Natural Resources Canada | Ressources naturelles Canada

SMART GRID IN CANADA

2020 2021

Canada

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About this Report

This report provides an update on smart grid activities in Canada since the [last report published in 2018](). Key research, development, demonstration and deployment activities related to smart grid are highlighted between 2019 and 2021. The report is intended to be a useful reference for national and international smart grid practitioners from research, academic, policy, industry and trade backgrounds to learn about smart grid activities across Canada.

This report is published by NRCan's CanmetENERGY research centre in Varennes, Quebec, with contributions from the Office of Energy Research and Development and the Renewable and Electrical Energy Division. CanmetENERGY manages the Canada Smart Grid Action Network (CSGAN) bringing together provincial and territorial energy ministries, federal departments, academia, innovation networks, and industry associations as shown in Figure 1. CSGAN exchange their knowledge and experience about smart grid activities, discuss regional activities, share research topics of interest, collect smart grid metrics in Canada, present international knowledge and experience sharing opportunities, track standard development, and explore smart grid outlook. This network was also established to connect Canadian smart grid stakeholders and to leverage opportunities under the International Smart Grid Action Network and Mission Innovation 2.0 on a Green Powered Future. CSGAN members have contributed significantly to producing this report.

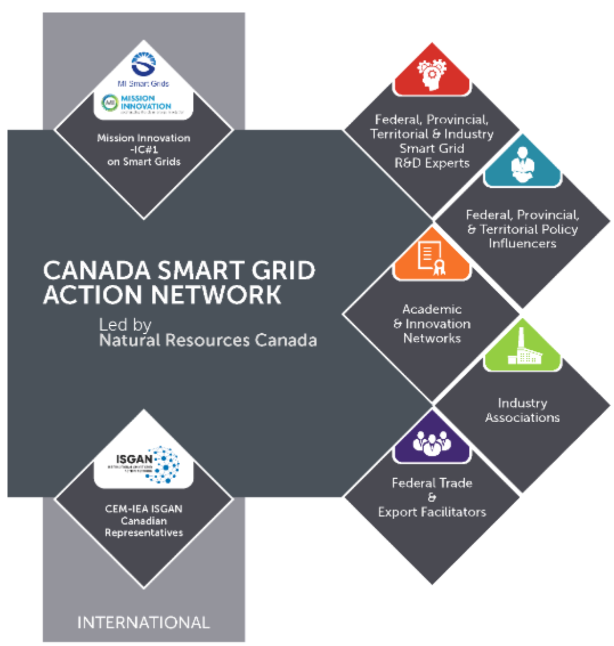

Figure 1: Canada Smart Grid Action Network Members

About CanmetENERGY

Natural Resources Canada's CanmetENERGY is Canada's leading research and technology organization in the field of clean energy. Over 200 scientists, engineers and support staff at the CanmetENERGY facility in Varennes design and implement clean energy solutions, and expand on research areas that help produce and use energy in ways that are more efficient and sustainable.

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Abbreviations

AESO	Alberta Electric System Operator	**ETNO**	Energy Transformation Network of Ontario
AIF	Advanced Inverter Functions	**EV**	Electric vehicle
AMI	Advanced Metering Infrastructure	**EVEMS**	Electric Vehicle Energy Management System
AMR	Automatic Meter Reading	**GHG**	Greenhouse gas
API	Application Programming Interfaces	**GIF**	Grid Innovation Fund
BC	British Columbia	**GI2**	Green Infrastructure Phase II
BTM	Behind-the-Meter	**GPFM**	Green Powered Future Mission
CCEI	Canadian Centre for Energy Information	**HQ**	Hydro Quebec
CEM	Clean Energy Ministerial	**IC**	Innovation Challenges
CER	Canada Energy Regulator	**IEA**	International Energy Agency
COP	Conference of the Parties	**IEC**	International Electrotechnical Commission
CSGAN	Canada Smart Grid Action Network	**IEEE**	Institute of Electrical and Electronics Engineers
DC	Direct Current	**IERI**	Innovation and Electricity Regulation Initiative
DER	Distributed Energy Resources	**IESO**	Independent Electricity System Operator
DERMS	Distributed Energy Resource Management System	**ISGAN**	International Smart Grid Action Network
DR	Demand Response	**IT**	Information Technology
ECCC	Environment and Climate Change Canada	**MI**	Mission Innovation
EDI	Equity, diversity and inclusion	**NB**	New Brunswick
EMS	Energy Management System	**NL**	Newfoundland and Labrador
ES	Energy Storage	**NS**	Nova Scotia

NSERC	Natural Sciences and Engineering Research Council of Canada	**SAE**	Society of Automotive Engineers
NSP	Nova Scotia Power	**SCADA**	Supervisory, Control and Data Acquisition
NZE	Net Zero Emissions	**SGP**	Smart Grid Program
OEB	Ontario Energy Board	**SIRFN**	Smart Grid International Research Facility
PEI	Prince Edward Island	**T&D**	Transmission and Distribution
PV	Photovoltaic	**TE**	Transactive Energy
R&D	Research & Development	**VRE**	Variable Renewable Energy
RDD&D	Research, Development, Demonstration & Deployment	**WEICan**	Wind Energy Institute of Canada
RE	Renewable Energy	**WG**	Working Group
RPF	Request for Proposals	**V2G**	Vehicle-to-Grid

General Framework

Recent reports by the Intergovernmental Panel on Climate Change, the United Nations Framework Convention on Climate Change, and the United Nations Environment Programme note a gap in global ambitions to achieve commitments in keeping global temperatures at or below 1.5 °C. In response to mounting concerns to this gap, and in-line with the targets set out in the Pan-Canadian Framework (PCF), Canada has committed to a clean energy future, supported by concrete actions, including:

- A strengthened climate plan, A Healthy Environment and a Healthy Economy, putting Canada on track to meet its previous emissions target;
- Legally enshrined commitments for enhanced emissions targets reductions—by 40 to 45% from 2005 levels by 2030, as well as a commitment to achieve net-zero Greenhouse gas (GHGs) emissions by 2050 through the Canadian Net-Zero Emissions (NZE) Accountability Act;
- Commitments to reducing oil and gas methane emissions by a minimum of 75% from 2012 levels by 2030, as recommended by the International Energy Agency (IEA); and
- Prioritized support for clean technology and an end to new direct public support for the international unabated fossil fuel sector by the end of 2022.

In order to reach a clean energy future, the fundamentals of the electric grid, which forms the backbone of the transition, must innovate to accommodate more renewables and loads. This evolution of the electric grid is taking shape through new smart grid capabilities, enabled by innovative applications of information, communication, technology, infrastructure and methods. In addition to facilitating the transitioning to a clean energy future and clean electric grid, smart grid benefits include:

- Improvements to system efficiency and asset utilization, at bulk and local levels;
- Increased reliability (keeping the power on) and resiliency (recovery from large one-time events);
- Greater customer participation through prosumer adoption and new markets;
- Cyber security awareness;
- Improved economic and job opportunities; and
- Reduced diesel and other fossil fuel use in remote communities.

In accordance with the evolution of the smart grid, the amount of electricity generated from renewable and non-emitting sources nationally has increased. While this expansion is necessary to reach decarbonization and electrification goals, new renewable energy (RE) sources and increasing loads need to be integrated in such a way that upholds the integrity and stability of electricity grids. As such, ongoing smart grid research, development, demonstration and deployment (RDD&D) projects across the country are receiving funding from federal, provincial and territorial initiatives.

In this report, the progression of the smart grid will be presented through national smart grid metrics and trends, including funding programs, first discussed nationally and then by province and territory. Select, relevant smart grid-related standards, which play a key role in smart grid adoption, are also highlighted. Some domestic and international networks and initiatives, that are helping to ensure that Canadian activities remain up-to-date with the latest advances and best practices for adoption, are reported. Finally, the Outlook provides future technical challenges and barriers that need the attention from the community and that can be addressed through RDD&D activities.

National Smart Grid Metrics and Trends

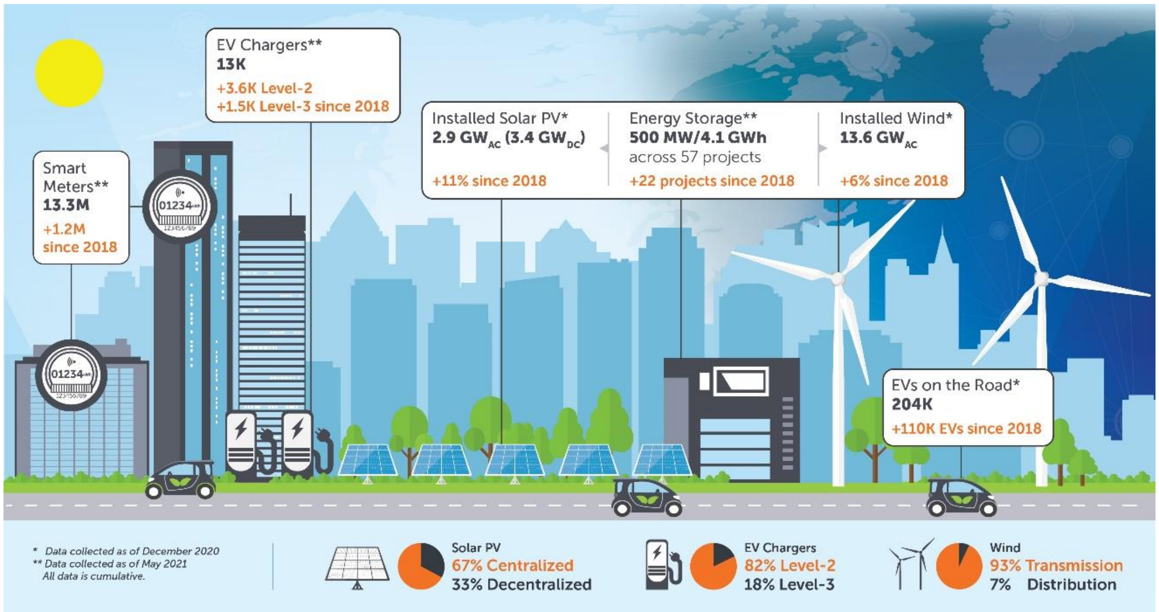


Figure 2: Key Smart Grid Metrics in Canada

Emissions from the electricity sector have been consistently decreasing since 2001 across Canada, where increasing clean and renewable energy generation has played a key role. Already composed significantly of clean and renewable resources, Canada's RE generation capacity increased by 18% from 2010 to 2019, from mostly wind and solar photovoltaic (PV) deployments[1].

SOLAR PHOTOVOLTAIC ENERGY

Currently, the cumulative solar PV installed capacity in Canada is approximately 2.9 GW[2], which represents an 11% increase since 2018. Of this capacity, 67% is considered centralized (generation not self-consumed) and 33% is decentralized (generation, at least in part, self-consumed). The predominant solar PV deployment trend in Canada has been towards centralized for the last several years. Ontario and Saskatchewan accounted for over 50% of the newly installed solar PV capacity representing 46 MW in Canada from 2019 to 2020, however, the total number of projects across Alberta, British Columbia (BC) and Nova Scotia (NS) resulted in 70% of the new deployment projects, or over 3,700 projects. In 2021, the majority of new solar PV capacity was increased due to centralized generation in Alberta.

WIND ENERGY

In terms of cumulative wind capacity in Canada, there is currently 13.6 GW installed, which is a 6% increase since 2018. Of this, 93% is transmission connected and 7% is distribution connected. The dominant trend for new wind generation is transmission connected with capacity more than tripling, and generation almost quadrupling since 2010. The provinces of Ontario, Quebec and Alberta make up over 80% of total wind capacity installed in Canada.

STORAGE

The growth of energy storage (ES) underlines an important necessity in the future of clean energy deployments in Canada, as RE generation such as solar PV and wind can benefit from storage to balance their inherent variability. Overall ES capacity is currently 500 MW/4.1 GWh, which was accomplished through an addition of 22 projects completed since 2018. This capacity is largely represented by battery technology, with over 80% of total installed capacity. Also, 10 of 13 provinces and territories have some type of battery storage deployed. Pumped hydro storage is the next largest capacity of storage. Other ES technologies recently deployed in Canada include compressed air ES and electric thermal storage. These ES deployments account for utility-scale and behind-the-meter (BTM) storage, which can be interconnected to the transmission or distribution grid. While utility-scale storage are larger deployments controlled according to power system needs, the BTM storage capacity is driven by customer adoption. Customers may choose ES systems to maximize return on investment for distributed generation, or to provide resilience. BTM storage units are unique as they are controlled by customers to meet their respective needs. Across Canada, steady demand growth for net metering and BTM battery storage is emerging.

