiative, working toward an initial report in late 2015.

Look internationally

Similar to the need to aggregate regional priorities into a national grid modernization program, Canada has the opportunity to learn from other countries that are aggressively pursuing innovation, spurred on by their own domestic drivers (in many cases, emissions reduction commitments, energy security concerns and cost containment).

Through the International Energy Agency's International Smart Grid Action Network (ISGAN), Canadian regulators, policymakers and utilities have access to the metrics that can serve as signposts of global trends. Canadian participation in the ISGAN program is managed through the CanmetENERGY program; support for these activities should remain strong moving forward.

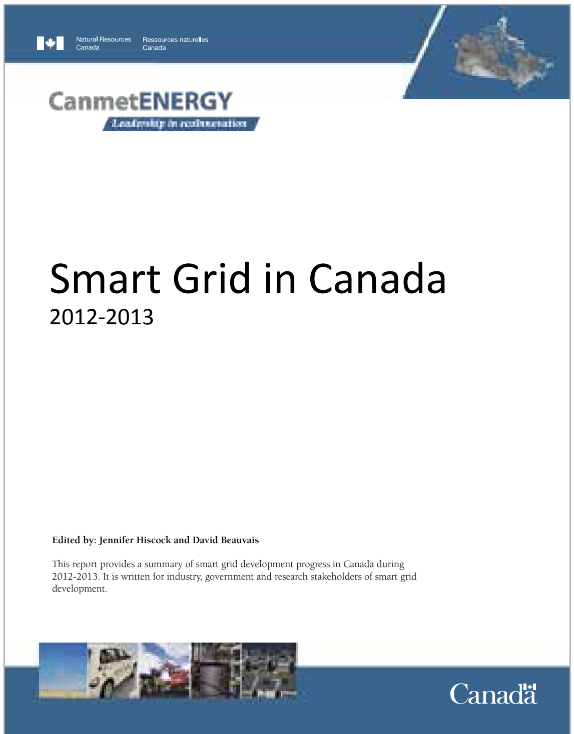
Pool Innovation Funding to Mitigate Risk and Spread Out Rewards

Utilities should maintain a balanced innovation portfolio, which includes funding for projects that address utility-specific needs, enable provincial priorities and/or support a common national vision. To mitigate risk, innovation funding for projects that support provincial or national policy objectives should be fully or partially matched by public funds, largely due to the fact that the benefits resulting from such projects will be more broadly applicable than those of a small-scale, utility-specific demonstration project.

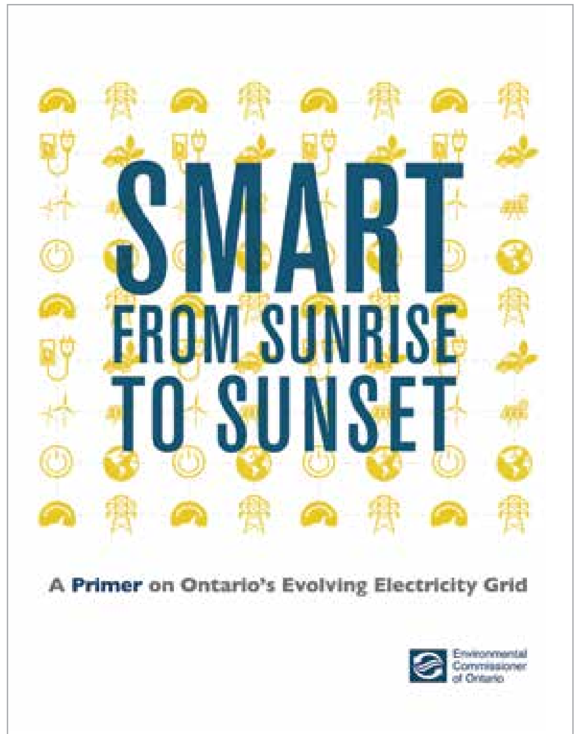
Share Lessons Learned

Whether funding is pooled or individual utilities take on individual projects, all stakeholders (including regulators, policymakers, utilities and customers) benefit from the key learnings from both successful and failed demonstration projects.

