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Smart Grid in Canada

2014

Canada

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Smart Grid in Canada

2014

Lead author: Jennifer Hiscock

This report provides a summary of smart grid development progress in Canada in 2014. It is written for industry, government and research stakeholders of smart grid development

Canada

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Introduction

This report is the fourth in a series of reports and is intended to be a useful reference for smart grid practitioners in Canada and for international smart grid stakeholders interested in learning more about smart grid activities in Canada. It is published by Natural Resources Canada's (NRCan) CanmetENERGY research centre, which manages the Canada Smart Grid Action Network (CSGAN). Members of this network have contributed to this report, which highlights the current status of smart grid progress in Canada in 2014. It includes provincial and regional activities, identifies projects under way, and explores elements of how smart grids will be implemented throughout electricity systems in Canada and in similar electricity markets.

The 2014 report follows the same format as the 2012–2013 report[1] with an overview of:

- CSGAN activities
- Smart grid deployment in Canada
- Smart grid demonstration projects and innovation in Canada
- Outlook for smart grid in Canada

The 2014 report is generally written as an update to the 2012–2013 report, with a technology feature on cyber security and storage activities. Readers should refer to the 2011–2012 report[2] for an introductory overview of smart grid activities in Canada and the 2010–2011 report[3] for a more detailed industry overview of smart grid in Canada.

[1] CanmetENERGY, *Smart Grid in Canada 2012-2013, 2013*: http://www.nrcan.gc.ca/smart-grid-in-canada-201213

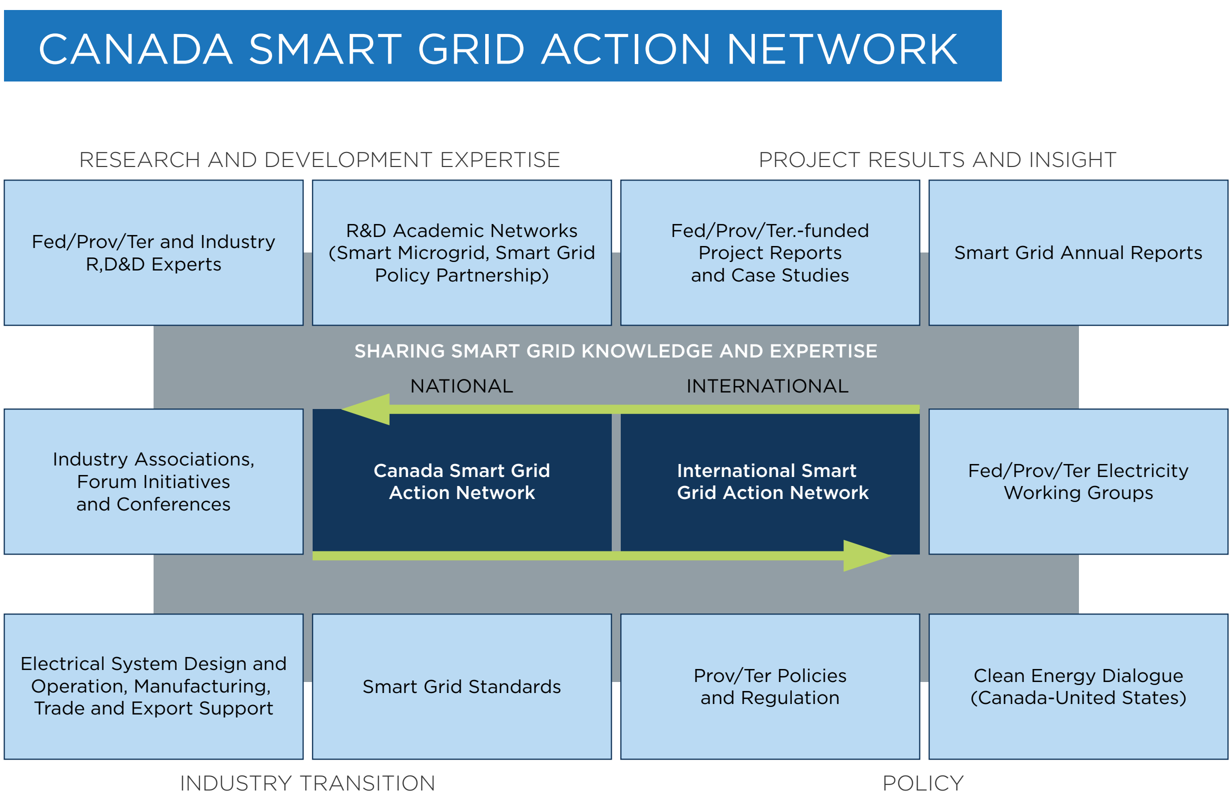
[2] CanmetENERGY, *Smart Grid in Canada 2011-2012, 2012*: http://www.nrcan.gc.ca/energy/publications/sciences-technology/renewable/smart-grid/6167

[3] CanmetENERGY, *Smart Grid in Canada – Overview of the Industry in 2010, 2011*: http://www.nrcan.gc.ca/energy/publications/sciences-technology/renewable/smart-grid/6133

Developing Smart Grids in Canada

CanmetENERGY established the CSGAN to connect national smart grid stakeholders and to leverage opportunities under the International Smart Grid Action Network (ISGAN)[4] for Canadians. Key enablers for smart grids in Canada are connected through CSGAN to bring together the various knowledge domains associated with smart grid development, namely research and development expertise; publicly and industry-funded project results and insight; industry transition efforts and experiences; and policy insights. The group meets during the year with members from provincial and territorial energy ministries, federal departments, members of academia, and utility and industry associations to share knowledge and discuss regional- and national-level smart grid issues. Highlights of smart grid initiatives during 2014 from CSGAN members and the jurisdictions they represent are included in this section.

Figure 1. Canada smart grid knowledge domains connected through the Canada Smart Grid Action Network



[4] ISGAN is a network under the International Energy Agency described later in this report.

Measuring progress in smart grid development

Figure 2 illustrates the deployment of different smart grid applications in Canada. With the additional procurement pilots for grid services from storage in 2014 in Ontario (described later in this report), a seventh category for distributed energy storage for peak shaving and ancillary services was added to this figure. These seven applications are defined more comprehensively in the Appendix of this report and include:

- Advanced Metering Infrastructure (AMI)
- New Rate Options (NRO); different rate structures or plans
- Demand Response (DR)
- Distributed Energy Storage (DES)
- Self-Healing (SH) Grids
- Microgrids (MG)
- Voltage and Var (reactive power) Control (VVC)

The level of deployment of these applications is indicated for each province and territory as either being under study or planned (1/3 pie chart), partially deployed or in a state of ongoing deployment (2/3 pie chart), or broadly deployed across the province or territory (whole pie). The deployment levels are indicated according to the publicly announced projects or programs and by nature are somewhat subjective. The following subsection describes a smart grid metrics pilot that was completed in 2014 and subsequent efforts to capture more quantitative data to compliment the deployment progress captured in Figure 2.

With each province and territory having a unique combination of infrastructures, system assets, and supply and demand characteristics, smart grid applications will not be deployed in the same order and same manner across the country. The number of projects in a province or territory indicates levels of technology deployment, but should not be interpreted to rank one province or territory above another in terms of smart grids. For example, some electric utilities will never broadly deploy self-healing grid technologies within their service territories, but rather choose to apply them only to certain parts of the system. Local and regional priorities will determine which applications are invested in more.