SMART METERS

Smart Meters in Canada are inclusive of Advanced Metering Infrastructures (AMI) and Automatic Meter Reading (AMR) devices. Modernization through smart meters has facilitated consumption data to be integrated with utility systems, so that data can help identify consumption patterns, outages, and theft. This is becoming more important as federal and provincial electrification initiatives are driving changes in demand patterns and there is increased focus on resiliency. Nova Scotia has most recently joined Ontario, Quebec, and BC in full smart meter roll-outs, and New Brunswick (NB) is in the process of broad smart meter roll-out as well[3,4]. Other provinces are being driven by industrial and commercial customers to push smart meters to have increased visibility into their usage patterns. The current national deployment level of smart meters is 13.3 million—an increase of 1.2 million since 2018.

ELECTRIC VEHICLES

Electric Vehicles (EVs) are becoming increasingly important for the future of electrification in Canada. This importance is driven by two main themes. The first is that between 2005-2019, transportation was the only sector in Canada to have an overall increase in CO2e: 14% or 27 Mt[5]. The second theme is that EVs not only reduce the amount of GHGs expelled by the transportation sector, but may also be able to act as a mobile BTM storage resource to support grid needs. As EVs are one of many types of Distributed Energy Resources (DERs) being adopted by customers, they are an asset that have a role to play in an interactive grid. For example, with proper equipment and communications, EVs are able to provide services such as demand response (DR) for peak shaving, as already witnessed in many pilots and some deployment programs. Currently, there are 204k EVs and Plug-in Hybrid EVs on the road—an increase of 110,000 vehicles since 2018.

ELECTRIC VEHICLE CHARGERS

A key feature to support the rapid adoption of EVs is having access to reliable and convenient charging station infrastructure. In 2020, the effort to electrify the Trans-Canada Highway, extending from Victoria, BC, to Stewiacke, NS, was completed. This federal, provincial, and municipally funded infrastructure project ensures that EV chargers are available no farther than 250 km apart from one another to facilitate continuous and reliable travel from coast to coast in Canada. The current number of level-2 and level-3 chargers is 13,000—an increase of 82% of level-2 and 18% of level-3 chargers since 2018. Figure 3 shows the deployment of level-2 and level-3 EV chargers across Canada related to population. The increase in demand due to EV charging is of significant interest to system operators as electrification efforts continue. Additionally, EV charging infrastructure with on-site solar PV (e.g. solar PV carports) has seen growing interest.

A scalable load management solution project piloted with 60 electric vehicle owners in collaboration with Alectra Inc. and Burlington Hydro, applies different price signals to determine their effect on charging behaviour. The project intends to encourage charging at times that are in line with grid needs.

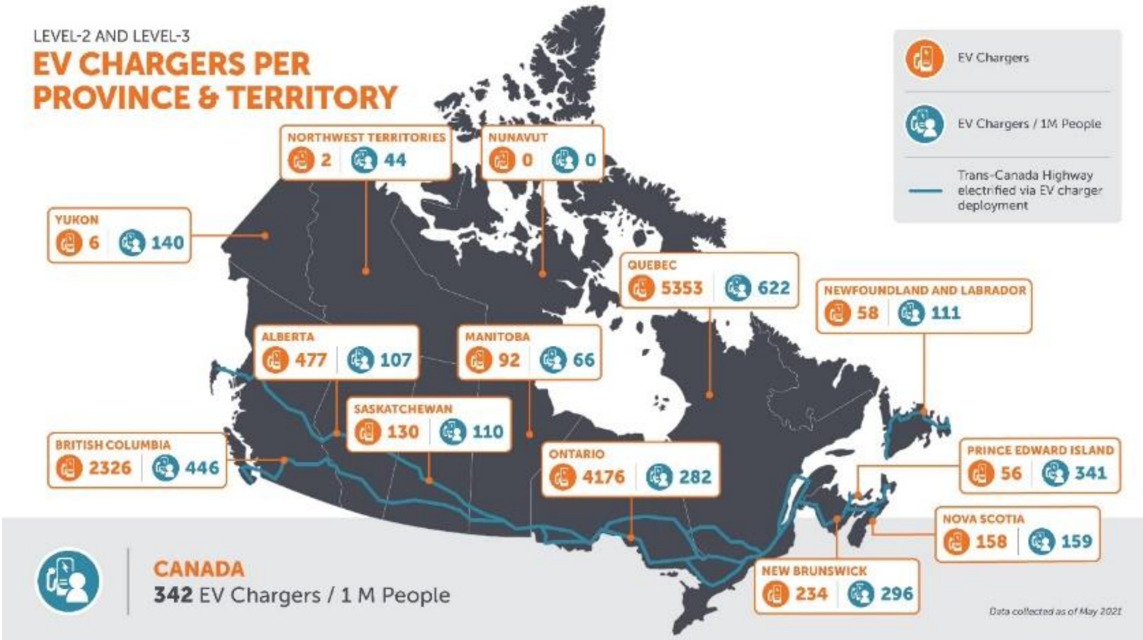


Figure 3: EV Chargers Across Canada

Trends in Smart Grid Technologies and Applications

Progression in smart grid technologies and applications can be categorized broadly by the degree of monitoring and control, level of automation, number of actively participating elements in the grid, and strength of customers and systems integration[6]. In Figure 4, smart grid deployment is organized into three levels: Foundational Smart Grid Systems, Key Smart Grid Technologies and Applications, and Advanced Smart Grid Technologies and Applications. While these levels apply to the whole power system, many of the noted components fall within the realm of distribution systems, as opposed to transmission.

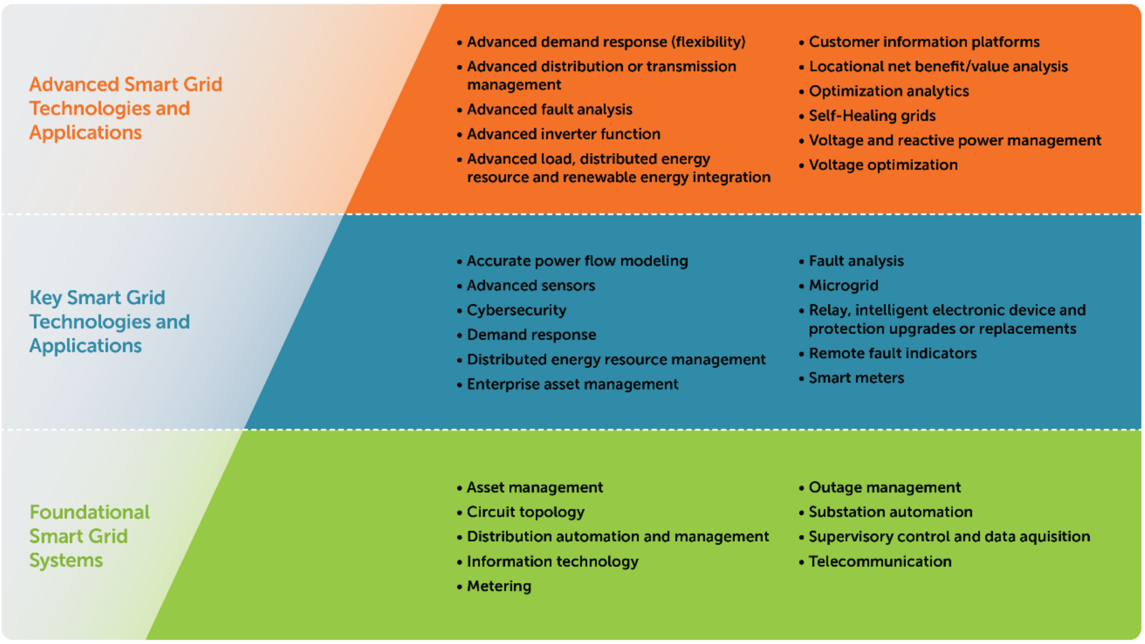


Figure 4: Level of Smart Grid Technologies and Applications

Foundational Smart Grid Systems facilitate modest improvements to the grid while leaving its traditional operating paradigm—the unidirectional flow of power from generation to the end loads—untouched. The core utility business of treating loads simply as an uncontrollable demand remains unchanged; it does enable better decision-making while also offering increased monitoring, automation, and control of major assets. Transmission systems, due to their importance as the backbone serving a large number of customers, have already largely adopted these foundational systems. Distribution systems are structured differently and have deployed these systems to varying degrees based on the unique needs of each distribution grid.

Example: Supervisory control and data acquisition (SCADA) systems provide grid control centres visibility and control of various points along the grid in order to ensure safe and reliable operation. Data related to the status, control and telemetry of various utility assets—switches, breakers, and transformers, including distributed generation—are all available.

Key Smart Grid Technologies and Applications improve upon foundational systems by facilitating enhanced monitoring and control of devices, such as visibility and management of a larger number of grid parts or devices at more frequent time intervals, as well as higher reliability and resiliency. It also enables additional grid connected elements beyond utility-owned assets to have a more active role on the grid, which in tur, can alter typical power flows. These applications also enable improved business operations, including billing, customer management, and asset management.

Example: A distributed energy resource management system (DERMS) is a platform using real-time control capabilities to manage collections of DERs to provide grid services both locally (e.g. through volt-var control) and to the bulk grid, via regulation.

Advanced Smart Grid Technologies and Applications bring about the full potential of information technology (IT)-grid integration, enabling active participation of most grid-connected elements while recognizing and facilitating the complete transformation of the grid operational paradigm, from uni-directional to bi-directional. This enables a fully autonomous grid capable of coordinating various resources at the distribution and transmission levels to support the highest level of safety, reliability and resiliency across the entire network. High levels of automation also result in more reliable and resilient systems with real-time, on-line optimizations, decreasing operation and maintenance costs.

Example: Advanced inverter functions (AIFs) are a suite of capabilities of the power electronics connecting resources such as solar PV, batteries, EVs, and some wind resource, to the electric grid. They enable the resource to provide grid services to support the grid, via grid following capabilities, or to form the grid, via grid forming capabilities, and are necessary as the grid's power demand is increasingly supplied by such resources.

Public Investments

Public sector investments support the comprehensive understanding of the technical and non-technical barriers for broad smart grid deployments through the financing of RDD&D projects. This funding allows technological innovations to be experimented for practical feasibility, which can address concerns such as commercialization, system integration and operation, as well as scalability. This RDD&D is aiding in the transition to a net-zero economy.

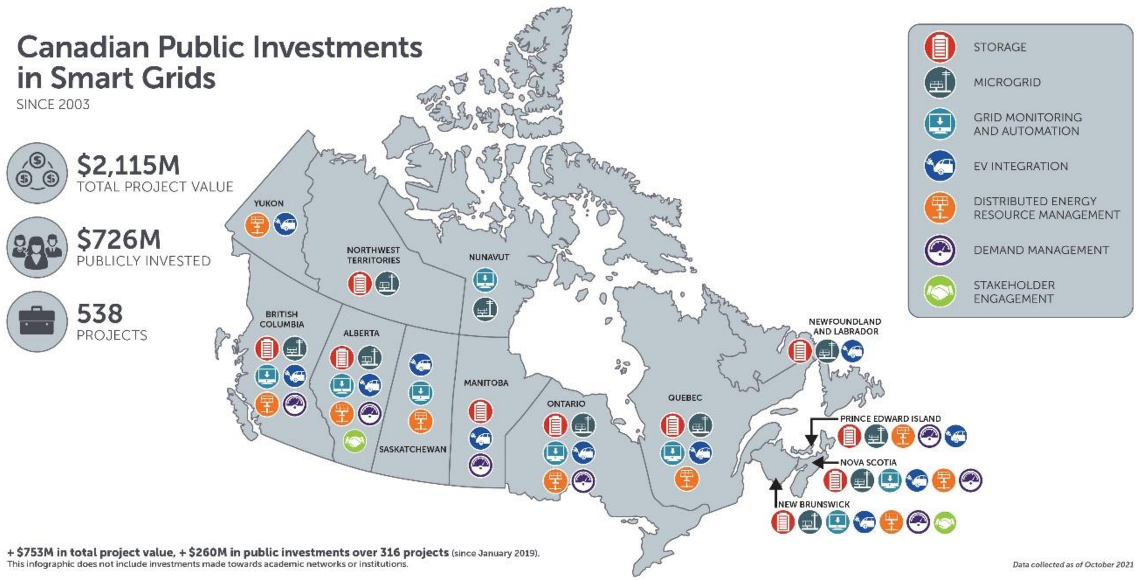


Figure 5: Canadian Public Investments in Smart Grid RDD&D Since 2003

Canadian public smart grid investments have increased in the reporting period. In terms of total project value, Figure 5 shows that there has been an additional $753 million invested across projects that span the provinces and territories since 2019. The amount of publicly invested funds has increased by $260 million, over an additional 316 projects. These increases in investments include newly funded projects across regions, which in 2018 did not exist. These categories of projects are Stakeholder Engagement in Alberta, ES in Saskatchewan, Demand Management in Manitoba, EV Integration in Prince Edward Island and Newfoundland and Labrador, Microgrid in Nunavut, and DERMS and EV integration in the Yukon.