CEA contributes to Natural Resources Canada's regularly updated *Smart Grid in Canada* report, which does a good job of collecting information on existing smart grid projects and initiatives. More must be done to identify key learnings and share them broadly. CEA is open to further discussions on how this can best be facilitated.



Smart Grid in Canada report cover, used with permission.



Smart from Sunrise to Sunset: A Primer on Ontario's Evolving Electricity Grid cover, used with permission.

Lock in Knowledge by Developing Codes and Standards

As technologies develop, demonstration projects move forward and lessons learned are distilled, knowledge gained should be formalized into codes and standards that guide utility technical planning, operating practices and work methods.

Participation in standards development requires two increasingly scarce resources: staff time and travel budgets. It is critical, however, that utilities continue to support the development and maintenance of Canada's system of codes and standards, in partnership with the Standards Council of Canada and the relevant standards development organizations.

Keep Customers Informed and Engaged

Whether a specific technology, process or program targets reliability, safety, environmental sustainability or cost control, at its core, grid modernization is about protecting and improving the value of electricity service. It is critical to communicate this to customers early and often.

The Environmental Commissioner of Ontario (ECO) has produced a customer-friendly report titled *Smart from Sunrise to Sunset: A Primer on Ontario's Evolving Electricity Grid*, which is intended to help policymakers and the public alike become more familiar with the concept and potential of the smart grid.[53] CEA fully supports public-facing efforts such as this, and applauds the ECO for taking the initiative to drive the dialogue forward in the public sphere.

53 Environmental Commissioner of Ontario. 2014. "Smart from Sunrise to Sunset: A Primer on Ontario's Evolving Electricity Grid." Available from http://www.eco.on.ca/uploads/Reports%20-%20Background,%20Discussion,%20Roundtable/2014%20Smart%20Grid%20Primer.pdf.

8 CONCLUSION

BC Hydro power line technicians work to ensure power. *Photo courtesy of BC Hydro and Power Authority.*

IN THE FACE OF DETERIORATING INFRASTRUCTURE AND INCREASING CUSTOMER EXPECTATIONS, INNOVATION IS CLEARLY NEEDED IF THE ELECTRICITY SECTOR IS TO ENSURE A RELIABLE SUPPLY OF POWER, CONTAIN COSTS AND REDUCE THE ENVIRONMENTAL IMPACT OF ITS OPERATIONS.

Fortunately, a number of promising technologies have emerged that will help utilities meet these goals and more—and the time to pursue those opportunities is now.

Policymakers and funding agencies should use this paper to inform funding decisions for new pilot projects, allowing them to focus their investments on the top priority areas identified by Canada's electricity sector: demand response; distributed generation; electric vehicles; asset optimization; and fault detection and mitigation.

Utilities can use this paper in a similar way as they continue to explore new technologies, systems and processes to prepare their networks for 2050 and beyond. Of course, there needs to be a recognition that such a focus on innovation, the kind that will help transform utilities from traditional commodity providers to suppliers of a diverse range of energy services, will require a much more customer-centric, agile and risk-adverse mindset, along with a re-invented organizational structure to match. While it is a vastly different culture than the one required for their day-to-day operations, utilities will not (and should not) be deterred from pursuing innovation. In fact, the sector has already shown that it is clearly committed to innovation—and for any utility with a promising pilot project applicable to any of the priority areas outlined in this paper, the Canadian Electricity Association is willing to provide the necessary support in making connections to industry to help them get it off the ground.

GRID MODERNIZATION GOES WELL BEYOND TECHNOLOGICAL IMPROVEMENTS; IT'S ABOUT TRANSFORMING THE ELECTRIC ECOSYSTEM AS A WHOLE.

In the end, grid modernization goes well beyond technological improvements; it's about transforming the electric ecosystem as a whole. As such, *collaboration* will be the most important factor in realizing *Vision 2050*. Every stakeholder has a part to play—utilities, customers, suppliers, regulators, policymakers—and it will be critical that they all work together to fully determine the future of Canada's electricity sector.

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