SMART GRID DEPLOYMENT IN CANADA 2014

67% OF METERS ARE SMART METERS	5 GW IN DISTRIBUTED GENERATION	> 5,050 ELECTRIC VEHICLES	1,850 CHARGING STATIONS

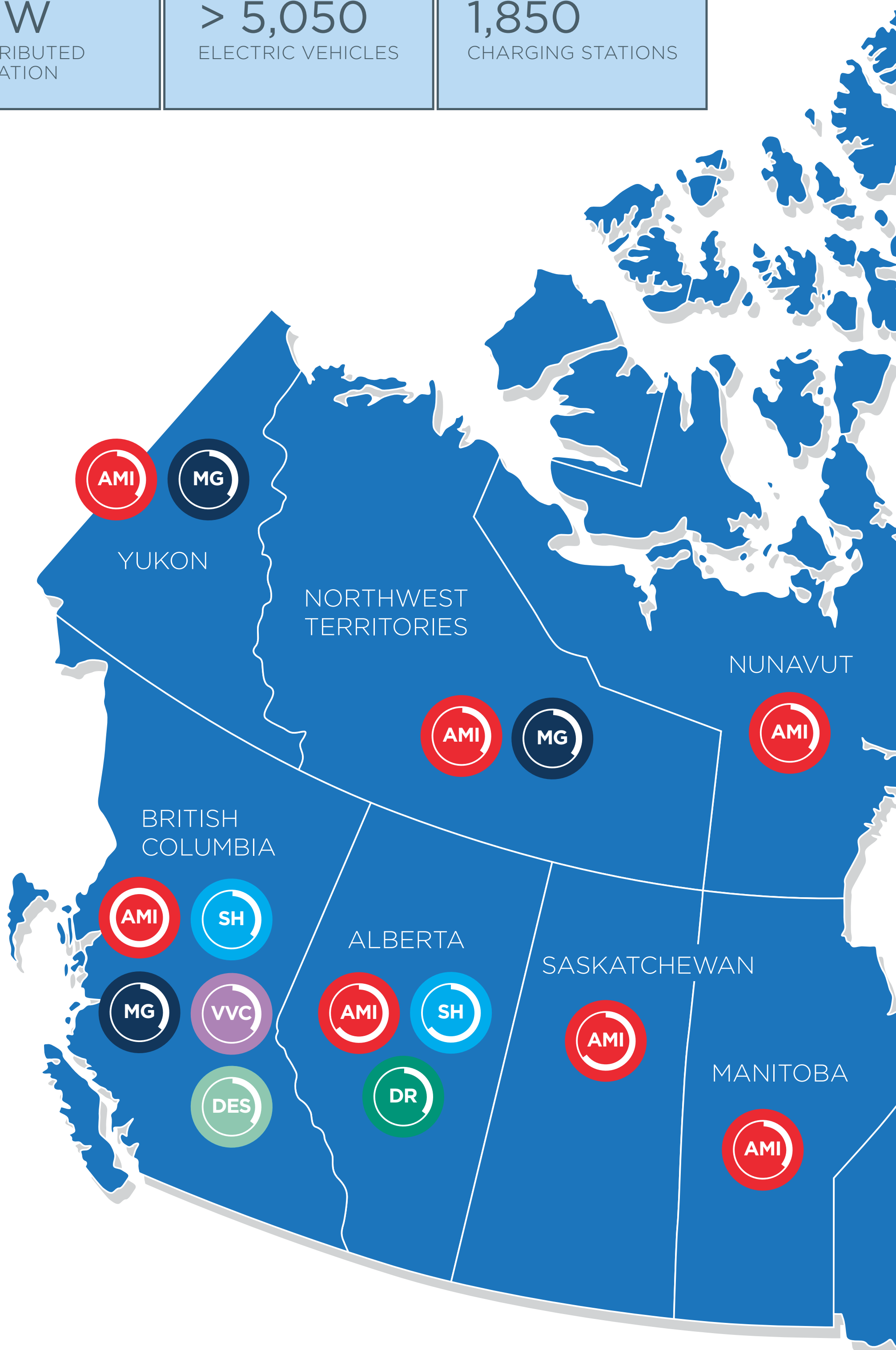


Figure 2. Smart grid deployment in Canada 2014

AMI ADVANCED METERING INFRASTRUCTURE

NRO NEW RATE OPTIONS

DR DEMAND RESPONSE FOR LOAD SHIFTING OR ANCILLARY SERVICES

DES DISTRIBUTED ENERGY STORAGE FOR PEAK SHAVING OR ANCILLARY SERVICES

SH SELF-HEALING GRIDS (fault detection, isolation and restoration)

MG PLANNED ISLANDING OR SMART MICROGRIDS (fault detection, isolation and restoration)

VVC VOLTAGE AND VAR (REACTIVE POWER) CONTROL

UNDER STUDY / SMALL PILOTS

PARTIAL / ONGOING DEPLOYMENT

BROAD DEPLOYMENT

Smart grid metrics pilot

Over 2013–2014, electric utilities from Ontario, Quebec and New Brunswick, along with industry and provincial government partners, participated in a metrics pilot to explore how smart grid deployment and benefits could be measured and presented publicly in Canada. The goal was to determine useful figures that could:

- Put Canada more visibly on the global smart grid innovation map; and
- Facilitate conversations across technology, policy, program and regulatory domains about supporting strategic investments in smart grid capabilities and promoting further innovation that leads to social, environmental and economic benefits to Canadians.

A survey of potential deployment and benefit indicators for various application and benefit metrics was developed and piloted by the participants. The pilot also conducted an analysis exercise from the data collected to explore how the relationship between various technology applications and benefits might be presented publically. This exercise provided encouraging results and positive feedback, but also exposed a number of concerns about oversimplifying the development of smart grids to one of deploying physical infrastructure alone. Presenting survey results would require interpreting the data with respect to the local context and acknowledging the surrounding dynamics of policy, regulatory and market development that influence the impact of smart grid technologies and capabilities.

The result of the pilot was a refined survey of smart grid application and benefit indicators. NRCan signed an agreement with the Canadian Electricity Association (CEA) to complete an appropriately scaled effort to survey smart grid deployment and benefits across Canada.

International collaboration on smart grids

In 2014, ISGAN entered its fourth year. Canada continued to actively participate in the network's activities and hosted network members from 23 countries with governments, agencies and industry federations in Montréal in October 2014. The international meetings and workshops[5] allowed Canada to showcase innovation in smart cities and the integration of electric vehicles, as well as facilitate discussions about how the international network activities can support national initiatives of member countries.

Select products with Canadian content include:

- Publication of the 2014 *Smart Grid Drivers and Technologies by Country, Economies, and Continent*. Canada is represented in this updated biannual report, available on the ISGAN website.[6]
- Publication of the *Spotlight on Demand Side Management* case book, which included Canada's PowerShift Atlantic project in a case study. The case book is available online through the ISGAN website.[7]

[5] ISGAN Montreal workshop presentations and reports: http://www.iea-isgan.org/?c=198/204/226

[6] ISGAN 2014 Report on Smart Grid Drivers and Technologies: http://www.iea-isgan.org/force_down_2.php?num=3

[7] ISGAN Demand Management Case Book: http://www.iea-isgan.org/?c=5/112/367&uid=1300

- Canada's PowerShift Atlantic Virtual Power Plant Project presented a webinar through the Clean Energy Solutions Center. The presentation slides and a recording of the presentation are available online through the Clean Energy Solutions Center website.[8]

The *Spotlight on Demand Side Management* case book was presented to the fifth Clean Energy Ministerial held in April 2014 in Korea. It includes 12 cases of country experience with various demand management projects. The cases represent several different approaches. Some cases rely on price signals, while others respond to grid conditions and system requests, and some rely on customer behaviour, while others rely on automated system controls. While there is no dominant design identified at this point, there does seem to be three general operational models:

- Customer behavioural response to electricity price signals or system-forecasted conditions
- Automated response to system conditions either through customer-programmed energy management systems or signals to specific customer loads
- Customer response managed through a third-party aggregator to respond to electricity markets or system conditions

The PowerShift Atlantic case study was included in the case book, which includes an overview of the project along with current results and lessons learned. Project lead NB Power presented on the project design, system architecture and experience engaging customers in smart grid functionality through a virtual power plant.

Provincial and territorial support for smart grids

Regions of Canada that are most active in deploying smart grid technologies and developing innovative solutions are supported by provincial and territorial policy and programs. Each province's and territory's approach to smart grids differs according to its assets and needs, but the more active regions are responding to economic drivers coupled with quality of service or environmental drivers. A selection of highlights from the provinces and territories is included here.

CANADIAN PREMIERS

The Canadian Energy Innovation Summit was convened in February 2014 by Premier Wynne of Ontario as chair of the Council of the Federation, which is a council made up of all 13 provincial and territorial premiers in Canada. There was strong consensus during the summit on the need to:

- Increase inter-jurisdictional cooperation on energy;
- Expand partnerships between government and the private sector, particularly in financing;
- Capitalize on opportunities in global markets; and
- Recognize the benefits of energy innovation in Aboriginal communities.

Examples of innovation in smart grids and renewable micgrogids were discussed amongst broader energy issues, highlighting this growing sector as a beneficiary or partner to the above efforts. A summary report for the summit is available on the MaRS Discovery District website.[9]

[8] PowerShift Atlantic presentation slides: https://cleanenergysolutions.org/training/powershift_atlantic_smart_grid
Presentation video from the Clean Energy Solutions Center, YouTube channel: http://tinyurl.com/CESC-PowerShift-video

[9] Canadian Energy Innovation Summit: Summary Report:
http://www.marsdd.com/mars-library/canadian-energy-innovation-summit-summary-report/

ALBERTA

With the third-largest total wind capacity and as host to some of the largest solar resources in the country, Alberta continues its smart grid focus on methods of integrating intermittent renewable generation:

- The Alberta Electric System Operator (AESO) released a discussion paper on the integration of storage[10] in May 2014. The discussion paper followed four connection requests: two for battery storage, one for compressed air and one for pumped hydro storage, to be able to operate within the interconnected system and participate in the Alberta Market.
- The Alberta Innovates – Energy and Environment Solutions division is the lead government agency for advancing environmental technology innovation in Alberta.[11] Late in 2014, it launched a two-phase request for proposals for next-generation energy storage technologies.[12] With $2 million available for proof of concept, development, demonstration projects or feasibility analyses, the call for proposals offers projects up to $250,000 or support for up to 75% of eligible project costs. Recipients can be located outside of Alberta, but the project must offer value to Alberta's electricity system.

BRITISH COLUMBIA

British Columbia's (B.C.) smart grid technology efforts are clustered around advanced metering infrastructure, microgrids, reliability and electric vehicle integration.

- Most customers in B.C. are served by BC Hydro, which completed its smart meter rollout in 2013. The remaining B.C. customers with analogue meters will receive smart meters in 2015. FortisBC began the testing and back-end systems integration to support a smart meter rollout to all of its customers. Smart meter installations began in the fall of 2014 for FortisBC. The rollout accommodates customers with an opt-out clause should they not wish to have digital meters, which is in compliance with the ruling by the British Columbia Utilities Commission.

Schneider Electric – Xantrex opened a new state-of-the-art microgrid lab in Burnaby, B.C. With 15,000 ft^2, it is one of the largest of its kind in North America and is capable of testing equipment reliability under extreme environmental conditions.

- B.C.'s public charging stations now total more than 550. PowerTech labs monitors more than 350 of those charging stations and reported that in 2014, the number of charging sessions doubled over the previous year.[13] The province is also continuing to expand the evCloud[14] project, launched as part of the BC Smart Infrastructure Project with support from the province of B.C., NRCan, and BC Hydro. With more than 70,000 charging events recorded at the time of writing this report, evCloud estimates that the province has prevented more than 423,000 kg of CO_2 from being emitted.

[10] Alberta Electric System Operator discussion paper on the integration of storage: http://www.aeso.ca/downloads/Energy_Storage_Integration_Discussion_Paper.pdf

[11] Alberta Innovates – Energy and Environment Solutions: http://www.ai-ees.ca/

[12] Alberta Innovates RFP for Next-Generation Energy Storage Technologies: http://albertainnovates.ca/media/22192/ai-ees_energy_storage__2millionfunding.pdf

[13] Plug In BC article on Electric Vehicle Charging: http://pluginbc.ca/charging-station-use-doubles-last-year/

[14] BC evCloud project: https://www.fleetcarma.com/evcloud

NEW BRUNSWICK

New Brunswick's smart grid development is guided by three key objectives: keeping energy prices stable and low; improving electricity system reliability; and demonstrating environmental responsibility. New Brunswick smart grid efforts are supporting the province and surrounding Maritime region to integrate greater levels of intermittent renewable generation, predominantly from wind.