Categorically, there has been significant funding towards EV infrastructure, which is approximately 45% more, in comparison to 2018. Following this, battery storage was the second largest funded category, with substantial increases to the number of projects and overall storage capacity.

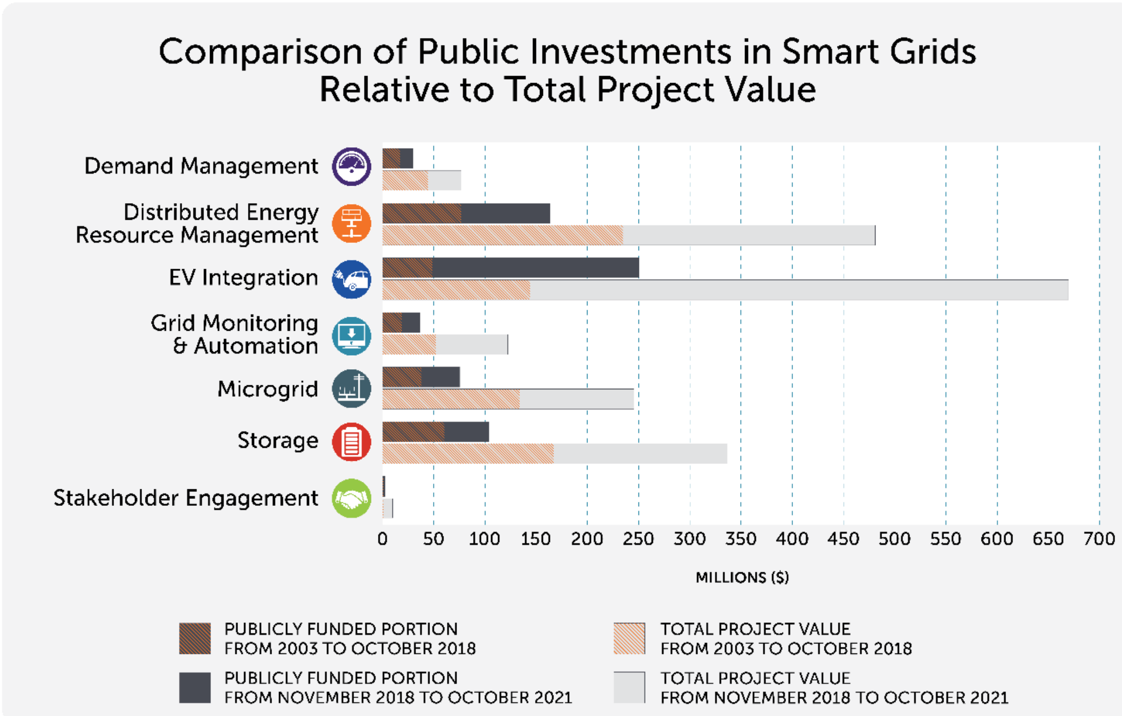


Figure 6: Comparison of Canadian Public Investments in Smart Grid Categories Relative to Total Project Value

Public investments in smart grids relative to total project value can be seen in Figure 6. Since 2018, there have been substantial increases in both public investments and the total value of projects, though they have not increased in the same order of magnitude. For example, public funding for storage increased by approximately 40%, yet total project value more than doubled, reaching over $336 million. DERMS, microgrid, and grid monitoring and automation, have nearly all doubled in investments and total project value, with DERMS receiving the second largest amount of funding and the second highest total project value, with approximately $163 million and $480 million, respectively. EV integration has had the most significant increase—by five times since 2018, and has had an over $200 million increase in public funding, with approximately $525 million in total project value since 2018. Note that all references made to 2018 are with regards to the 2018 Smart Grid in Canada report, and not necessarily representative of all projects announced in the year 2018.

Natural Resources Canada Programs

Smart Renewable Energy Pathways Program

The Smart Renewables and Electrification Pathways Program is a $964 million program which provides $922 million over four years, starting in fiscal year 2021/22, to support the deployment of smart RE and electrical grid modernization projects, using market ready technologies[7]. The funded projects allow provinces and territories to meet growing energy demand using renewable power, provide increased reliability and resilience to the electricity grid, and continue to reduce GHGs in the electricity sector. Through an Equity, Diversity, and Inclusion (EDI) component, the program aims to support projects across the country and encourage the participation and leadership of those underrepresented in the energy sector, such as First Nation, Inuit and Métis communities. The Program funds renewable electricity deployment projects that are capable of providing essential grid services from various organizations, including Indigenous groups, private enterprises, and communities. The Program also funds projects that enable utilities and system operators to gain experience with, and develop, new operational processes to better support higher levels of renewable electricity generation. Project applicants can apply for funding under three deployment streams: established renewables, emerging technologies, and grid modernization.

The Strategic Energy Data Management Solutions project led by Screaming Power integrated energy data, weather, billing and meter information into a smart cloud-based mobile technology platform using artificial intelligence. The data collected is used to learn historical experience to provide feedback to the local distribution company; to customers to better inform operational decisions; and, to help conserve as well as manage energy and GHG emissions.

In November 2021, the Program closed the Capacity Building stream competitive request for proposals (RFP) for projects that build knowledge and skills related to RE and grid modernization technologies. This stream supports community-driven activities that build energy knowledge and skills to ensure a successful transition to RE technologies and projects, including performing technical studies and considering EDI principles. The Program's funding is currently fully allocated and the Program is not able to fund additional projects at this time. Applications were accepted on a continuous intake basis. As of March 2022, 139 deployment applications and 234 capacity building proposals were received, of which 86 projects (both deployment and capacity building) were approved, representing $922 million funds committed.

The Energy Innovation Program

This flagship program of the Office of Energy Research and Development accelerates clean energy technology research and development (R&D) across energy sectors by investing $52.9 million per year both internally and externally[8]. The Program funds early to late-stage technology development projects related to investigating renewable, smart grid and storage systems; decreasing diesel usage in northern and remote communities; reducing methane and volatile organic compound emissions; lowering GHG emissions in the building sector; advancing carbon capture, use and storage; and improving industrial efficiency. This Program funds research projects led by the federal labs, as well as research and demonstration projects led by innovators external to government.

Program of Energy Research and Development

The Program of Energy Research and Development funds $32 million per year towards internal energy R&D projects focused on building a sustainable energy future for Canada's economy and environment. This fund only supports federal departments and agencies, or outside organizations working directly with a federal department or agency.

Green Infrastructure Programs

Several programs have been offered under the Green Infrastructure Program to accelerate building a clean economy. The Green Infrastructure Phase 2 (GI2) houses the Smart Grid Program (SGP), but other programs related to buildings, EVs and communities have also supported the adoption of smart grid-related projects[9].

The Energy Efficient Buildings RD&D Program supports the development and implementation of building codes for existing buildings and new net-zero, energy-ready building initiatives. The EV Infrastructure Demonstrations Program supports the demonstration of next-generation and innovative EV charging infrastructure projects. There are 29 projects announced to date, five of which are led by utilities. These projects address charging infrastructure in multi-unit residential buildings, superfast charging, vehicle-to-grid (V2G), incentivizing charging behaviour, and charging infrastructure for heavy-duty vehicles. The Clean Energy for Rural and Remote Communities Program under GI2 aims to reduce reliance on diesel fuel in Canada's rural and remote communities and industrial sites by supporting a transition to more sustainable energy solutions, and the design and operation of RE microgrids.

The SGP is a $100 million program (2018 to 2023) that supports the demonstration and deployment of smart grid technologies from utility-led projects to reduce GHG emissions, better utilize existing electricity assets, and foster innovation and clean jobs[10]. In total, there are 22 projects, which demonstrate and deploy a variety of technologies and system categories. In Figure 7, the inner circle outlines the utility ownership for awarded projects while the outer circle describes the project proponent structure.

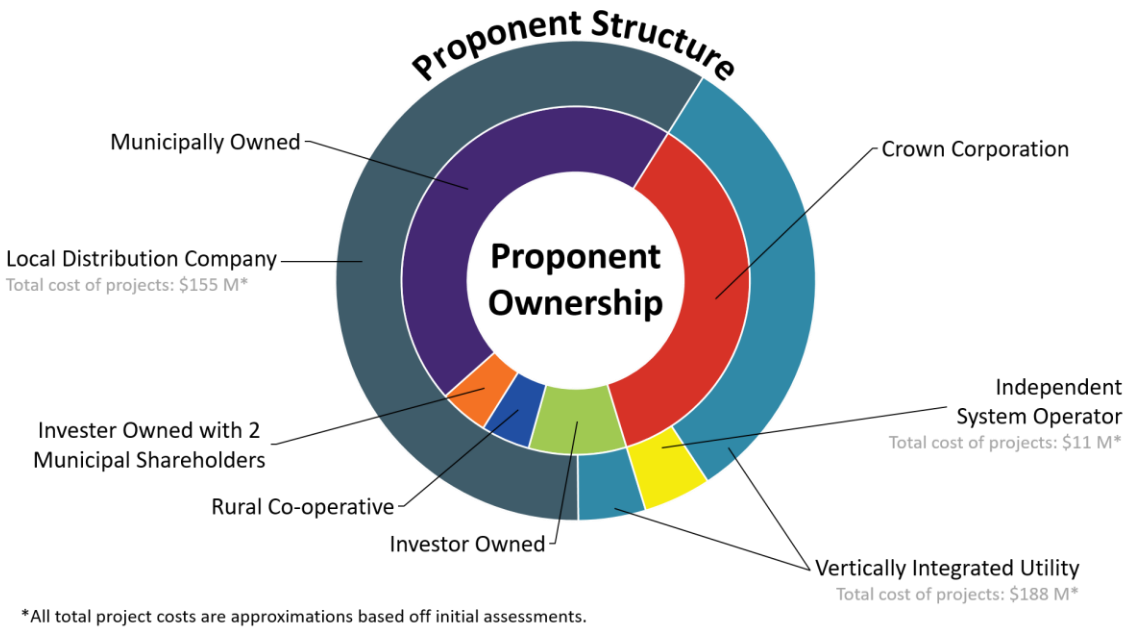


Figure 7: Green Infrastructure Phase 2 Smart Grid Program Project Proponent Details

The most prevalent technologies in projects funded by the SGP included (in order) load management, storage, solar PV, EV integration, artificial intelligence, energy market and rate innovation, as well as AIFs. These technologies were integrated most commonly as DERMS, microgrids, grid monitoring and automation, new market and rate options, followed by remote off-grids. Some of the top system objectives reported for initial project proposal submissions focused on increased system flexibility, or RE penetration, GHG emission reductions and economic or social benefits for hybrid projects; improved asset utilization and increased efficiency, with the rest distributed evenly across all categories for demonstration projects; and, further emphasized reliability and resiliency for deployment projects.

More details about the Smart Grid Program can be found in the brochure.

Other Federal Programs

Innovation and Electricity Regulation Initiative

The Innovation and Electricity Regulation Initiative (IERI) is a two-year initiative launched in November 2020 to formally engage stakeholders (regulators, utilities, provincial and territorial governments, Indigenous groups, customer advocacy groups and other intervener groups) within Canada's provinces and territories to explore how federal programs can better support effective scaling of electricity system innovation projects in support of net-zero by 2050 targets[11].

The IERI was proposed within the Clean Technology Regulatory Roadmap in response to concerns from utilities and private sector companies regarding regulatory barriers impeding electricity grid modernization efforts. It seeks to formally engage Canada's provinces and territories' regulators, governments, utilities and other stakeholders in two phases to develop a collaborative framework, which could allow federal programs to more effectively increase the level of electricity system innovation projects and facilitate the scaling of successful innovations in support of NZE by 2050 targets.