- New Brunswick Power, as the project lead for PowerShift Atlantic, was awarded by the Peak Load Management Alliance for its "Innovative Application of Technology."[15] This award joins two others the project has already won for its progress toward sustainability and wind integration in the region.

NOVA SCOTIA

Nova Scotia launched an Electricity System Review[16] for the province, reaching out to experts from across the country and internationally and engaging local citizens and stakeholders to determine priorities for modernizing its electricity system and creating opportunities for future innovation. This would build upon the progress it has already made with integrating wind power into the electricity systems and enabling customers to participate in energy markets through distributed generation supported by the province's Community Feed-in Tariff Program and opt-in Time-of-Day rates. The Electricity System Review has produced a number of technical studies, which are available on its website.[17] The consultation and planning process is expected to release preliminary results in 2015.

ONTARIO

Ontario continues to stand out internationally for its leadership in developing and deploying smart grid technologies. The province has a trifold strategy for using smart grid to enable more active participation in energy management from customers, improving system performance and generating economic growth through developing and commercializing smart grid technologies and services. The province committed to realizing further benefits from smart grid capabilities, which was outlined as part of its Long-Term Energy Plan released at the end of 2013.[18] Many of the highlights included here stemmed from the Long-Term Energy Plan.

The Advanced Energy Centre was launched in Ontario as a public-private partnership with support from the Ontario Ministry of Energy, MaRS Discovery District, Cap Gemini and Siemens. The centre was created to support the adoption of innovative energy technologies in Ontario and Canada, while also fostering international market opportunities for Canada's energy innovations.

- A 50-MW procurement for storage was included in the Long-Term Energy Plan and administered by the Independent Electricity System Operator (IESO) and the Ontario Power Authority for procurements of storage to provide regulation and voltage support and to resolve capacity issues, respectively.

[15] PowerShift Atlantic Wins Peak Load Management Award: http://www.peakload.org/?page=Awards11

[16] Nova Scotia Electricity System Review: http://energy.novascotia.ca/electricity/electricity-system-review

[17] Nova Scotia Electricity System Review Studies: http://energy.novascotia.ca/electricity/electricity-system-review/electricity-review-phase-i

[18] Ontario Long-Term Energy Plan: http://www.energy.gov.on.ca/en/ltep/

- The Ontario Ministry of Energy's Smart Grid Fund announced 17 additional projects to bring the total number of supported projects to 28.[19] The Smart Grid Fund supports projects in the area of behind the meter services, data analytics, electric vehicle integration, energy storage, grid automation and microgrids.

Schneider Electric partnered with Ryerson University's Centre for Urban Energy to create the first university-based Smart Grid Laboratory. With initial support from the Ontario Smart Grid Fund, the lab is set up to be a collaborative facility for industry and academia research, development and testing of smart grid algorithms, products and systems.

- Almost two thirds of Ontario's customers have access to their electricity data in a standardized format, allowing them to better understand and manage their own consumption, with 10 local distribution companies having adopted the Green Button Standard.[20] London Hydro and Hydro One have embarked on the next phase of the standard with a Connect My Data pilot to allow customers to integrate their data into a local energy management tool that they can program to manage their own consumption. The results of this pilot are expected in 2015.

The MaRS Data Catalyst team worked with Ontario utility, government and industry stakeholders to bring the standard to Ontario. The team is now engaging with utilities, industry associations and stakeholders across Canada to assist in their learning and adoption of the Green Button Standard to streamline reporting and energy management processes.

QUEBEC

Quebec has extended its smart grid efforts in the last year to include a province-wide roll-out of smart meters and investments in storage projects. This is added to achievements noted in earlier reports with electric vehicle integration and volt and var optimization.

- Hydro-Québec continued its province-wide smart meter roll-out in 2014, totalling almost 2.3 million meters installed as of November 2014. The installation has gone very smoothly with less than a 0.5% refusal rate from customers. In light of this, the provincial regulator had HydroQuébec reduce its opt-out fees, initially set to deter customers, to a level that covers only the added costs of supporting the analogue meters.
- The province's first northern wind-storage project was announced for the Raglan Mine. Led by Tugliq Energie Co. in partnership with Glencore Group, the project is supported by NRCan and the province of Quebec. In its first month of operation, the project is expected to reduce the mine's diesel consumption by 140,000 litres. The province is expecting to take lessons learned from this project to consider projects for its Inuit communities, which are also dependent on diesel.

Hydro-Québec announced a joint venture with Sony to conduct research and develop utility-scale storage systems. The research facility will be located in Varennes, Quebec.

[19] Ontario Smart Grid Fund Projects: http://www.energy.gov.on.ca/en/smart-grid-fund/smart-grid-fund-projects/

[20] Green Button Standard in Canada: http://greenbuttondata.ca/

SASKATCHEWAN

Saskatchewan continued its smart meter roll-out in 2014, but the initiative was reversed by order of the government after 8 of the more than 100,000 meters installed had caught fire. A review by the Crown Investments Corporation of Saskatchewan found that safety issues related to the particular smart meters that were being installed should have been more carefully considered.[21] Three independent expert firms were hired to investigate the issue and made recommendations regarding the management of process safety and of infrastructure projects such as a smart meter roll-out.

Industry support for smart grids

Industry associations and networks are contributing to the vision and development of smart grid technologies, policies and markets in Canada. Individual industry leadership and contributions are highlighted in boxes throughout this report.

CANADIAN ELECTRICITY ASSOCIATION

Founded in 1891, the CEA is the national forum and voice of the evolving electricity business in Canada. Early in 2014, the CEA prepared an industry vision for how Canada's electricity systems can evolve into modern systems that deliver the maximum value for customers while contributing to a low-carbon economy.

Entitled *Vision 2050*,[22] the report centres on four key recommendations:

1. Accelerate innovation and customer management of energy
2. Implement financial instruments for carbon reduction
3. Enable electric vehicles
4. Expand collaboration across borders

Of the $350 billion required in electricity infrastructure investment over the next two decades estimated by the Conference Board of Canada,[23] the CEA expects that about 20% of that would be in distribution infrastructure, and about 13% in transmission infrastructure. Most smart grid technologies would fall within the distribution infrastructure category with certain investments in transmission infrastructure, making the estimated investment opportunity to apply smart grid technologies in the order of $70 billion.

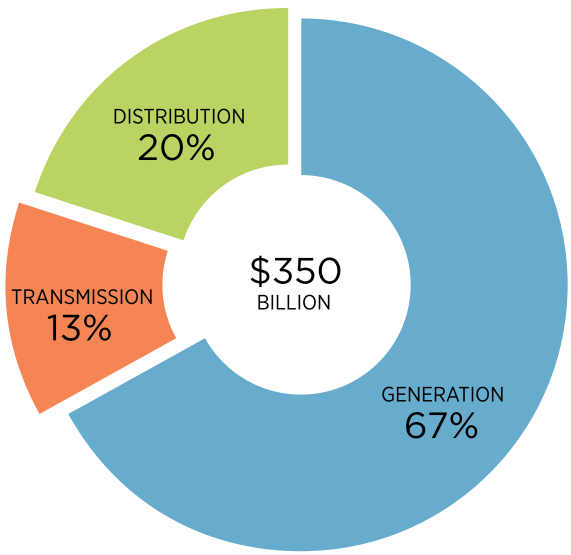
The CEA added its voice to calls for a North American price on carbon to be established in order to allow market forces to incentivise carbon reductions. With close to 80% of Canada's electricity generation coming from non-emitting resources, it argued that Canada's fleet would be well positioned to compete in a low-carbon market.

[21] Saskatchewan Crown Investments Corporation Review of Smart Meter Installation: http://www.saskatchewan.ca/government/news-and-media/2014/october/27/smart-meter-review

[22] Canadian Electricity Association Vision 2050: http://powerforthefuture.ca/vision-2050/

[23] Conference Board of Canada, *Shedding Light on the Economic Impact of Investing in Electricity Infrastructure, 2012*: http://www.conferenceboard.ca/e-library/abstract.aspx?DID=4673

Required distribution and transmission infrastructure investment where most smart grid technologies can be applied



Of the $350 billion estimated infrastructure investment into Canada's electricity sector, approximately $70 billion is expected in distribution infrastructure where most smart grid applications offer value.

SMARTGRID CANADA

SmartGrid Canada is an industry association committed to promoting the Canadian smart grid nationally and internationally. Among its numerous activities, the organization acts as a national expert through the Global Smart Grid Federation and organizes trade missions to promote the industry. SmartGrid Canada brings together smart grid stakeholders annually for the largest smart grid conference in Canada.