Impact Canada – Clean Technology Challenges

Charging the Future

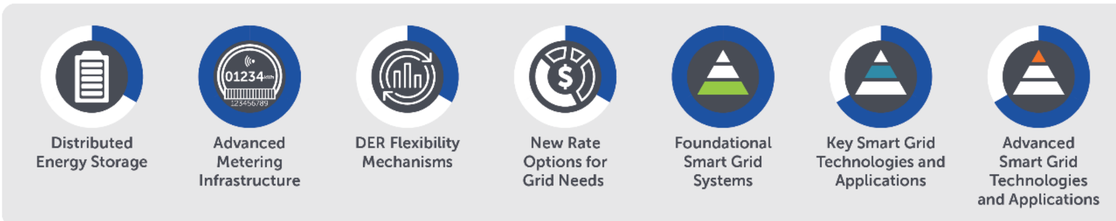
The Charging the Future Challenge seeks to accelerate battery innovations from the laboratory to the marketplace, and support a transition to clean energy[12]. The Challenge aims to increase the pace of Canadian innovation of battery technologies to strengthen the battery value chain in Canada and the world. Five finalists were selected from a group of 39 project proposals. Each finalist received up to $700 thousand to start their prototype. In spring 2022, eZinc was awarded the $1 million prize for their acceleration of battery innovations that have the potential to substantially reduce GHGs. Through the development of a breakthrough electrochemical technology for storing energy in zinc metal, this low-cost, flexible and long-duration ES solution could help increase the share of the world's energy markets powered by RE sources.

Power Forward Challenge

The Power Forward Challenge seeks to increase collaboration between innovators from Canada and the United Kingdom to develop end-to-end solutions integrating DERs[13]. After the Challenge was launched in the fall of 2018, finalists were announced in June 2019, with seven finalist teams selected from a group of 44 project proposals, which were received in the main proposal intake of the Challenge in March 2019. A total of $9 million is available for finalists in each country. Each finalist team is made up of Canadian and U.K. partners and is eligible to receive up to $3 million to start developing its smart energy systems solution. Announced in the spring of 2022, Equilibrium Engineering won the $1 million prize for their use of an innovative artificial intelligence platform to predict solar PV and wind energy generation and demand of customers for the day ahead. The project takes place in the Town of Berwick, NS, introducing a replicable and unique smart grid solution that integrates intelligent ES, energy efficiency, RE generation and demand-side response.

Provinces and Territories

British Columbia



Under the Clean Energy Act, BC previously instituted a minimum threshold target requiring that at least 93% of electricity generation in the province be from clean or renewable resources, in collaboration with BC Hydro, the provincially-owned vertically integrated utility serving most areas of the province. Currently, BC has an average of 98% clean electricity from renewable source. BC Hydro's 2021 Electrification Plan outlines how the province will create a clean future powered by water to advance the switch from fossil fuels to clean electricity in homes, buildings, and vehicles. BC's Hydrogen Strategy includes an emphasis on the production of green hydrogen from RES.

In May 2019, BC became the first jurisdiction in the world to legislate a 100% Zero Emission Vehicle (ZEV) sales requirement. The ZEV Act required ZEV sales targets to reach 10% of light-duty vehicle sales by 2025, 30% by 2030, and 100% by 2040. In 2021, an updated ZEV law was passed to accelerate sales to meet the requirements of 26% of new light-duty vehicles by 2026, 90% by 2030, and 100% by 2035. In 2020, BC had the highest uptake rates of ZEVs in North America, reaching 9.4% of all new light duty vehicle registrations[14]. BC has also committed to installing 10,000 public EV charging stations by 2030. At the end of 2020, the province met 25% of that goal, and now has one of the largest EV charging networks in Canada. BC launched the CleanBC Go Electric Public Charger Program in 2020 to support the Direct Current (DC) fast charging network and the Go Electric Fleets Program in early 2021, offering rebates for the purchase and installation of level-2 and DC fast-charging stations for EV fleets. There are also charging pilots underway to explore EV grid management and time-of-use rates.

To help reach electrification commitments, BC's CleanBC Better Homes Program gives rebates for space and water heat pump equipment and additional incentives for fuel switching, from natural gas or oil. Net metering is offered for generation up to 100 kW and below; customers with excess generation receive a bill credit towards future electricity use.

BC Hydro's recent smart grid initiatives have focused on decarbonization and electrification, reliability, resiliency, technology, and business development, including efforts to improve employee safety through increased monitoring and automation in response to hazards. Benefits of these initiatives also include increased operating efficiency through energy efficiency and smart control options, use of centralized control systems and distribution automation, along with smart meters to minimize service interruptions and reduce restoration response times. In addition, communicating line monitors (sensors) and lateral reclosers are planned for deployment on distribution circuits and other initiatives are underway to increase grid flexibility through pilot programs. One such initiative is DR Management System presently piloted to enable end users to manage peak demands using smart controllers connected to electric water heaters.

In 2020, British Columbia Institute of Technology's Centre for Applied Research and Innovation completed its NuGrid Medium Voltage Testing Lab for optical medium-voltage current and voltage sensors, which provided an environment to explore next generation sensors for utility distribution applications and developing new expertise.

Alberta

The modernization of Alberta's power system, complemented by provincial policy and funding mechanisms, is being driven by electrification of rural, remote and northern communities; RE targets and decarbonization; technology and business development; and prosumer adoption. The province's Renewable Energy Act has set targets that are driving utilities to modernize, and is a key factor in increasing the integration of such generation into the electricity mix.

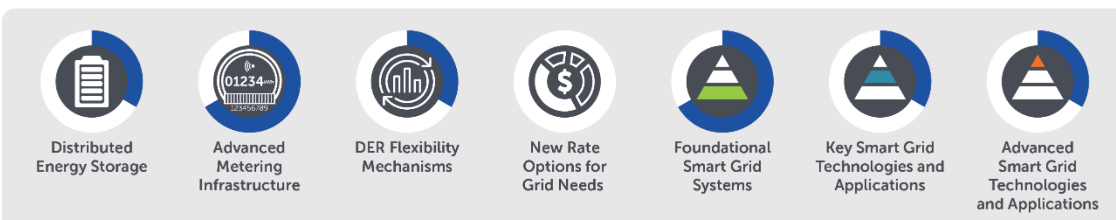
Alberta is one of two provinces operating an electricity market which, in this instance, is an energy-only market, operated by the Alberta Electric System Operator (AESO). In 2020, the AESO published the DER Roadmap, which outlines a future with a higher penetration of DERs driving significant changes for the AESO, distribution facility owners, industry participants and consumers, and, developing a plan to prepare for such a future.

There are a number of notable initiatives supporting RE. In partnership with municipalities, the Alberta Municipal Services Corporation offers the Clean Energy Improvement Program, following the property assessed clean energy financing model. This program allows owners to finance energy efficiency and renewable installations through their property taxes. Alberta Innovates' Clean Technology program invests in projects to adapt, develop and deploy innovative clean technologies to contribute to the growth of the province's low-carbon economy, through the three streams of the Renewable and Alternative Energy portfolio: Grid Modernization, ES, and Electricity Generation.

In addition, technology deployment initiatives in the province have included solar PV, battery storage, and geothermal. Utility-scale renewables, primarily solar PV, are being driven by the demand for corporate power purchase agreements. Recent smart grid developments include meter integration in rural communities and new DERMS applications. The province has rolled out over 1.25 million smart meters. These devices complement the rates and credits provided by net billing, which compensate micro-generation owners of facilities less than 150 kW with credits based on retail rates and facilities with 150 to 5,000 kW, with credits based on hourly wholesale market prices.

New ES deployments include the province's first utility scale battery storage project of 10 MW, attached to the Summerview II wind farm. Additionally, Canyon Creek will feature Alberta's first ever pumped-storage hydro ES project—a closed loop, off-stream facility that will provide 75 MW for up to 37 hours. In the future, this project could expand within the same footprint to 400 MW and will be used to provide peak shifting and capacity, and to support RE integration.

Saskatchewan



Saskatchewan's electricity grid is actively evolving, with the latest smart grid developments driven by decarbonization and emission reduction goals of 50% compared to 2005 levels by 2030. Focus areas include RE targets, technology and business development, and grid reliability.

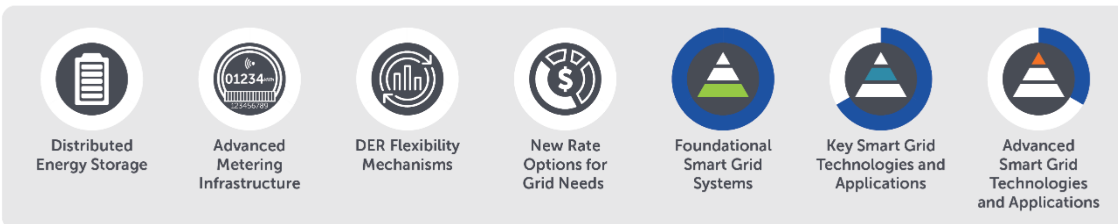
Saskatchewan is deploying smart meters with 21,515 residential smart meters installed since 2021, and 47,012 commercial and industrial smart meters since 2017. SaskPower, the province's vertically integrated utility, has announced the mass deployment of residential smart meters starting in 2022, enabling the utility to more rapidly respond to outages and provide detailed power use information to customers.

In 2018, SaskPower began an ongoing Distribution Modernization Program with funding support from NRCan. This Program aims to modernize the monitoring and control infrastructure supporting and feeding into the Provincial Distribution Control Centre.

Additionally, the province's first battery-ES system, with a capacity of 20 MW/20 MWh, was deployed in 2021 to support the storage of variable renewable energy (VRE) sources.

A net metering program for systems under 100 kW offers a 7.5¢/kWh credit for electricity exported to the grid, which can be carried forward indefinitely. Additionally, SaskPower offers a DR program for large industrial customers capable of reducing power by 5 MW from a single location, to aid in the shift of power usage when electrical demand is high.

Manitoba



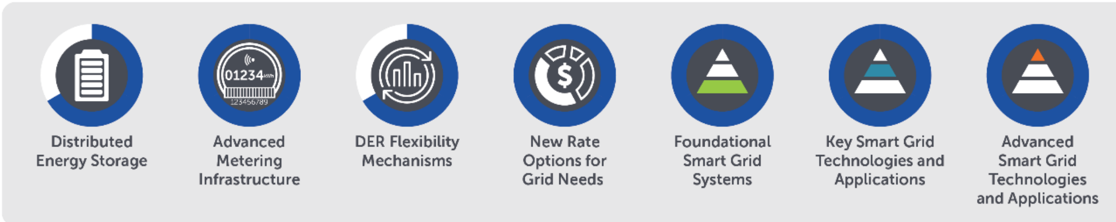
Manitoba's smart grid initiatives, including smart grid automation, modernization, and RE integration, are being driven by system adequacy and reliability needs, upgrading of aging infrastructure, and opportunities to reduce operation and maintenance costs.

Currently, Manitoba Hydro, the province's vertically integrated utility, is targeting automation on 55 distribution circuits within the City of Winnipeg and deploying remote switching control on 14 sub-transmission circuits in rural Manitoba. In addition, work is continuing to install intelligent monitoring equipment on the secondary network system.

Supporting RE and storage deployment, Manitoba Hydro has connected approximately 1,140 DERs, composed primarily of small rooftop solar PV and ground mount solar PV systems with a median size of 16 kW totalling 36 MW. Manitoba allows up to 100 kW in generation capacity for net billing, with excess electricity credited at about 2.403¢/kWh for 2021-22.

Demonstrating the potential of advanced interval metering, EnerTrend, an energy-profiling tool, uses collected data to give users additional insights into their energy use which can be then used to identify potential cost-saving opportunities. It is offered on a subscription basis by Manitoba Hydro to 134 large industrial and commercial users.

Ontario



Ontario's electricity grid is modernizing and electricity structures are actively evolving. These changes are in large part being driven by the need for distribution adequacy, reliability, power quality, optimal asset use, as well as necessary upgrades to aging infrastructure. Ontario's distributors are beginning to consider investments in the second generation of smart metering.