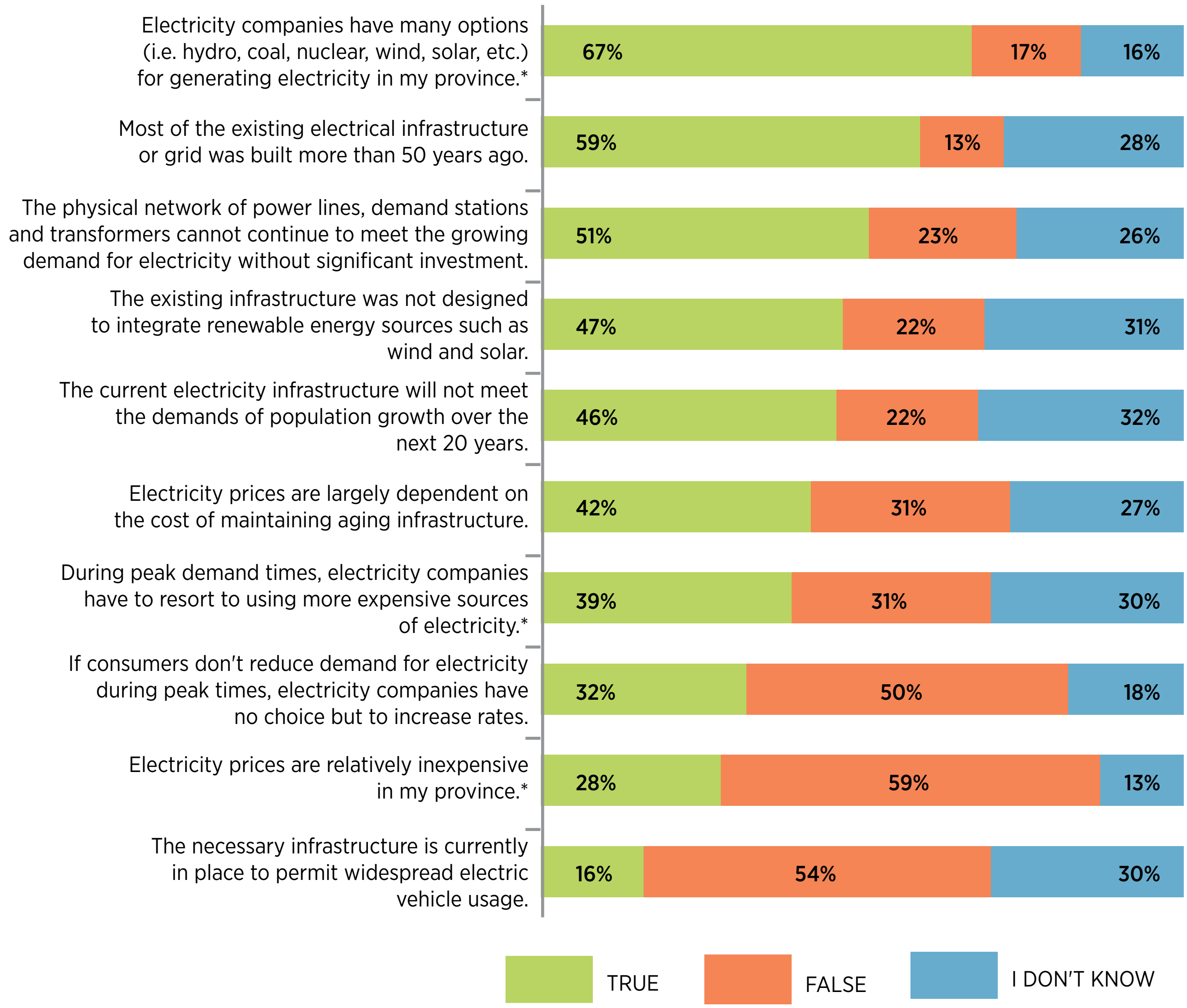
During its annual conference, SmartGrid Canada released the 2014 edition of the Smart Grid Consumer Research Survey. The results of just over 2,000 survey responses indicated a similar and generally quite favourable consumer perception of smart grid technologies compared to previous years. The survey also explored the customer's belief in statements describing the drivers for smart grid, which are illustrated in Figure 3.

The survey results showed no major variation in responses across provinces, except for those three statements marked with an asterisk in Figure 3. For the statement "Electricity companies have many options (i.e. hydro, coal, nuclear, wind, solar, etc.) for generating electricity in my province," respondents from Saskatchewan and Ontario were noted to have 83% and 78% belief in that statement to be true. For the statement "During peak demand times, electricity companies have to resort to using more expensive sources of electricity," respondents from Manitoba were noted to have only 20% belief in that statement to be true. For the statement "Electricity prices are relatively inexpensive in my province," respondents from Canada's hydro provinces agreed more with that statement, with 44% of respondents from Quebec and B.C. and 53% of Manitoban respondents believing that statement to be true.

The annual Smart Grid Consumer Research Survey provides a useful sign post for monitoring the evolution of customer perceptions of smart grid in Canada. The full report will be made available on the SmartGrid Canada website.[24]

[24] SmartGrid Canada website: http://sgcanada.org/

Figure 3. Customer understanding of smart grid concepts



Average customer belief in statements describing typical smart grid priorities and drivers were true for their province. Results reproduced from the SmartGrid Canada 2014 Smart Grid Consumer Research Survey.

**Some provincial variation in responses to the statements.*

Smart grid cyber security

As more of the world's systems become digital, so do the risks that they must manage. Building smart grid systems involves adopting real-time monitoring and control that rely on a variety of communications systems designed to operate in local conditions and provide high-quality services. All levels of government in Canada have a responsibility to manage cyber security issues in partnership with private sector institutions. The federal government has initiated and is participating in a number of efforts to coordinate the government and industry response to cyber security threats. Canada has been involved in the North American effort to maintain the security of power systems since the beginning, with increased activity since the government created a Cyber Security Task Force[25] in 2006 to build a strategy for protecting critical infrastructure, including electricity infrastructure.

In 2010, Canada released its five-year Cyber Security Strategy[26] built on three pillars of securing government systems, critical infrastructure and Canadian citizens' online activities. The second pillar of the strategy applies to electricity systems and includes application to smart grid infrastructure. Activities under this pillar broadly include system monitoring and tracking of cyber incidents, knowledge-sharing, creating frameworks, guidelines and processes for responding to incidents, developing industry capacity development to deal with incidents, and investments in science and technology to secure and protect Canada's infrastructure.

The National Energy Infrastructure Test and Training Centre was established at NRCan in collaboration with several other federal partners including Defence Research and Development Canada and Public Safety Canada.[27] The centre provides facilities for research and training for operators of Supervisory Control and Data Acquisition (SCADA) systems and Industrial Control Systems. Facilities were designed for equipment testing and research, and training is continually being developed for industry professionals on performing cyber security assessments and developing and institutionalizing response methods to cyber attacks. The centre has been in operation since early 2013. The centre expanded its course focus to include smart grid systems in 2014. The centre's offerings continue to evolve, having received positive reviews from participants to date.

[25] Public Safety and Emergency Preparedness Canada Report on Plans and Priorities, section on cyber security: http://www.tbs-sct.gc.ca/rpp/2006-2007/psepc-sppcc/psepc-sppcc02-eng.asp

[26] Canada's Cyber Security Strategy 2010-2015: http://www.publicsafety.gc.ca/cnt/rsrcs/pblctns/cbr-scrt-strtgy/index-eng.aspx

[27] Report on the development of the National Energy Infrastructure Test and Training Centre: http://pubs.drdc-rddc.gc.ca/BASIS/pcandid/www/engpub/DDW?W%3DSYSNUM=539278&r=0

Efforts under the Canadian Cyber Security Strategy are complemented by additional activities led by the Government of Canada, the North American Electric Reliability Corporation (NERC) and the CEA. The Canadian Cyber Incident Response Centre[28] (CCIRC) was created to coordinate efforts at the provincial, territorial and municipal level in partnership with private-sector institutions in Canada's international counterparts. The CCIRC provides:

- Advice and support to prepare for and mitigate cyber events;
- Technical advice and support to respond to and recover from targeted attacks; and
- Access to trusted fora for information sharing and collaboration, in particular for organizations that are part of the Critical Infrastructure Sector, including electric utilities.

The CCIRC services offer guidelines and best practices to be referenced by the provincial and territorial plans for adopting cyber security standards and institutionalizing procedures such as those under Ontario's Cyber Security Forum[29] management by the IESO.

Because Canada's grids are connected with the United States grids, North American-wide standards and procedures are developed and adopted. To keep pace with the ever-evolving nature of cyber threats, NERC created an industry-wide grid security exercise, GridEx,[30] which brings together industry and government agencies from the United States, Canada and Mexico. GridEx was designed to strengthen the North American capability to respond to and recover from severe events. It uses timely real-world scenarios to exercise the readiness of existing cyber and physical security plans and procedures. In 2013, more than 2000 players from 234 organizations responded to a 1.5-day simulation of a coordinated cyber and physical attack on the bulk power system. The results of the 2013 GridEx will be built into the scenario design for GridEx in 2015.

The greatest cyber security risks to the electricity system are those that are posed to the bulk system and have far-reaching consequences, which makes cyber security a generation and transmission concern first. For smart grid technologies that are applied mainly on distribution systems, similar guides and best practices will be developed to improve the government and industry capabilities to protect, respond to and recover from cyber security incidents. While efforts are dispersed and vary across Canada, as more organizations become involved with Canada's cyber security efforts, our understanding and management of cyber security issues will continue to improve.

[28] Canadian Cyber Incident Response Centre: http://www.publicsafety.gc.ca/cnt/ntnl-scrt/cbr-scrt/ccirc-ccric-eng.aspx

[29] IESO Cyber Security Forum: http://www.ieso.ca/Pages/Participate/Stakeholder-Engagement/Standing-Committee/Cyber-Security-Forum.aspx

[30] NERC GridEx: http://www.nerc.com/pa/CI/CIPOutreach/Pages/GridEX.aspx

Energy storage in smart grids

Distributed energy storage is an illustration of the degree of evolution that electricity systems are undergoing in the Western World to become smart grids. Managing supply to meet demand in real time has been the distinguishing principle of electricity system design from its beginning. Canada's hydro power reserves have offered the ability to store energy that can be called upon to respond to forecasted shifts in demand from season to season and night to day in the bulk power system. With the advance of smart grids, Canada is seeing storage technologies integrated into the electricity system for reasons other than providing bulk power shifting. Providing the capability to respond over a range of time, power and energy ratings, distributed energy storage systems can be integrated into an electricity distribution system to provide a variety of different services. Represented by a growing number of technologies, distributed energy storage systems are a heterogeneous group of technologies that are challenging the original premise under which energy markets, operating schemes and the overall electricity systems were designed.

eCAMION's 500 kW/ 250 kWh community energy storage project with Toronto Hydro

CHARACTERIZING THE PROBLEM

The International Energy Agency (IEA) considered the potential for storage globally in smart grid applications in *Technology Roadmap – Energy Storage* released in 2014.[31] The overview of the many benefits that storage can offer and the technologies that are being developed to offer them covers many of the technologies and applications being researched and developed within Canada. The problem to which the IEA roadmap responds is the need to limit the rise in average global temperatures from greenhouse gas (GHG) emissions. To this end, the IEA anticipates a need for more than 310 GW of storage globally by 2050 to enable the required level of renewable generation and system efficiency, assuming a decrease in system prices over time. The roadmap provided an annex of successful pilots around the world, including Canada's 500 kW/250 kWh community energy storage project by eCAMION and Toronto Hydro, in operation since late 2013. The roadmap concluded with a series of recommendations geared around further developing the technologies, systems and markets in order to reduce costs and capture the value for services rendered. Ontario's 50-MW storage procurement initiative was referenced as an example of progressive policy supporting the development and integration of storage technologies into smart grids and energy markets.

[31] IEA Energy Storage Roadmap: http://www.iea.org/publications/freepublications/publication/technology-roadmap-energy-storage-.html

The IEA's *Technology Roadmap – Energy Storage* used a systems approach to optimize for GHG reductions with the integration of storage, as opposed to focusing on methodologies for cost reductions and performance improvements for specific technologies. It identified scenarios and activities required by stakeholders to minimize the global average temperature increases to 2°C by 2050. In order to meet that target, the grids require a certain amount of flexibility to support greater penetrations of intermittent renewable energy and greater system efficiencies. The IEA modelled the daily requirements of electricity systems in the United States, Europe, China and India and proposed that 310 GW of storage would be able to deliver those benefits, provided that per MWh costs came down. The model factored in storage technologies once their projected costs declined to match the current per MWh costs of combined cycle gas turbines providing similar services over the life of the project.

DEVELOPING SOLUTIONS

Provincial planners and system operators supporting energy storage development are responding to many of the same drivers found internationally. The existing challenges of reducing emissions and meeting increasing renewable energy targets, reducing energy losses, and increasing reliability in grid-connected and remote off-grid systems all provide opportunities for energy storage in Canada. The support for storage technologies is notable for its contribution to innovation and new technology development, as well as market development and technology deployment. The growth of the sector, particularly in Ontario and increasingly in Alberta, is in many ways a testament to the confluence of storage's potential to address the key challenges listed above with supportive policy via a variety of provincial and federal programs intended to provide grid solutions and support local economic development. Key among them are those supported by:

- Ontario Centres of Excellence (academic research and industry partnerships)
- Natural Sciences and Engineering Research Council (academic research and industry partnerships)
- National Research Council (research)
- Natural Resources Canada (research and demonstrations)
- Ontario Ministry of Research and Innovation (demonstrations)
- Sustainable Development Technology Canada (demonstration and pilots)
- Alberta Innovates – Energy and Environment Solutions (technology development and demonstration)
- Ontario Ministry of Energy (policy direction, demonstration and pilots)
- MaRS Cleantech (business development, venture funding)
- Ontario Energy Board's Smart Grid Advisory Committee – Storage Working Group (regulatory development)
- Ontario Independent Electricity System Operator – 2012 Alternative Technologies for Regulation Procurement Pilot (demonstration, market development)
- Alberta Electric System Operator – Energy Storage Working Group (market integration)

BC Hydro battery at remote substation to improve reliability

Many of these players have afforded a substantial amount of attention and investment in distributed energy storage technologies over the last 10 years. In that time, NRCan's CanmetENERGY has tracked more than $73 million of public funding for over $187 million in demonstration and pilot project value of storage projects across the country by various federal and provincial funds. This is in addition to research by universities, the National Research Council and CanmetENERGY[32] into the next generation of energy storage design, manufacturing and controls that will integrate storage technologies into more efficient, reliable and resilient grids.

In Canada, storage technologies are being piloted and deployed in systems to provide demand-side services, such as peak shaving and load shifting, and supply-side services, such as back-up power and generation-smoothing for intermittent renewable generation from wind and solar photovoltaic. They are also providing system services such as frequency regulation and voltage control, typically managed at only a few points along the system, such as substations and generators, but now potentially available at any point throughout the network where storage is located. A number of new storage projects have recently come online and been contracted for smart grid applications, creating a diverse energy storage technology portfolio in Canada. Many are battery storage projects, but there are also flywheel and hydrogen storage systems. Examples provided below illustrate a variety of applications including in remote and urban communities, renewable energy support, and frequency regulation:

- BC Hydro completed a demonstration of a sodium sulphur NaS battery to improve reliability for an outage-prone community in the Rocky Mountains, which provides backup power during outages and peak shaving during high demand periods.
- eCAMION completed a lithium ion battery community energy storage project with Toronto Hydro that provides load-shifting services for the grid and arbitrage services for the community recreation centre.
- Temporal Power has flywheels providing 2 MW of frequency regulation services under a contract with NRStor to the Ontario IESO under its 10-MW pilot program.
- RES Canada is also providing 4 MW of frequency regulation services from battery storage under the IESO pilot.
- Hydrogenics' electrolyzer and fuel cell technology, along with a flywheel and Electrovaya's Li-ion battery storage, has been contracted to supply Quebec's first northern wind-storage project, announced for the Raglan Mine.

[32] CanmetENERGY Research Brief: Integrating Electricity Storage into Smart Grid: https://www.nrcan.gc.ca/energy/offices-labs/canmet/publications/smart-grid/16697

One defining characteristic of many of the energy storage systems being developed and demonstrated in Canada is that they have the ability to behave both as a controllable load and a generator. This allows storage to provide supply and demand services to balance the system—a dual-characteristic that was not built into the way the electricity systems and energy markets are regulated and managed. This, along with the fact that storage can provide so many different services that benefit multiple players in the system, has yielded an array of storage technology and storage system characteristics that can be optimized for a range of specific conditions and use cases, with no dominant design appearing at this stage. With so many potential applications and associated business cases in electricity markets not yet capturing the full value offered, the sector's ability to achieve economies of scale through production has been constrained. Consequently, many energy storage research, demonstration and pilot projects in Canada have the objective of determining the value added to the system in addition to the technical learning and development.

SECTOR GROWTH AND MARKET INTEGRATION

Along with these demonstration and pilot projects, there has been increased industry activity and mobilization. Energy Storage Ontario[33] was formed as the first energy storage-only alliance in Canada. The non-profit membership-based organization is based in Ontario, but also includes members from across Canada. Energy Storage Ontario's mission is to advance the energy storage industry through collaboration, education, policy advocacy and research. There have also been a number of international projects and partnerships announced for Canadian storage companies such as those in the United States,[34] Europe[35] and the Caribbean.[36] The joint venture between Sony and Hydro-Quebec to develop utility-scale storage technologies provides an example of a model for collaboration between an electric utility and the private sector.

As of 2014, the AESO had received four connection requests: two battery, one compressed air and one pumped-hydro storage project. The AESO Work Group on energy storage released a discussion paper on the integration of storage[37] in May 2014 as a follow-up to the issue identification paper released in 2013. The discussion explored priority issues for connecting energy storage to the system and facilitating its market entry. The top three priority issues were developing operating requirements, determining tariffs and developing requirements for operating reserves considering energy storage characteristics.

Following Ontario's Long-Term Energy Plan commitment to include 50 MW of energy storage resources into procurement processes, the IESO competitively procured 33.54 MW[38] of ancillary services from five proponents to

[33] Energy Storage Ontario website: http://www.energystorageontario.com/

[34] Eguana residential solar energy storage project in Hawaii: http://www.eguanatech.com/images/pdf/2014-12-16_Eguana%20Strikes%20Multi-Year%20Supply%20Contract%20Corrected.pdf

[35] Hydrogenics project with E.ON in Germany: http://www.hydrogenics.com/about-the-company/news-updates/2013/08/29/e.on-and-swissgas-begin-commercial-operations-at-power-to-gas-facility-in-germany-using-hydrogenics-technology

[36] Hydrostor partnership in Aruba: http://www.newswire.ca/en/story/1247453/hydrostor-announces-partnership-for-underwater-energy-storage-in-aruba

[37] Alberta Electric System Operator discussion paper on Integration of Storage: http://www.aeso.ca/downloads/Energy_Storage_Integration_Discussion_Paper.pdf

[38] Ontario IESO storage procurement: http://www.ieso.ca/Documents/Pages/Ontario%27s-Power-System/Backgrounder-Energy-Storage-July_25.pdf

complete the first phase of the procurement focused on grid reliability services. Successful vendors will be contracted to provide:

- Regulation service that acts on a second-to-second basis to match generation to demand and helps correct variations in power system frequency; and/or
- Reactive support and voltage control that are needed to maintain voltages and support the flow of electricity along power lines.

The IESO's phase 1 request for proposals was oversubscribed, with approximately 400 proposals for a potential 35 MW. Proposals had a series of criteria to meet, including the ability to build and certify facilities within 30 months, with proposed contract terms for 10 years or less. In an effort to learn as much as possible while integrating new technologies into the system, the IESO set a goal to procure the broadest range of technologies. The successful proposals in phase 1 of the procurement include batteries, flywheels, thermal storage and hydrogen storage.

Phase 2 of the IESO energy storage procurement (formerly under the Ontario Power Authority) is now underway and will have a different focus from that of phase 1, aiming to satisfy longer-term system needs, such as capacity support and renewable integration. At the time of writing, the IESO is undergoing the evaluation of applications submitted to the request for qualifications, with the aim of selecting those that will be qualified to participate in the request for proposals stage that will run in early 2015.

Canada's electricity storage activities are notable because of the diversity of technologies and applications represented. Projects demonstrated in Canada will provide local solutions, but will also provide solutions for electricity systems around the world. As reflected in smart grid strategies across the country, Canada offers a valuable testing ground for the development of technologies such as energy storage needed globally to reduce fossil fuel dependence and GHG emissions from energy.

Table 1. Successful proponents and technologies for the Independent Electricity System Operator energy storage procurement

Proponent	Technology	Capacity (MW)
Canadian Solar Solutions Inc.	Battery	4.00
Convergent Energy and Power LLC	Battery Flywheel	12.00
Dimplex North America LTD	Thermal	0.74
Hecate Energy	Battery	14.80
Hydrogenics Corp.	Hydrogen	2.00

Smart Grid Innovation in Canada

Smart grid projects

Smart grid research and development (R&D), demonstrations and pilots in Canada continued to tell a story of government support, utility leadership, industry innovation and evolving markets. Demonstration and pilot projects provide critical opportunities for technical learning, but almost more importantly, they provide insight into the non-technical barriers to commercializing, scaling or replicating the solution. Moving from technical demonstrations to market pilots and procurement exercises is an encouraging move that Canada witnessed for storage technologies in Ontario and Alberta announced in 2014 by their electricity system operators.