Like Alberta, Ontario also has an electricity market which, in this instance, includes both energy and capacity, operated by the Independent Electricity System Operator (IESO). Most residential, small business and farm customers pay rates set by the Ontario Energy Board (OEB), with the choice of tiered or time-of-use rates. Ontario has also implemented pilots for residential consumers to test new price structures, such as critical peak pricing, variable peak pricing, enhanced time-of-use ratios, and alternative time-of-use structures. For larger customers, the Industrial Conservation Initiative gives incentives for reducing demand during Ontario's top five peak demand hours over a 12-month period. There are explorations taking place to ensure that incentives and market structures encourage DERs and consumer participation where it creates value for customers. This includes work consultations by the OEB, IESO, and the former Energy Transformation Network of Ontario (ETNO).

Ontario has a net-metering program under which participants can reduce their net electricity consumption, and thus their electric energy costs. Bill credits for electricity sent to the grid can be carried forward for up to one year. The province is also exploring, via a demonstration project, community net metering which will allow bill credits to be shared across multiple participating load accounts and participating generation.

Ontario's Local Distribution Companies continue to invest in grid modernization. The latest smart grid policy developments have included a focus on metering integration: the meter data management system, and the implementation of the Green Button standard by electricity and natural gas utilities. This internationally recognized data standard enables customers to access their data in a consistent digital format and authorize their utility to automatically share their energy data with data applications of their choice. Current and upcoming initiatives address energy efficiency programs, building codes and equipment standards, which form the foundation of electricity conservation and demand management, DER integration at local and regional levels, and regulatory sandboxes.

Formerly convened as the Ontario Smart Grid Forum, ETNO has completed its work. Senior leaders and experts across Ontario's energy sector came together to provide guidance on an efficient and affordable future energy system. ETNO's focus was on recognizing the potential of DERs and how DERs can be effectively integrated as grid modernization progresses. A number of reports have been published, summarizing discussions on DER integration, access to data, and key grid modernization principles: Structural Options for Ontario's Electricity System in a High-DER Future, Improving Access to Data Recommendations, Principles Guiding the Transformation of the Energy System in Ontario, and Distribution System Structures for a High DER Future – A Blueprint to Guide the Local Energy Transition in Ontario. While written for Ontario, several concepts may be applicable across Canada.

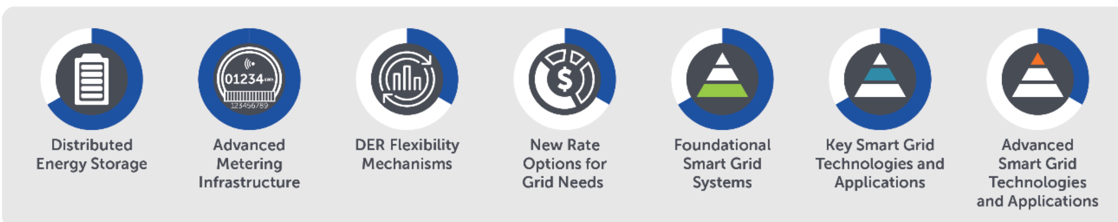
The province is offering programming such as the Local Initiatives Program, which leverages competitive mechanisms that seek to explore how targeted electricity conservation and demand management can be used as a resource to address local and regional system needs identified through the IESO's regional planning process. The IESO Grid Innovation Fund (GIF) has been targeting the performance of new technologies, practices and services, the mitigation of market barriers, and the adoption of cost-effective energy solutions. In 2021, the IESO, GIF and the OEB Innovation Sandbox also held a joint call for innovative R&D proposals that would test the capabilities of DERs in providing services at both the local and provincial levels while providing value to both consumers and the grid. The OEB has also launched its Innovation Sandbox 2.0 to support the generation and adoption of new ideas and technologies within Ontario's energy sector.

There are several innovative smart grid technologies being piloted, demonstrated, and deployed in the province. Oshawa Power and Utilities Corporation is testing and demonstrating supervisory predictive grid controllers for distribution substations for DER management. These capabilities were leveraged by the Solar Energy Management System Homes virtual power plant for battery capacity prediction, microgrid project in collaboration with the University of Ontario Institute of Technology, and EV impact assessment at the distribution level. Oakville Hydro has installed advanced automated outage restoration systems in the downtown core. By modernizing the grid, the impacts of outages on businesses and residents are reduced, increasing economic benefits to the community. If interruptions occur, local equipment automatically determines the location of the fault and reconfigures the grid, quickly restoring service to customers.

Ontario's innovators are also driving grid modernization. At Elocity, a project is underway to demonstrate EVPLUG, a peer-to-peer charging network solution designed to remove barriers to the rapid adoption of EVs. EVPLUG is a smart technology designed to convert chargers into blockchain nodes, enabling public and private owners to share charging stations, providing consumers with greater information on their charging behaviour, and giving electricity providers the capability to manage charging loads and implement EV incentive programs.

The York Region Interoperability and Non-Wires Alternatives Demonstration project, led by the IESO with Alectra, is underway to explore market-based approaches to secure energy and capacity services from DERs for local needs, while coordinating across the larger bulk electricity system and studying potential avenues for transmission and distribution (T&D) system interactions.

Quebec



Quebec is largely served by the provincially owned and vertically integrated utility Hydro-Québec (HQ). While most of its non-industrial consumers are on a tiered rate schedule, HQ has introduced dynamic rate options for select customers who can choose between receiving credits for reducing consumption during peak demand events or paying a high peak demand event rate in return for a lower base rate. There are also new rate options for photosynthetic lighting and heating within greenhouses and cryptographic mining applications. Generation capacities up to 50 kW may qualify for net metering, given as a credit that may be carried forward for up to 24 months.

The province's top smart grid drivers are RE targets; new or emerging business and market models; technology and business development; rural, remote and northern electrification; and smart city development. Quebec has 3.9 million smart meters deployed. This smart meter network, in addition to current applications, will be used by HQ's Subsidiary Hilo to complement energy transition technologies and programs, increasing energy efficiency and capturing load flexibility.

Further driving grid modernization in Quebec is the 2030 Plan for a Green Economy to promote electrification and reduce GHG emissions. Under the plan, Quebec will supply 70% of its off-grid energy system needs through renewables by 2025; 1.5 million EVs on the road by 2030, and no sales of new gasoline-powered vehicles as of 2035. Broadly speaking, Quebec is aspiring to be a 'battery' for North America—a flexible source of clean and renewable electricity.

HQ's EVLO ES will soon be deploying a 4 MW/20 MWh battery, made of a self-developed lithium-ion phosphate, in northern Quebec as a first supporting transmission-level grid resiliency for a local community. This technology is also being used in the new Lac-Mégantic Microgrid, which, combined with solar PV and other smart grid flexible load components, allow connected buildings to operate for several hours disconnected from the power grid.

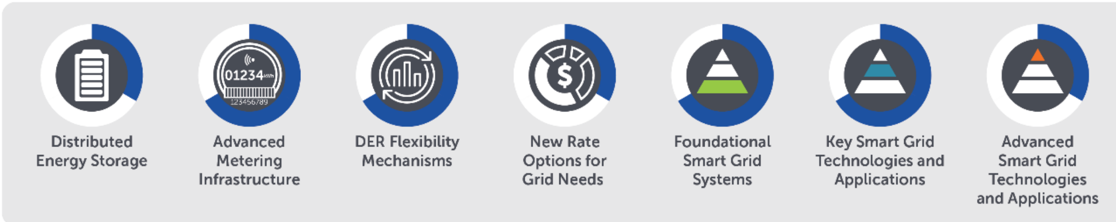
Newfoundland and Labrador

Smart grid modernization in Newfoundland and Labrador (NL) is being driven by needs in transmission adequacy, generation adequacy, reliability to support provincial RE, as well as decarbonization and electrification targets.

NL Hydro, the provincially owned vertically integrated utility serving Labrador, some rural communities along with all industrial customers in Newfoundland, has deployed approximately 19,000 smart meters, with customers able to track electricity usage. Both NL Hydro and Newfoundland Power, the investor-owned utility serving the majority of the island's customers, offer net metering for capacities up to 100 kW; surpluses are credited annually.

Smart grid projects in NL include an engagement from The NunatuKavut Community Council with residents of southern Labrador to create a community-driven clean energy plan and project to reduce diesel. Also, the Nunatsiavut Government is engaging with multiple communities to implement aspects of its Energy Security Plan, having already installed a 50 kW solar PV array in Makkovik, and advancing plans for a number of small-scale projects, ranging from approximately 10 to 50 kW for each project. The Nunatsiavut Government is also advancing the design of a potential larger-scale wind generation and battery storage installation in Nain, the most northerly community in Labrador. There are two off-grid communities in NL in which investor-owned projects are already in service: Mary's Harbour, with a combined small hydro, solar PV and battery storage system; and Ramea, where planning is underway to increase the capacity of existing wind generation and install a battery storage system in the near term.

New Brunswick

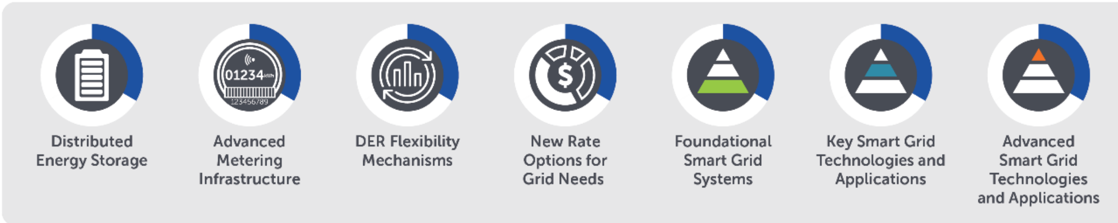


In NB, smart grid modernization is taking form through programs on energy technologies and efficiency, emissions reductions, smart meters, and renewables. These activities are driven by needs related to reliability, resiliency, RE targets, decarbonization and electrification, and new and emerging business or market models.

NB Power, the vertically integrated utility serving most of the province, has engaged in a number of smart grid-related activities. The Peak Rebate Program, offered to commercial and industrial customers, gives a $25 per average kW reduction to DR event calls. Net metering is available for distributed generation up to 100 kW, with credits reset annually.

The Shediac Smart Energy Community Project includes three activities: testing of new smart energy technologies and DERs; NB Power's first utility scale—a 1.63 MW solar PV farm with a 2 MW/4 MWh Fluence battery storage system; and conversion of two commercial buildings to self-sufficient net-zero through integration of DERs and efficiency upgrades. Saint John Energy, a municipally owned utility, has installed a 1.25 MW/2.5 MWh Tesla (lithium-ion) Megapack, which will be used for peak shaving. Saint John Energy's Smart Energy project will use weather forecasts and relevant data to predict peak and valley forecasting when correlated with the utility load shape. This artificial intelligence machine-learned predictability can then be used for system optimization and to deploy utility- and residential-scale batteries, EVs, and thermal storage devices. Additionally, NB Power has a project related to conservation voltage reduction and is demonstrating management of water heaters during peak demand periods.

Prince Edward Island



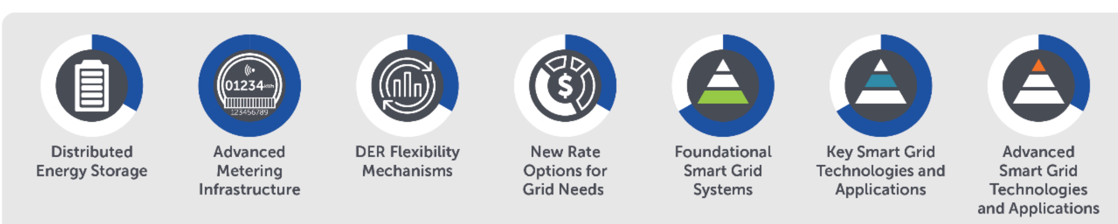
In Prince Edward Island (PEI), initiatives to transition to an electrified, low carbon and sustainable community are being driven by the need for grid reliability and resiliency to respond to natural threats, including those related to climate change.

Ongoing clean energy programs in the province include the Solar Program, which provides up to 40% of the installed costs, up to a maximum of $10,000. Maritime Electric, the investor-owned, vertically integrated utility serving the majority of PEI, administers a net metering program for distributed generation up to 100 kW; credits can be carried forward for one year.

Within the last two years, the latest smart grid developments are related to distribution automation and management systems as well as planning the installation of a transmission line to support wind integration. Summerside Electric is also piloting AMI with 762 smart meters deployed.