Figure 4 highlights publicly funded demonstration and pilot projects across the country, with 22 new projects added in 2014. Figure 4 also includes smart grid projects funded through the Conservation Fund in Ontario administered by the IESO, which were not captured in the 2012–2013 edition of this report. This brings the total number of publicly funded demonstration and pilot projects to 72 in Canada since 2005. The vast majority of these projects have been funded in the last five years.

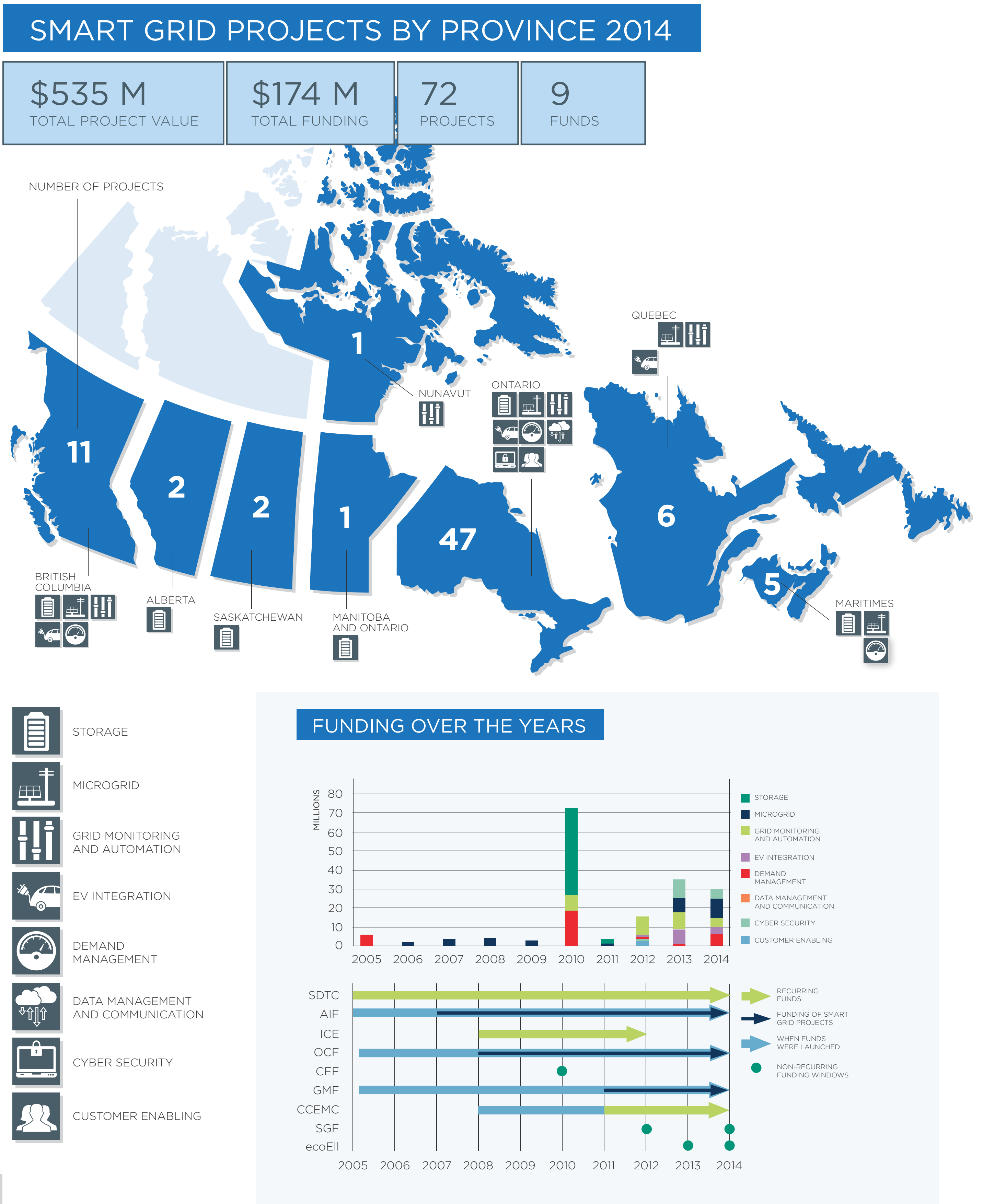
In total, Figure 4 captures more than $174 million in government support for demonstration and pilot projects worth more than $523 million (nominal) in total project value. These projects were supported from nine different funds: five funds either administered federally or seeded by federal funds and four from funds administered by provincial governments, agencies or provincial corporations. About 70% of the total funding comes from federal funds; however, about 60% of the number of projects identified have been funded by provincially administered funds.

BC Hydro Field substation battery controls

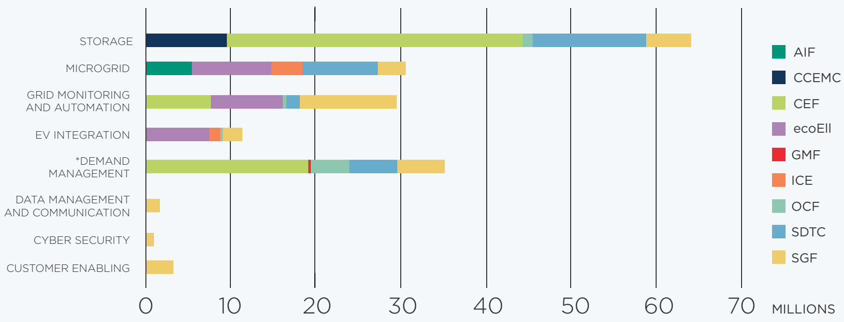
The projects were categorized into seven different categories, with 90% of the funding going toward storage, demand management, grid monitoring and automation, and microgrid projects. Most of the remaining funding went to electric vehicle (EV) integration projects. Finally, there are a handful of demonstration projects related to smart grid data in the categories of data management and communications, cyber security and customer-enabling projects such as home energy management systems.

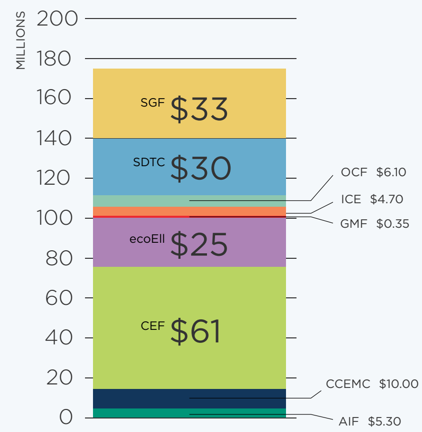
Over half of the demonstration and pilot projects are led by smart grid companies in Canada. Canadian utilities lead roughly one fifth of the projects, but utilities both large and small are participating in almost all of the projects in Figure 4. This year's report also identified universities playing a significant role in the demonstration space in addition to the ongoing research described in the following section. Approximately one tenth of all projects have been led by universities in partnership with industry and utilities.

Figure 4. Publicly funded smart grid demonstrations and pilots in Canada

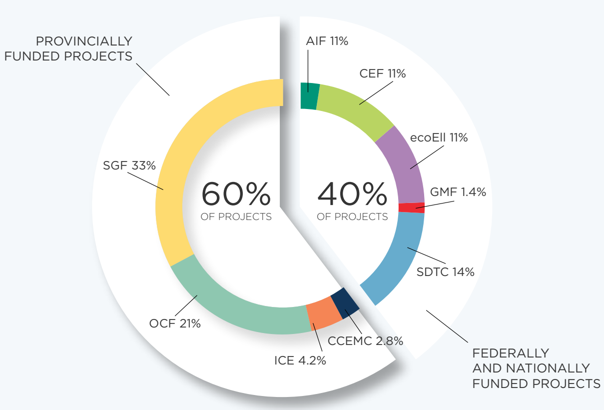


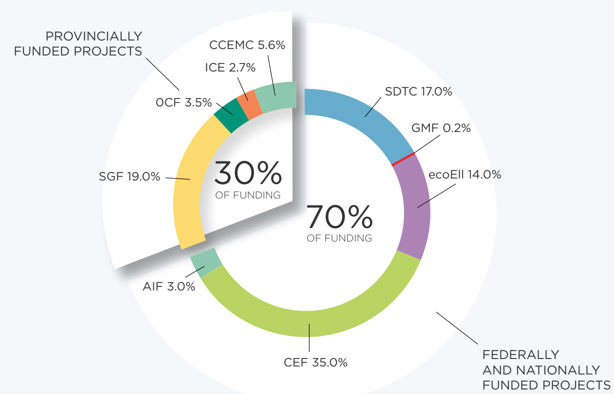
FUND COMPARISON



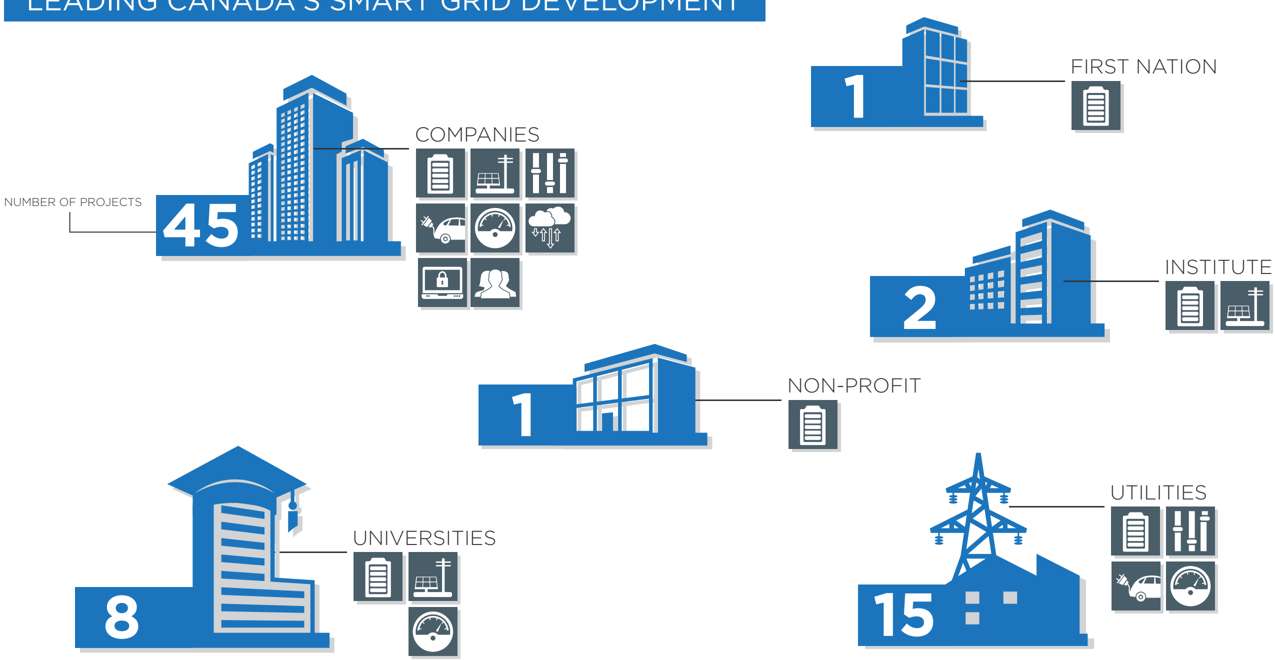


THE MOST FUNDING COMES FEDERALLY,
WHILE PROVINCES FUND THE MOST PROJECTS.





LEADING CANADA'S SMART GRID DEVELOPMENT



Only half of the funds presented are continuing with periodic application windows, while the other half have been fully allocated with no indication of being recapitalized. Thus far, over 70% of the funding for smart grid demonstrations has been accessed through single or short-term funding announcements by federal and provincial governments. The benefits of predictable and recurring funding programs for sector growth are broadly recognized, but these funds typically cater to products and systems much closer to commercialization. This gives some indication of the stage of development of many of the innovative smart grid products and businesses being developed in Canada and the maturity of the market in general. Given the relative infancy of this domestic and global smart grid market, we hope to continue to see new projects in the early innovation and demonstration phases, with many of the current products and businesses moving further toward commercialization.

The nine funds represented in Figure 4 have provided the direct support, but they are not the only sources of support for the smart grid industry. Other indirect supports such as the Scientific Research and Experimental Development (SR&ED)[39] tax incentives to offset research expenses, and industry support for business development and research, such as the Industrial Research Assistance Program (IRAP)[40], provide influential for innovating businesses in Canada. The Funding Portal[41] launched in 2014 tracks government funding programs in Canada, including those eligible for smart grid projects.

Smart grid research clusters

Canada's smart grid R&D is being connected more closely with industry, leading to nearer-term demonstrations and product development. The recent creation of several microgrid test labs and smart grid test labs in partnership with utilities, universities and industry is evidence of that. Canada has long been recognized amongst the OECD[42] (Organisation for Economic Cooperation and Development) countries for its strengths in research, which is attracting smart grid companies to form and innovate within Canada. Canada currently has two research networks dedicated to smart grid development, connecting researchers in the natural sciences and social sciences, while training the next generation of skilled leaders in this field.

Canada now has five dedicated microgrid test centres in operation or under development:

- **BC Institute of Technology, Burnaby, B.C.**
- **Schneider-Xantrex, Burnaby, B.C.**
- **Power Stream, Vaughn, Ont.**
- **Canadian Solar Inc., Guelph, Ont.**
- **TechnoCentre éolien, Rivière-au-Renard, Que.**

NSERC SMART MICROGRID NETWORK

The NSERC Smart Microgrid Network (www.smart-microgrid.ca) is in its fifth and final year, bringing together academia, industry and government for R&D of the components of smart microgrids. Contributing to transforming Canada's electricity grid, this collective endeavor continues to develop the microgrid sector capacity by:

[39] Scientific Research & Experimental Development Tax Incentive Program: http://www.cra-arc.gc.ca/txcrdt/sred-rsde/menu-eng.html

[40] Industrial Research Assistance Program: http://www.nrc-cnrc.gc.ca/eng/irap/index.html

[41] The Funding Portal http://thefundingportal.com/

[42] Organisation for Economic Co-operation and Development, Canada Data: http://www.oecd.org/canada/

- Training personnel ready to meet the new needs of industry;
- Conducting collaborative research to develop microgrid solutions in electric power engineering and communications;
- Providing evidence and insight to address policy-making, system planning and regulatory issues;
- Acting as a resource of information for the public, industry and government; and
- Providing business development opportunities by working with the network's industry partners to translate R&D into real-world, marketable products and solutions for utilities and their suppliers.

Since it began, this network has trained more than 80 students. In the past year alone, its researchers have produced more than 55 journal and conference papers and presented their research in key forums such as CIGRE Canada in Toronto and the Smart Grid Canada Conference/Roadshow in Montréal. Year 2014 saw enhanced cross-team collaborations and new and strengthened bonds with non-academic partners and industry. New domestic and international partnerships have also been developed, including with the RWTH Aachen University E.ON Energy Research Center in Germany.

As the network wraps up its mandate, it has undertaken the major task of compiling its findings from the past five years into unified models and design and performance tools into packages for specific use cases, making it easier for stakeholders to find the information they need. As it makes these final strides, the network welcomes opportunities to work with new or existing partners to share the knowledge it has helped develop over the past five years.

SSHRC SMART GRID POLICY DIMENSIONS RESEARCH PARTNERSHIP

Created in 2012, "Unlocking the potential of smart grids: A partnership to explore policy dimensions" entered into its third year of programming. This research network, supported by the Social Sciences and Humanities Research Council (SSHRC) of Canada, brings together researchers from five Canadian universities to investigate the policy and other social dimensions of smart grid development and deployment. Joining the researchers are representatives from eight utility, government, business and civil society organizations and partners at three universities in the United States. The network has engaged eight graduate students in the projects thus far.

In May 2014 at its annual workshop, the partnership reviewed progress following its first two years and agreed on plans for its final two years. Presentations examined regional political and policy developments (focusing on B.C., Ontario and Quebec), customers' attitudes toward plug-in EVs, media representations of smart grid positions and framings, a Summerside, Prince Edward Island, case study and analyses of United States stakeholders' perspectives. The coming year will see continued detailed investigation of the various different regional locations (as well as relevant cross-comparisons), of utility control charging, of resilient communities and of issues associated with renewable energy integration. Additional details, including presentations from the workshop, may be found at the partnership's website.[43] Further information may also be obtained from either of the partnership's lead investigators,[44] Prof. James Meadowcroft, Carleton University, and Prof. Ian Rowlands, University of Waterloo.

[43] SSHRC Smart Grid Policy Research: http://tinyurl.com/SG-Partnership

[44] James Meadowcroft: james_meadowcroft@carleton.ca; Ian Rowlands: irowlands@uwaterloo.ca

Smart Grid Outlook

The outlook for smart grids in Canada is influenced by the dynamics of a number of related sectors and can be considered in comparison to Canada's clean tech sector as a whole. Policy drivers for smart grid development in Canada identify some of the key market sectors whose dynamics will influence the growth of smart grids. Those drivers vary regionally across Canada but are chiefly the integration of renewable energy, grid reliability and resiliency, system efficiency, managing aging infrastructure and enabling customer participation in the electricity system.[45]

It is worth noting the recent growth in renewable energy in Canada when considering the business environment and prospects for the smart grid industry. Clean Energy Canada published a report this year[46] that found that the renewable energy growth from wind, solar and run of river biomass increased by 93% over five years (2009–2013). At the time of writing this report, that total number has surpassed 10 GW, with 9.6 GW coming from wind[47] and approximately 1.5 GW coming from solar[48] alone.

Another driver for smart grid development is with the electricity customers who support smart grid development through electricity rates, further support innovation through taxes, and increasingly are directly supporting smart grid market development through their own investments and purchases. From 2014 to 2015, Canadian consumers are projected to spend $0.66 billion and $0.79 billion, respectively, on smart home systems, devices and software, or approximately $48 per household according to Zpryme Research & Consulting.[49] This exceeds the $39 per household estimate for consumers in the United States.

[45] ISGAN 2014 Report on Smart Grid Drivers and Technologies: http://www.iea-isgan.org/force_down_2.php?num=3

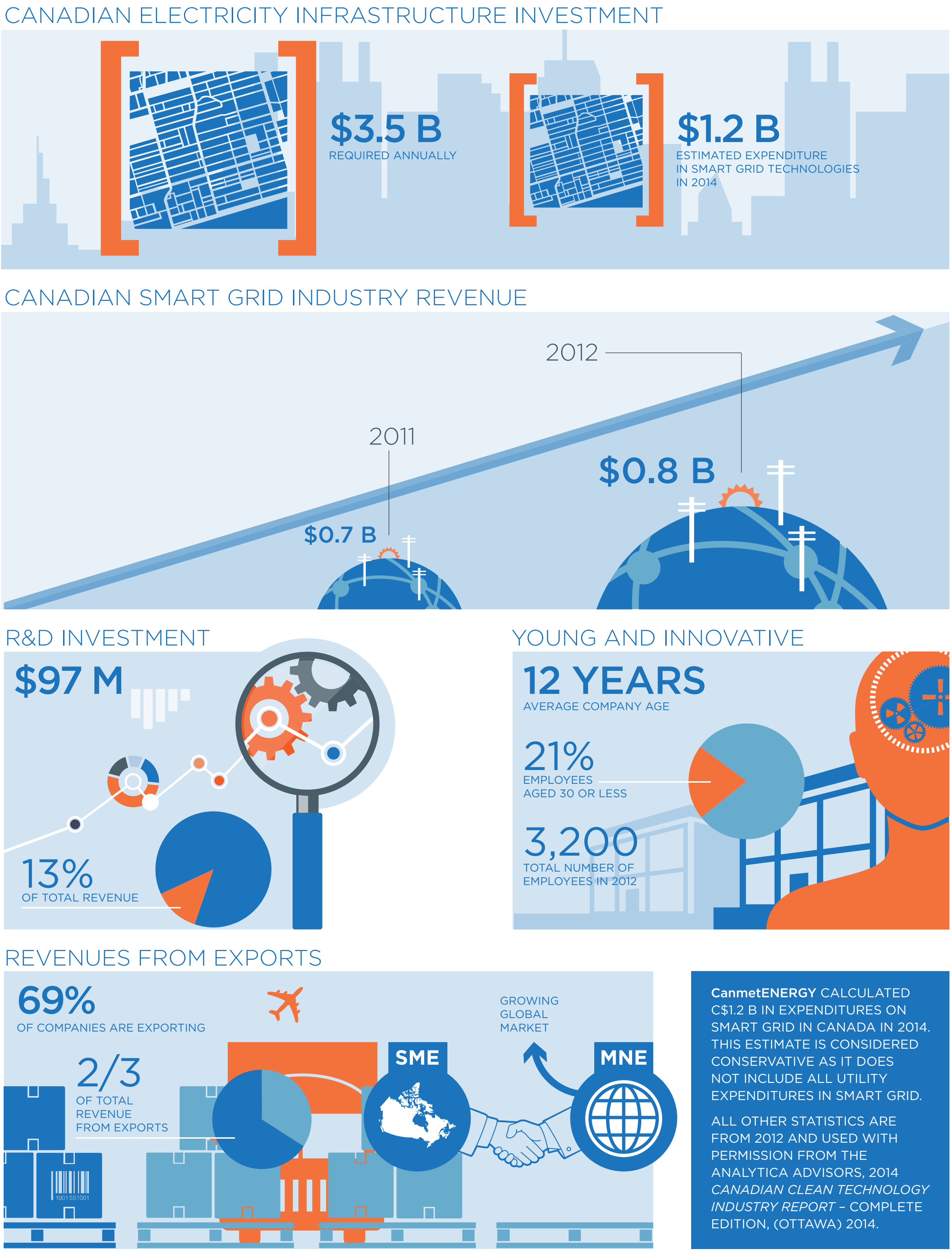
[46] Clean Energy Canada, *Tracking the Energy Revolution; Canada Edition 2014*, retrieved January 2015: http://cleanenergycanada.org/2014/12/02/tracking-the-energy-revolution-canada/