In 2020, in addition to lithium-ion units at the Wind Energy Institute of Canada's (WEICan) Wind Energy R&D Park and Summerside's Credit Union Place, the Summerside Sunbank project, a 21 MW solar PV farm and 20 MWh battery storage project in the City of Summerside, saw construction begin. With the provincially owned PEI Energy Corp., the Slemon Park Microgrid project, co-locating ES with 10 MW of solar PV, was also announced.

Nova Scotia



In NS, smart grid initiatives in the areas of energy efficiency, transport electrification, reliability, ES, and solar PV energy are being driven by targets in RE, decarbonization and electrification, and job creation. Recently, in its Environmental Goals and Climate Change Reduction Act, the province committed to a variety of clean energy initiatives, including to a Renewable Electricity Standard of 80% by 2030, coal closure by 2030, and a zero-emission vehicle mandate of 30% by 2030. To help achieve these initiatives, NS has issued an RFP for 350 MW/1,100 GWh of renewables through independent power producers, which will supply 10% of the province's electricity.

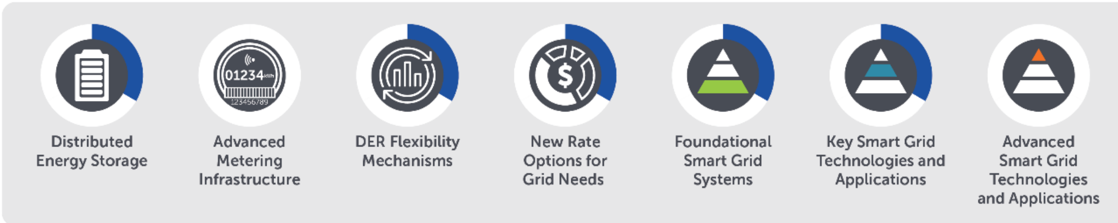
Under its 2020 Integrated Resource Plan, Nova Scotia Power (NSP), the province's privately-owned, vertically integrated utility, identified DR and electrification of transportation and heating as key strategic activities to meet safe, reliable, affordable, clean and robust long-term electricity needs.

NSP has nearly completed their deployment of 500,000 smart meters across the province, with more than 90% of homes and businesses having been upgraded. The utility offers net metering to customers with RE generation up to 100 kW, with virtual net metering also available. Customers with multiple accounts can use personal generators to supply electricity to all accounts if within the same geographical area or distribution zone, allowing credits to be applied to multiple properties within a single zone. In April 2021, the province's net metering regulations were amended to allow third party and shared ownership, allowing projects such as community solar gardens to participate. In addition, the province is increasing the net-metering cap of 100 kW for non-residential, demand-charged customers. Both the community solar garden and increased net-metering cap programs are currently in development. Efficiency NS currently offers homeowners up to $3,000 in rebates for solar PV systems up to 10 kW.

In the community of Elmsdale, NSP with Opus One Solutions and Sustainable Development Technology Canada have an ongoing pilot, the Intelligent Feeder Project, to help manage supply from a local wind farm. Incorporating one 1.2 MW/2.3 MWh grid-sized and 10 residential lithium-ion batteries, this project also enables a number of customers to stay powered during outages.

With federal and provincial support, NSP is also in the midst of deploying their Smart Grid pilot project, which includes a 2 MW community solar garden, commercial rooftop solar PV and battery storage, distributed batteries, and smart EV chargers, including bi-directional capabilities. The province has also seen increased interest in communities for smaller-scale smart grid deployments.

Yukon



The Yukon's top smart grid drivers include increasing and managing power system capacity, maintaining and improving reliability, achieving RE targets, and facilitating decarbonization and electrification, including of its remote communities. Recent initiatives have focused on clean transportation, EV chargers and net-zero communities.

Currently, the Yukon Government has a net-metering program that allows end users to sell surplus energy generated through RE systems. The program reimburses end users by crediting the exported surplus energy, up to the minimum of 65% annual modelled generation-capacity or 32,500 kWh, at higher than retail rates: $0.21/kWh for hydro service areas and $0.30/kWh for diesel service areas. Rebates of up to $5,000 are also available for home RE systems.

In the remote community of Old Crow, the Vuntut Gwitchin First Nation and local utility, ATCO Electric Yukon, collaborated on the Old Crow Solar project. Comprised of a First Nation-owned solar PV and utility-owned microgrid controller and battery, the project has enabled the community to reduce and, at times, shut down diesel generation. In Whitehorse, the installation of a 7 MW/40 MWh grid-scale battery is underway by Yukon Energy, the territory-owned generator and transmitter, which will help reduce peak demand and subsequent diesel generation needs.

Northwest Territories

The Northwest Territories' smart grid drivers include increasing electricity reliability and affordability, reducing GHG emissions and reliance on diesel, and decarbonization. The territory has commissioned studies examining RE integration potential in remote communities and the feasibility of developing EV charging infrastructure.

Net metering is offered through the territory's utility, Northwest Territories Power Corporation, for generation up to 15 kW; excess energy is credited at the retail rate.

Nunavut

Nunavut's clean energy projects focus on increasing understanding of energy use, supporting RE in remote Arctic communities, and reducing GHG emissions. The territory is fostering Community Energy Plans, the first phase of which will focus on understanding the energy landscape and, for select communities, developing comprehensive energy plans. An ongoing project in Sanikiluaq will demonstrate a high-penetration wind and battery system to displace more than 50% of current diesel-based electricity generation.

Standards

Standards bring together proven technical specifications, tests, and procedures to ensure the safety and performance of products and systems. Recent updates on smart grid-related standards are highlighted in this section.

Distribution System Interconnection and Inverter Standards

Standards are being developed to interconnect DERs that will bring new product compliance and safety testing requirements, and will also leverage the inherent grid support functions, especially for inverters. The building blocks to specify interconnection requirements for DERs used by Canadian utilities are the 2018 edition of the Institute of Electrical and Electronics Engineers (IEEE) 1547 standard on Interconnection and Interoperability of DERs with Associated Electric Power Systems Interfaces and the Canadian equivalent standard, CSA C22.3 No. 9 – Interconnection of DERs and Electricity Supply Systems published in 2020[15,16]. For interconnection compliance, IEEE updated the IEEE 1547.1 standard that was published in 2020 under the title IEEE Standard Conformance Test Procedures for Equipment Interconnecting DERs with Electric Power Systems and Associated Interfaces[17]. Efforts are needed in the coming years to perfect the alignment between CSA C22.3 No. 9, which also contains product conformance testing, and the IEEE 1547 series.

While the standards above provide the interconnection framework and conformance requirements, they are not per se product certification standards. An amendment to CSA C22.2 No. 107.1 – Power Conversion Equipment, published in September 2021, requires grid compatibility testing according to C22.3 No. 9 (2020) for products within its scope (DERs that interconnect with distribution systems up to 50 kV line-to-line), and targets the Canadian market[18]. Inverters that do not fall under the scope of C22.3 No. 9 may nevertheless be tested according to it, or choose a different interconnection standard as long as the equipment is marked as prescribed in CSA C22.2 No. 107.1.

Transmission System Interconnection

In 2020, the IEEE began developing a new standard to address transmission system interconnection requirements for inverter-based generation, which is currently under draft IEEE P2800 – IEEE Draft Standard for Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems[19].

Communication and Interoperability

A smart grid has a diverse set of DERs connected that need to be uniquely identifiable within electrical networks and able to exchange data with known interfaces, thus driving the need for communication and common representation models. In addition to hardware, software components also need to interface with each other using unified Application Programming Interfaces (API) and auto-discovery protocols (e.g. Web Service Description Language).

To ensure interoperability, interconnection standards often require compliance with a minimum set of communication standards. For instance, IEEE 1547 requires for equipment to implement at least one of the following protocols:

- IEEE 2030.5 – IEEE Standard for Smart Energy Profile Application Protocol[20]
- IEEE 1815 – IEEE Standard for Electric Power Systems Communications – Distributed Network Protocol (DNP3)[21]
- SunSpec Modbus[22]

Products and systems can implement and use other protocols, as long as they are in compliance with the requirements of their jurisdiction. For example, the International Electrotechnical Commission (IEC) 61850 series of standards has expanded beyond power system substation automation to include support of DERs and Common Information Model (CIM) to ensure better visibility and interoperability[23]. MultiSpeak is another specification being used for interoperability by distribution utilities to streamline the integration of various services, from meter data management to DR events handling[24].

The need for interoperability also extends to the devices meant to control these DERs, namely energy management systems (EMS), DERMS and microgrid controllers. Projects are underway to develop specifications, design, and testing requirements for these foundational smart grid management systems. Standard committees are very active on these topics, notably:

- IEEE 2030.7 – IEEE Standard for the Specification of Microgrid Controllers (published April 2018)[25]
- IEEE 2030.11 – IEEE Guide for Distributed Energy Resources Management Systems (DERMS) Functional Specification (published June 2021)[26]
- IEC 61970 series – Interface de programmation d'application pour système de gestion d'énergie (EMS-API)[27]

Electric Vehicles

The Society of Automotive Engineers (SAE) standard J1772 – EV and Plug in Hybrid EV Conductive Charge Coupler, and its IEC counterpart in the IEC 62196 series, defines a current control pilot to allow modulation of the charging rate of EVs[28,29]. This capability enables an EV Energy Management System (EVEMS) to control EV loading.

In the 2018 edition of the Canadian Electrical Code (CSA C22.1), the terminology of EVEMS was introduced and its capabilities of monitoring and control recognized and allowed[30]. In addition, provisions for bi-directional operation for standby or export to the grid for grid purposes have been included in the code and refer to proper interconnection rules.

While standards exist for bi-directional electrical power converters, such as inverters, these standards do not cover the unique aspects of EVs. Hence, in 2021, the UL and CSA standards organizations initiated the development of a bi-national standard, UL 9741/CSA C22.2 No. 348[31,32]. While its full scope is still in development, this standard is expected to cover safety certification and interconnection of off-board EV power conversion equipment intended to deliver power to loads or the grid from the vehicle battery.

National Networks and Initiatives

Academic Networks

In 2020, the Natural Sciences and Engineering Research Council of Canada (NSERC) Energy Storage Technology Network (NESTNet) came to an end. Supported by $5.2 million from NSERC and $3.5 million from partners, NESTNet brought together 15 universities and 26 utility, industry and government partners to conduct research under four themes: ES technologies; power electronics converters; power systems integration; and economics and policy. During the five-year program, 350 highly qualified personnel were trained, with 124 students graduating. Results form the Network included patents and publically accessible conference, journals, presentations, and reports.

In 2021, Hybrid Thermal Electric Microgrid (HyTEM) received funding of $1.65 million from NSERC and $1 million from Mitacs. Focused on training, the 6-year program led by Simon Fraser University and supported by several university partners, aims to increase knowledge capacity in hybrid microgrids which are integrating DERs, and building heating systems.

Energy Transition Dialogue: Policy Dialogue with Canadian Electricity Modellers

NRCan issued an RFP during the summer 2021 to establish a long-term Energy Transition Dialogue to support ongoing dialogue between Canadian electricity system modellers, policy makers and stakeholders interested in the role of electricity in Canada's net-zero transition. The purpose of the RFP is to support Canada's nascent electricity-modelling ecosystem and provide it with a national forum to elevate its work. The dialogue is to bring Canadian electricity modelling expertise and clean energy policy insight closer to governments and utilities, and help inform complex and far-reaching policy decisions.

This initiative follows the NRCan-funded Energy Modelling Initiative, led by the Institut de l'énergie Trottier during the last two years. The Energy Modelling Initiative conveyed a dialogue within the power system modelling community in Canada. It delivered an inventory of Canadian models, modellers and users, as well as Economic Impacts of Electrification Initiatives models. The Initiative also funded thirty projects which demonstrate modelling and research capacities across Canada, showcasing a range of analytical approaches applied across different scales, including techno-economic and environmental analysis, electricity use, and power system generation.

Canadian Centre for Energy Information

As announced in the 2019 federal budget, the Canadian Centre for Energy Information (CCEI) was as an initiative to create a one-stop shop for energy-related data in Canada. Statistics Canada is leading the Centre, which is still actively evolving, in collaboration with NRCan, Environment and Climate Change Canada (ECCC), and Canada Energy Regulator (CER). Currently, the CCEI web portal houses a searchable and centralized inventory of 750 data products from over 100 data sources, which make energy data more accessible. In addition to the CCEI linking data sets and publications related to different energy sources, trends and uses, it also provides interactive federal and provincial data on a variety of topics including electricity generation, consumption, exports, imports, employment characteristics, and the environment. New data on electricity from heat sources are in development. Additionally, work is also underway to assess the data quality and to make recommendations to coordinate electricity production and trade data, and to develop harmonized concepts on electricity.

Utility Forum

The Utility Forum is comprised of all provincial transmission system operators convened by NRCan and hosted by WEICan to collaborate on common issues related to planning and operating grid transition to a high penetration of RE. Most recently, the Utility Forum completed two projects. The first project, Wind Farm Enhanced Capability Demonstration Project, was performed at NSP's 50.6 MW Nuttby Mountain Wind Farm. It demonstrated wind turbines' capabilities to provide fast-frequency response, power-frequency response and automatic generation control services, which have been traditionally provided by conventional synchronous generators. The second project, Canadian Provincial Grid Code Study, was an initiative to harmonize grid codes across Canada to make it easier for RE integration. The report provides a comprehensive summary of traditional and emerging grid service codes across the provinces. It also gives some relevant international examples, along with recommendations to evolve Canadian provincial grid codes including considerations for the impact that DER uptake will have on the bulk grid.

Cyber Security

The Canadian Centre for Cyber Security, the national authority on cyber security, brings together federal operational cyber expertise from across the government under one organization. This organization acts as a single unified source of advice, guidance, services and support on cyber security operational matters for government, critical infrastructure owners and operators, and the public.

NRCan manages the Cyber Security and Critical Energy Infrastructure Program, launched in 2019, to enhance the cyber security and resilience of domestic and cross-border energy infrastructure through R&D, knowledge transfer, tools, industry standards, best practices and guidelines. Projects funded under this program address gaps in industrial control system cyber security, and strengthen the capability of the energy and utilities sector to prevent, prepare, respond to, and recover from cyber threats and incidents. NRCan is also developing unclassified and classified threat briefing programs for stakeholders who are deemed to be part of the critical infrastructure sector or relevant government partners. The dissemination of protocols within and across government and industry allows NRCan to share important updates faster to relevant stakeholders. In collaboration with Public Safety, NRCan is also contributing to the Critical Infrastructure Gateway online portal to share relevant security and threat information with energy stakeholders.

The NRCan Canadian Resources Infrastructure Resilience Nexus research lab engages in R&D, technology testing, operational simulation exercises, and intelligence and information sharing related to electricity sector technical challenges on security and resilience. Collaborations with industry, academia and government labs explore different fields of research that feed into helping smart grid cyber security—including vulnerabilities in control centers as well as sensor and data analytics.

Canada's Energy Future

Previously the National Energy Board, the Canada Energy Regulator (CER) has been releasing long-term projections since 1967. The Energy Futures series explores how possible energy futures might unfold for Canadians over the long term, using economic and energy models to make these projections. The long-term scenarios are based on assumptions regarding technology innovation, energy and climate policies, energy markets, human behaviour, and the structure of the economy.

With the Government of Canada's commitments toward moving to NZE by 2050, the Canada's Energy Future 2021 report takes a first step towards modelling a net-zero future with six net-zero scenarios of Canada's electricity system. These scenarios show potential pathways that the grid may have to adapt to, and highlight the importance of today's smart grid RDD&D.

International Collaborations

International Smart Grid Action Network

Canada is a founding member of the IEA Technology Collaboration Programme on Smart Grids, the International Smart Grid Action Network (ISGAN). There are currently 26 country governments and the European commission supporting high-level engagement for the accelerated development and deployment of smarter, cleaner, more flexible, and more resilient electricity grids. The network enables a diverse range of activities which support a better global understanding of smart grids—and the value they offer—by addressing gaps in knowledge and tools, enhancing peer-to-peer exchange, and improving international coordination.

The ISGAN organizes its activities into streams within nine standing working groups (WG). Canadian national experts participate actively in WG 2 on Smart Grid Case Studies, WG 4 on Synthesis of Insights for Decision Makers, WG 5 for the Smart Grid International Research Facility (SIRFN), WG 6 on Power T&D Systems, and the newly formed WG 9 on Flexibility Markets.

A summary of smart grid drivers and technology trends in ISGAN member countries was released to better understand how smart grid has evolved over the years. Additional publications have explored new developments and given insights on utility digital transformation, micro versus mega grids, improving interoperability across information communication technology systems, T&D system technology deployment and market analysis, EV integration, and ES systems.

The study of transmission system operator and distribution system operator interactions has gained particular traction, with a first deliverable synthesizing lessons learned on projects mainly in Europe. There were also several activities related to flexibility, including workshops on local energy systems and the future power system, and a presentation at the 12th Clean Energy Ministerial (CEM) about power system flexibility.

The SIRFN, a collaboration between the research facilities of 15 member countries, seeks to improve smart grid international testing and evaluation capabilities. The work is geared towards increasing grid operator confidence in smart grid technologies. Recent publications and presentations include a survey of lab testing methods using real-time simulation and hardware-in-the-loop techniques, development of interoperable DER certification protocols, microgrid testing, power system testing, and advanced laboratory testing methods.

A series of interactive knowledge transfer workshops was organized on regulatory sandboxes. A regulatory sandbox casebook was published and presented at CEM12, which included the OEB Innovation Sandbox project along with four policy messages.

Following the success of this project, an international Community of Practice was struck for countries, including Canada, to continue conversations on regulatory experimentation and innovation.

The third 5-year work program of ISGAN was recently approved. Between 2022-2027, ISGAN will continue to accelerate actions addressing climate change focusing on customer-centric solutions, including electrification across sectors and building secure digitalized systems. Furthermore, there will also be an emphasis on the role of smart grids in pandemic recovery in order to support the global efforts of attaining NZE economy-wide by 2050, and NZE in the power sector even sooner.

In partnership with the Global Smart Energy Federation, ISGAN is also responsible for the annual ISGAN Award of Excellence, showcasing leadership and innovation in smart grid projects worldwide. The 2021 competition recognized exemplary projects in the field of smart grids with special focus on future proofing the grid operation via advanced digitalization and the Internet of Things. The winning project, The Smart Energy Project by Saint John Energy in NB, Canada, was announced as the winner at CEM12 held in June 2021 in Santiago, Chile.

Honourable mentions were also given to Canadian projects in 2020 for "Digitalization Enabling Consumer Empowerment" to London Hydro for Digitizing the Customer Experience with Real-Time Control, and in 2019 to the City of Summerside's MyPowerNet project and Oshawa Power & Utilities Corporation Energy Service's Solar EMS Smart Grid Pilot for "Local Integrated Energy Systems (Smart Microgrids)".

Mission Innovation – Green Powered Future Mission

Canada is an active participant in Mission Innovation (MI), a global initiative of 22 countries and the European Commission, launched at the 21st session of the Conference of the Parties (COP), in 2015. MI countries work together to catalyze action and investment in research, development and demonstration to make clean energy affordable, attractive and accessible to all this decade.

During MI's initial phase, Canada showed leadership in supporting the governance and international delivery of the initiative, met its target to double spending in clean energy research, development and demonstration, and participated in all eight of MI's Innovation Challenges (ICs), including IC1 on Smart Grids. The second phase of MI (MI 2.0) was launched in June 2021, stimulating a decade of global action through public-private Missions that set ambitious innovation goals. These missions target the rapid uptake of technology adoption, through overcoming barriers in cost, performance, or scale of clean energy solutions.

The Green Powered Future Mission (GPFM) co-led by China, Italy, and the United Kingdom, is one of MI 2.0's seven Missions. The GPFM will continue work on smart grids initiated under IC1 during the first phase of MI. Canada participates in the GPFM coalition as a Support Member, sharing knowledge and contributing technical expertise and analysis to inform the Mission's work. The GPFM aims to demonstrate that, by 2030, power systems in different geographies and climates are able to effectively integrate up to 100% VRE in their generation mix and maintain a cost-effective, secure, and resilient system. Through large-scale demonstrations and enhanced investments in R&D, Mission members will develop a toolbox of innovative solutions to provide confidence that all countries can build a renewable-powered future, and realize an affordable energy transition.

Canada participates in and contributes technical expertise and analysis in support of all three pillars of the Mission. The pillar on Affordable and Reliable VRE Technologies is focused on reducing cost and increasing efficiency, resilience, and reliability in various climates and system configurations. The pillar on System Flexibility and Market Design is focused on flexibility solutions to meet network infrastructure needs, supported by regulation and innovative market design. The final pillar on System Integration, Data, and Digitalization is focused on accelerating the digitalization of energy systems through development of interoperable data exchange and effective system integration to unlock the full value of VRE. Each of these pillars has identified 'tipping points' in support of the Mission's 2030 goal, as well as specific innovation priorities, and areas of interest for pilot and demonstration projects.

In November 2021, at COP26, the GPFM released its Joint Roadmap of Global Innovation Priorities. This Roadmap and its identified innovation priorities will help to inform the development of a targeted Mission 2022-24 Action Plan outlining specific activities and demonstration projects to support the Mission's 2030 goal. By participating, Canada is supporting international collaboration on innovative solutions to enable effective integration of VRE into electricity systems, which will be important to achieve NZE by 2050.

Summary and Outlook

A smart, modernized, and flexible power grid plays a critical role in providing affordable, GHG-free energy solutions to all of Canada's citizens and economic sectors, especially seeing as demand accompanying electrification is expected to increase significantly. Policies, regulations, and markets will need to support new solutions, participants and business opportunities to realize this technological achievement while keeping infrastructure investments sustainable and affordable. Federal, provincial, and territorial investments in RDD&D can catalyze smart grid advancement by providing a mechanism to engage collaboratively with stakeholders to explore and adopt innovative technologies and business models.

Overall progression in the smart grid can be measured by the degree of monitoring and control, level of automation, number of actively participating grid elements, and strength of customer and system integration. The role of the smart grid technologies and applications, namely, where they fall in this progression, can be categorized into one of three maturity levels shown in Figure 8.

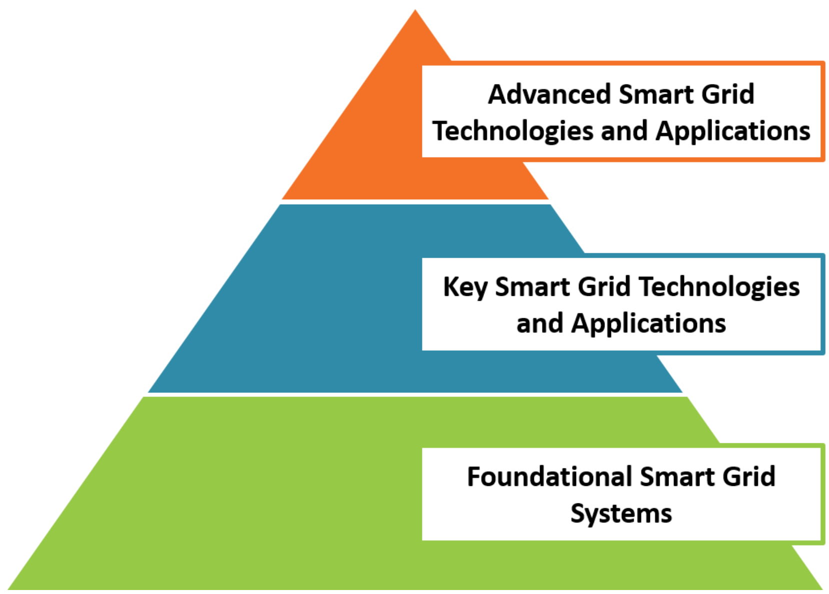


Figure 8: Smart Grid Progression of Technologies and Applications

Foundational smart grid systems, providing the backbone of a smart grid, have been deployed by most provinces and territories; as of 2019, distribution automation and outage management systems have been adopted the most, closely followed by substation automation, SCADA, circuit topology and asset management technologies and applications.

The last two years have seen significant gains across Canada in the deployment of *key smart grid technologies and applications.* Now widespread, a large part of the gains are due to the deployment of AMI and smart meters, which is a key enabler to modernizing utility business and customer relationships. As a key digital solution, AMI and smart meters allow for customer integration with other utility functions (e.g. outage management and automated billing systems). Other applications being explored include DERMS, DR, advanced sensors, and microgrids.

Advanced smart grid technologies and applications have not yet been broadly deployed and remain mostly at the pilot stage. Voltage and reactive power management projects as well as advanced customer information platforms are the most pursued and, to a lesser degree, optimization analytics and self-healing grids.