[47] CanWEA, *Canada's Current Installed Wind Capacity*, retrieved January 2015: http://canwea.ca/wind-energy/installed-capacity/

[48] Estimated 2014 installed solar capacity based on NRCan, CanSIA, *National Survey Report of PV Power Applications in Canada – 2013*, retrieved January 2015: http://www.iea-pvps.org/index.php?id=93&eID=dam_frontend_push&docID=2312

[49] Zpryme Research & Consulting, *UK and Canada Smart Home Market Brief*, retrieved June 2014: http://etsinsights.com/reports/uk-canada-smart-home-market-brief/

Figure 5. Smart grid industry growth in Canada



The electricity sector is continuing through a significant period of investment as reported by the CEA.[50] This investment is in response to many assets reaching their end of life, significant advances in information technology, severe weather events and evolving requirements for the North American integrated grid, to name a few. The utility investment environment for new technologies remains a challenge across much of Canada. The combined influence of regulations and energy markets that were established before smart grid capabilities were considered, on electric utilities that have to uphold high standards of safety and reliability, makes for a challenging market for smart grid companies to enter. Despite this challenge, every year Canada is adding new smart grid projects hosted by forward-looking utilities in Canada.

You could arrive at the potential smart grid market size from utility investments by using the Conference Board of Canada estimates at roughly $70 billion required investment in distribution systems over two decades—or perhaps $3.5 billion annually—in infrastructure where smart grid are likely to be applied. CanmetENREGY was able to identify over $1.2 billion in smart grid infrastructure investments in 2014 in Canada simply by adding the value of all known project costs over the project development period. This figure is estimated to be quite conservative given that private investments without public funding are usually unknown, and minor utility investments on smart grid projects are not reported separately and thus not included in this estimate.

The 2014 *Canadian Clean Technology Industry Report*,[51] by Analytica Advisors, estimated that Canada's smart grid industry claimed $762 million in revenues in 2012, which remains consistent with what was reported in the previous year. Smart grid companies collectively reported $97 million in R&D investment, or an average of 13% of revenues, which is above that of the overall clean tech sector R&D investment. It reflects a young sector with an average company age of 12 years, but also a very innovative sector, which bodes well for its potential in the rapidly growing global market. Approximately 69% of companies reported revenues from exports, which accounted for almost two thirds of the total revenues. The combination of R&D and export capabilities, and partnerships with larger Canadian-based companies with international supply and distribution channels, is an important strategy for this sector, largely made up of small and medium-sized enterprises.

The next few years ahead promise important opportunities to gain knowledge and insight for smart grid stakeholders developing technology solutions and stakeholders creating the enabling environment for smart grids to thrive. Many of the recent demonstration projects identified in this report will be complete by 2016, providing an opportune time for collective analysis and review of smart grids in Canada. CSGAN will continue to facilitate information sharing and analysis throughout this time.

[50] Canadian Electricity Association Vision 2050: http://powerforthefuture.ca/vision-2050/

[51] Analytica Advisors, 2014 Canadian Clean Technology Industry Report – Complete Edition, (Ottawa) 2014

Acronyms

AESO	Alberta Electric System Operator
AIF	Atlantic Innovation Fund (Atlantic Canada Opportunities Agency)
AMI	Advanced Metering Infrastructure
CCEMC	Climate Change and Emissions Management Corporation
CCIRC	Canadian Cyber Incident Response Centre
CEA	Canadian Electricity Association
CEF	Clean Energy Fund (NRCan)
CSGAN	Canada Smart Grid Action Network
DER	Distributed Energy Resources
DR	Demand Response
ecoEII	ecoENERGY Innovation Initiative (NRCan)
EV	Electric vehicle
GHG	Greenhouse gas
GMF	Green Municipal Fund (Federation of Canadian Municipalities)
GW and GWh	Gigawatt (power) and gigawatt-hours (energy)
ICE	Innovative Clean Energy Fund (British Columbia)
IEA	International Energy Agency
IESO	Independent Electricity System Operator (Ontario)
ISGAN	International Smart Grid Action Network
kW and kWh	Kilowatt (power) and kilowatt-hours (energy)
MG	Microgrids and/or planned islanding
MW and MWh	Megawatt (power) and megawatt-hours (energy)
NERC	North American Electric Reliability Corporation
NRCan	Natural Resources Canada
NSERC	Natural Sciences and Engineering Research Council
NSMG-Net	NSERC Smart-Microgrid Research Network

OCF	Ontario Conservation Fund (IESO)
OEB	Ontario Energy Board
OECD	Organisation for Economic Cooperation and Development
NRO	New rate options to facilitate customer demand response
R&D	Research and development
SCADA	Supervisory Control and Data Acquisition
SDTC	Sustainable Development Technology Canada
SGF	Smart Grid Fund (Ontario)
SH	Self-healing grids; able to reroute power automatically
SSHRC	Social Sciences and Humanities Research Council
VPP	Virtual Power Plant
VVC	Voltage and VAR (reactive power) Control

Appendix

The following table defines the terms used in Figure 2.

Application	Description of deployment
Advanced Metering Infrastructure (AMI)	Smart meters or advanced metering is commonly referred to as advanced metering infrastructure (AMI), which refers to the meters and the associated communications infrastructure. In Canada, it supports automatic remote meter reading and interval metering, enabling new methods of electricity data collection and network planning. The smart meter could also be used as a gateway for information exchange with the customer. Depending on the local conditions, AMI could be used to support outage management, new rate options, demand response, electricity system loss detection and link to in-home displays and energy management systems.
New Rate Options (NRO)	New rate options are made possible with the deployment of interval meters (smart meters recording hourly or subhourly consumption). New rates can serve different customer energy needs and help to increase the value proposition of electricity services to customers. For example, time of use and off-peak rates offer customers incentives to reduce and or shift their peak demand to take advantage of off-peak heating and cooling rates. Net metering rates can be used to measure the contribution of embedded generation to system value. Prepaid rates can offer budget-constrained customers a means of avoiding expense and keeping the lights on.
Demand Response (DR)	The primary purpose of demand response programs is to decrease system peaks. Electricity systems have a capacity limit beyond which new electrical infrastructure must be built to satisfy any increase in demand. Demand response applications provide cost-effective solutions to avoid or at least defer the capital expenditures and operational costs of increasing the size of the system. In general, demand response can be implemented in one of two ways: through a direct load control (instructional signal) sent by the utility or system operator or third party aggregator to a customer; or through an indirect control (price signal) sent to a customer. New forms of load management and technologies, such as virtual power plants, are being developed to provide ancillary services to the grid, such as spinning reserve, load following (e.g. wind variation smoothing) and frequency regulation.

Application	Description of deployment
Distributed Energy Storage (DES)	This category captures the deployment of electricity storage technologies to provide grid services such as frequency regulation and peak shaving. Backup power systems are not included in this category unless the storage technology also provides grid services when it is not providing backup power during an outage. This category also does not include large storage connected to the bulk system, such as large pumped-hydro.
Self-healing (SH) Grids	Sometimes referred to as fault location, isolation and service restoration (FLISR), or fault detection, isolation and restoration (FDIR), technologies applied to increase the capacity of the distribution grid to re-route power around faulted sections or restore power from a fault all fall under this category. A fully self-healing grid requires little-to-no intervention from a grid operator. However, the deployment of remote controlled switches and reclosers on utility feeders is considered a starting point. Greater intelligence can be provided through real-time feeder sensing and information and control systems such as outage management systems (OMS) and distribution management systems (DMS).
Microgrids (MG)	Planned islanding takes advantage of distributed generation or storage as a way to create a "microgrid" within a larger network that can be isolated and maintained during outages on the surrounding grid. The distributed resources could also be used to reduce the peak demand in the area. At this point in Canada, the deployment is rare, but guides are being developed to facilitate the transition to this functionality in locations across the country.
Voltage and Var (reactive power) Control (VVC)	Voltage and reactive power (var) control uses substation automation and capacitors to flatten the voltage profile of a feeder, leading to energy conservation and loss reduction. VVC applications can also allow distribution networks to support greater amounts of variable power from renewable electricity generation such as wind and solar photovoltaic. VVC applications can be stand-alone installations at substations, or integrated into distribution management systems (DMS).

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