Canada has a diverse generation mix that varies across provinces and territories; electrification and GHG reduction goals will drive changes through the adoption of new clean and renewable resources. New and upgraded utility assets need to be better utilized, in addition to leveraging and supporting customers to become active grid participants. Customers are shifting consumption patterns with increasing penetration of DERs, including adopting new electrification solutions, and creating a unique opportunity for the grid to tap into BTM flexibility potential. Since several of these deployments are happening at local levels, T&D coordination is becoming increasingly important. However, for this to happen, there are several technical, regulatory, economic, and social challenges that need to be addressed. Several smart grid challenges and developing areas are discussed below.

Variable Renewable Energy

VRE resources are becoming more widely deployed, driven by decarbonization goals and decreasing technology costs—especially of wind and solar PV. At current and expected near-term levels, VREs do not present a significant challenge to the electric grid. However, as the penetration of VREs rises and becomes more dominant, new smart grid solutions will be required to facilitate their integration.

The impact of integrating VREs to the grid varies from location to location. Hosting capacity—the technical considerations for how much VRE the grid can handle without requiring modifications to maintain its safety, reliability and power quality—must thus be calculated in a very granular manner. Establishing a common methodology to determine and present hosting capacity could simplify interconnection for distributors, regulators, vendors, and customers. Integrating VREs into the electric grid at high penetrations presents a number of challenges: often inverter-based, VREs can have electrical characteristics different than the conventional synchronous generators they are supplementing or replacing; VREs add additional variability to the grid, in turn requiring more grid flexibility; many VREs are distribution connected, requiring new approaches to power system protection and control to accommodate changing power flows; and VRE ownership can take many new forms, requiring suitable market and remuneration structures.

Inverter-Based Resources and Advanced Inverter Functions

The prevalence of inverter-based resources, including solar PV, batteries, and some wind, on the electric grid is rapidly increasing. These resources have different operating characteristics from the synchronous-based resources that dominate today. As these types of resources are increasingly connected, new inverter capabilities, known as AIFs, will need to be used. New equipment coming to the market today are required to implement these functions to be able to support the grid now and in the future. While generally well understood, deployment is for the most part at its infancy (e.g. capabilities are requested but not necessarily enabled). The determination of when and how to use AIFs are current R&D topics.

Inverters are also characterized by their grid interaction method, for example, following the lead of the grid (grid-following), or being capable of forming a grid (grid-forming). At low to mid penetrations, grid-following modes will be sufficient. Grid-following standards have been established and are continuing to evolve. At high penetration though, research indicates that grid-forming modes will be required to ensure grid stability and provide grid restoration capabilities after a major outage.

The understanding of the grid characteristics with a significant fraction of inverter-based generation will be critical to achieving higher penetrations of VREs. Further research into the application of grid-following inverters, such as their settings and coordination with distribution protection and control systems, is required. Much more research is needed into grid-forming inverter capabilities and their application to the grid.

Hydrogen

There exists a connection between VRE and hydrogen, as described in the Hydrogen Strategy for Canada, to reach decarbonization targets. Green hydrogen, which is produced from RE, can be used for RE balancing and grid flexibility acting as an ES system. By extension, the hydrogen produced by VRE then allows for other sectors to decarbonize despite not being connected to the electric grid.

Hydrogen-related technologies—electrolyzers, fuel cells, storage, and hydrogen vehicles—are not yet economically mature. There are several sub-sectors, such as in transportation and industry, where hydrogen's high energy density can replace existing fossil fuels and support cross-sector decarbonization. Low production volumes and adoption rates are among the reasons why hydrogen-related technologies are not yet cost-competitive. The ability to predict and understand long-term hydrogen demand patterns is essential to plan for seamless scaling up of hydrogen-related technologies within future smart grids.

Cross-Sector Electrification

Cross-sector electrification will have a significant impact on Canada's power grid and will require huge investments in related infrastructure. Activities by NRCan, ECCC, and other organizations are ongoing to help inform policy, utilities and industry on how this transition can be economically achieved.

The electric power grid needs significant upgrades to supply both the energy and power required for cross-sector electrification. Without a cohesive strategy, such upgrades will be inefficient, adding significant costs and possibly threatening the safe and reliable operation of the grid. For each sector, strategies are required to identify the prime targets for electrification and the technology development required to make it possible. Grid impacts must also be estimated, which in turn will be used by the grid to determine the most efficient techno-economic paths forward. There will exist an opportunity for electrified loads to provide flexibility, not only through electricity but also thermal inertia, as hot water and space heating systems have already proven.

Electric Vehicles

Zero-emission vehicle uptake, especially of battery electric vehicles, is increasing. New power electronic charger interface standards are in development and enabling applications for V2G. While electric charging infrastructure is being widely deployed across Canada, smart charging implementations are limited.

The unpredictable and unmanaged charging of EVs will add significant new peak power demands to the electric power grid. Smart charging, through the smart grid, can provide utilities with the flexibility to reduce these peaks of power demand, and thus minimize the capacity costs of associated charging infrastructure. Taken one step further, such smart charging approaches can even be used to store VRE, and perhaps reinject it at a more convenient time when the grid is starved for power. However, there are significant regulatory and technical challenges that need to be investigated, including gaining a better understanding of EV charging and battery aging patterns. Additionally, products to allow for such technical features must be developed, certified and adopted.

Flexibility

Currently, the equilibrium between load and generation is mainly achieved through large, centralized generators. However, loads can also participate to the effort by offering flexibility; that has been demonstrated through DR programs. Applications seen today are mostly limited to peak shaving at the industrial and, to a lesser degree, residential sectors. More complex grid service applications of DR, like regulation, are very limited; however, loads could be an alternative to fossil-fuel backed plants or expensive batteries for such applications.

Flexibility will be needed to address variability and uncertainty for a decarbonized grid with high penetration of VRE and changing load patterns amplified by electrification. As the grid continues to modernize, new types of grid services will also be needed at local levels to maintain the quality of service customers expect. Especially with the assortment of loads electrification will introduce, identifying and capturing their unique flexibility opportunities can enable cost-effective and better integrated systems, deferring capital expenditures for infrastructure upgrades.

In addition to understanding how much flexibility is needed to support a grid that meets all NZE targets, the value DERs can bring needs to be better quantified. For cases where flexibility can be harnessed from DERs with smaller capacities, aggregators can play a key role in tapping into this potential. Flexibility applications need to be more widely accepted as a non-wires alternative to meet grid technical and economic needs. Further research and demonstration is required to understand how to control and harness the flexibility potential across DERs.

Creating markets and other mechanisms to acquire load-based flexibility will be unique depending on the structure of the electricity system and regulatory environment. Net metering exists in almost all jurisdictions to produce, consume and sell RE; however, the way in which DERs will be compensated for providing grid services is yet to be determined. Methods will be needed to coordinate between local distribution and bulk transmission grids to effectively integrate flexibility while considering procurement, visibility and control aspects, like Transactive Energy (TE) for example. With loads gaining more DER capabilities, there are opportunities to better manage voltage and reactive power, thereby allowing the system to operate more efficiently.

Microgrids and Remote Microgrids

Canada's remote communities have unique systems with no interconnections, limited long-term storage options, and often no to limited road access; additionally, northern communities have harsh climates. Eliminating their dependence on fossil fuels is essential for achieving healthier populations and net-zero objectives. Despite the challenges, there are several microgrid projects using batteries in combination with RE to reduce reliance on diesel.

Microgrid solutions for remote and northern communities are more expensive because of the isolated nature of these locations, which adds to costs and limits access to readily available expertise and equipment. Further R&D is required that both empowers the communities and addresses their unique technical challenges.

On the interconnected system, there are a few microgrid projects focusing on resiliency that demonstrate the ability to transition from a connected to islanded system while sustaining minimum priority loads. While lower battery and RE costs are making connected and remote microgrid deployment easier to attain, they are not yet widely feasible from an economic and technical perspective.

Cost-benefit challenges remain when it comes to creating microgrids where a seamless transition between connected and islanded states is possible. The idea of DC microgrids, which may bring improved energy efficiency by reducing conversion losses, is also gaining traction. However, there is a lack of DC standards and guidelines, which requires significant amount of R&D to accomplish.

Cyber Security

In a Statistics Canada Survey, 39% of Canadian energy and utility businesses reported being impacted by a cyber incident in 2019[33]. Cyber threats are increasingly becoming a concern as more Internet-of-Things devices are connected to critical infrastructure. The smart grid relies on several connected devices to provide data acquisition and control in order to operate the grid. These devices, including DERs, are becoming more connected, from customer appliances to industrial plants to communities and cities with significant data being exchanged across electricity and IT networks alike. Utilities are working to protect the grid and customer data from all forms of intrusion. Information and communication technologies continue to be developed and tested in order to improve cyber-physical systems.

Seeing as the smart grid is critical infrastructure, the system needs to be resilient and demonstrate integrity in its operation. The continuous improvement of cyber security measures and practices is required to protect the system. The task of uncovering cyber security vulnerabilities and implementing solutions will be an ongoing challenge. Best practices must be consistently improved related to building security into every layer of the smart grid architecture, protecting internal and customer data, and testing the system for vulnerabilities. Further investigation of novel methods and approaches to protect networks and customer data will be needed to safeguard the smart grid. As these risks span across multiple sectors, collaboration may help to develop better solutions to address cyber security threats.

The smart grid is continuing to evolve with modernization efforts underway as the electricity sector transitions to NZE. To achieve these targets, electricity structures will need to adapt to allow for a just, equitable, diverse and inclusive transition across all stakeholders, with an emphasis on customers. All provinces and territories across Canada are moving at different paces given their respective priorities, but many drivers including RE targets, grid reliability, and decarbonization through electrification, are shared. Further work will be necessary to address the different contexts for remote and northern communities, rural communities, and urban centres when it comes to modernization efforts. New technological solutions and methods, including those involving inverters and EVs, will need to be further researched, demonstrated and deployed. New participants, offering flexible loads and distributed generation, will both challenge and offer solutions to utilities as electrification advances. However, standards and regulations need to evolve in step with these advancements to bring about their adoption as the smart grid deployment continues.

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Appendix

Glossary

Term	Definition
Advanced Inverter Function (AIF)	AIFs are a set of features or capabilities enabling inverter-based generation or storage units to support the grid during normal operation and disturbance conditions. Necessary to integrate higher numbers of inverter-based generation, they can provide (e.g. voltage and frequency support) as well as ride-through (i.e. remaining connected for a short period following a fault) capabilities.
Advanced Metering Infrastructure (AMI)	AMI is the deployed smart meter and associated communication networks enabling automated methods of electricity data collection. AMI can be integrated with other utility systems like operations, outage management or customer billing, to assist in distribution planning, improve reliability, or introduce new rate options.
Demand Response (DR)	DR is the change in a load's power consumption, away from typical, in response to a grid need. While typically associated with peak shaving (demand reduction during peak periods), it can encompass any flexibility service provided by loads. It is generally instigated i) based on a schedule; ii) directly by control or instructional signal from a utility; iii) directly by control signal from a third party aggregator; or iv) indirectly through price signals.
Distributed Energy Resource Management System (DERMS)	DERMS is a platform using real-time control capabilities to manage collections of DER to provide grid services both locally (e.g. through volt-var control) and to the bulk grid, via regulation.

Term	Definition
Energy Storage (ES)	ES is a unit or system that can i) withdraw electric energy in one period for injection at a later period or ii) withdraw electric energy in one period for consumption (electric or otherwise) at a later period. These technologies can be used for energy arbitrage, balancing variable RE sources, increasing reliability or resiliency, or providing ancillary services such as frequency regulation or reserves.
Grid Automation (GA)	GA is the digitalized monitoring, measurement, and subsequent automated protection and control, of – in the context of this report – distribution networks. It represents the capability of the grid to autonomously react to current conditions including service interruptions. It includes, for example, fault location, isolation and service restoration (FLISR), fault detection, isolation and restoration (FDIR), and other technologies and methods to increase the capacity of the distribution grid to reroute power to ensure system reliability. A fully automated grid requires little to no intervention from a grid operator.
Microgrid	Generally, a microgrid is a local electric grid with a collection of renewable DG, flexible and non-flexible loads, and optionally storage that, through automated communication and controls, can operate either in a connected mode or independently of other microgrids or a larger grid.
New Rate Options for Grid Needs	New rate options for grid needs are new electricity tariffs for electricity that are structured to alter consumption by better reflecting grid needs and service costs.

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