Pathway Study on Demand Side Management and Energy Storage in Ottawa

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The City of Ottawa
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Executive Summary

This paper examines the role of demand side initiatives in electricity and thermal energy, including demand response, conservation and time of use pricing, with a particular focus on electrical and thermal energy storage.

Electricity production has lower GHG emissions in Ontario than in many other jurisdictions. However, conservation demand management (CDM) and electricity storage can further reduce greenhouse gas emissions in multiple ways. Electricity demand peaks—which are met by natural gas generation in Ontario—can be reduced through demand response, conservation and time of use pricing. Electricity storage can also time-shift renewable electricity generation to displace natural gas electricity generation at peak periods, further decreasing the GHG intensity of typical grid-supplied electricity.

In heating systems, natural gas Demand Side Management (DSM) reduces energy demand. Thermal energy storage supplements low carbon fuel sources to displace natural gas heating as an aspect of district energy or other systems.

Currently, Ontario has a surplus of baseload electricity generation, which can be used in power-to-gas or power-to-thermal storage applications to displace natural gas heating demands. The electrification of heating and transportation systems will also displace fossil fuel use, which will reduce their associated emissions. The resulting increased electricity demands will reduce the surplus baseload periods. CDM and electricity storage will be required to mitigate future peaks by reducing demand, as well as increasing the inclusion of variable renewable energy generation.

Section 1: Present Assessment of DSM and Energy Storage

Pathway Description

This paper examines the role of Demand Side Management (DSM) and energy storage in a low carbon future for the City of Ottawa.

Energy DSM programs reduce greenhouse gas (GHG) emissions by reducing overall energy consumption through conservation and energy efficiency. DSM includes technologies, policies and strategies that reduce or modify energy demand, targeting energy efficient devices, time-shifting energy loads and energy conservation. DSM also includes energy storage, innovative energy pricing structures, and policies that target efficient buildings, appliances and processes. In the context of electricity in Ontario, DSM is referred to as Conservation and Demand Management (CDM), and this term will be used in this document when discussing electricity.

This paper has a particular focus on the role of energy storage. Energy storage technologies store energy for use at a later time. In traditional electricity systems, electricity must be used as it is generated, requiring considerable system oversight and ongoing processes to turn generation on and off to ensure that supply meets demand at a given moment. Electrical storage technologies transform electricity into other forms of energy (chemical, mechanical potential, magnetic), a process which is then reversed to release electricity at a later time, either injected back into the electrical grid, or to be used directly in applications. This process enables the capture of excess thermal or electrical energy at certain times, storing it for use at other times, thus avoiding additional generation.

Energy storage enables increased use of variable renewable energy (VRE) in heating and electricity systems by reducing the time discrepancy between VRE generation and actual energy demand.[1] Electricity storage increases the utilisation of each unit of electricity generating capacity, while also reducing the overall electricity capacity required to address spikes in demand. Additionally, surplus electrical energy can be transformed into thermal energy and stored for periods during which heating and cooling services are required.

Electricity storage technologies can also encourage the electrification of the transportation and heating sector, by providing flexibility in the supply of electricity, and alleviating the impact of potential demand spikes associated with new demand from electric vehicles and electric heating systems.

Energy storage and DSM strategies add complexity to energy distribution, but can provide many benefits including potential cost savings, supply reliability, resilient distribution, and emissions reductions.

Pathway Boundaries

This pathway examines the role of DSM, CDM and storage within thermal and electricity energy systems in Ottawa, including system benefits, drivers and barriers to uptake, and opportunities to reduce GHG emissions. The study provides background information, focusing on high level descriptions of technologies and policies and noting the relevance of these systems to the context of Ottawa. The current pathway section explores existing deployment in Ontario and Ottawa and identifies the opportunities which are most significant locally. Finally, this paper examines the future pathway, using modelling to explore and potential DSM, CDM and storage options for the City.

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[1] IEA. (2014). Technology Roadmap: Energy Storage.

Background Information

Demand Side Management

DSM is a broad term that incorporates strategies and technologies that modify or reduce energy demand. In Ontario, electricity and natural gas providers are required to provide DSM programs to customers.

Electricity

DSM is referred to conservation and demand management (CDM) in relation to electric utilities in Ontario, and includes the following program structures:

Demand response (DR) seeks to reduce electricity use at a given moment, often at peak demand. DR programs often allow energy customers to sell a reduction in energy use at peak demand, referred to as 'negawatts' by Hydro Ottawa.[2] The key principle is to encourage peak demand reductions, rather than increase supply. DR is more easily achieved with large consumers of electricity which can individually cause considerable peak load reductions by curtailing their energy demand and can easily compete in auctions for energy use reductions. Currently, class A accounts (users that exceed 5 megawatts for the applicable base period) and any organization with a peak demand of more than 1 MW are eligible for DR.[3] DR strategies for residential or small commercial customers rely on intermediaries that pool a group of residential customers in the sale of energy reductions. Examples of DR strategies include adjusting temperatures to draw less electricity during peak heating/cooling periods, turning off production processes in industry during peak demand, and using "behind the meter" generation or storage during peak periods. DR will become increasingly critical to managing costs as the share of intermittent renewable energy in the electrical system increases.[4]

Innovative pricing structures also provide incentives for energy customers to reduce use, often at peak times. Time-of-Use pricing structures make electricity more expensive during peak demand periods, encouraging consumers to shift energy use to low demand periods. Examples of time of use pricing structures include variable pricing for on and off peak and prices that include seasonal critical peak pricing.[5] One study found that pricing strategies combined with solar PV battery storage can result in mean peak net demand reductions between 46% - 64%, reducing mean net demand fluctuations by 25% - 49%, and increasing the mean solar PV self-consumption between 24% - 39%.[6]

Electricity CDM programs also encourage uptake of energy efficient appliances, buildings and materials. Utilities frequently provide rebates and incentives to consumers who purchase energy efficient lights, appliances and other electrical plug loads.

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[2] Hydro Ottawa. (2016). Strategic Direction 2016-2020.

[3] IESO (2017) Demand response: A smart approach to energy management.

[4] The value of electricity and reserve services in low carbon electricity systems. (n.d.). https://doi.org/10.1016/j.apenergy.2017.05.094

[5] Ministry of Energy. (2017). Ontario's Long-Term Energy Plan: Delivering Fairness and Choice. Government of Ontario.

[6] Babacan, O., Ratnam, E. L., Disfani, V. R., & Kleissl, J. (2017). Distributed energy storage system scheduling considering tariff structure, energy arbitrage and solar PV penetration. *Applied Energy*, *205*, 1384–1393. https://doi.org/10.1016/j.apenergy.2017.08.025

Natural Gas DSM

Natural gas utilities in Ontario are required to provide customers with tools to reduce natural gas consumption, predominantly through energy efficiency upgrades.[7] For residential and commercial customers, this includes incentives for high efficiency heating and cooling systems, building retrofits, as well as energy management devices (ex, programmable thermostats) that encourage conservation by the building occupant. Industrial DSM programs range from energy management advice to specific system upgrades.

Demand Response programs can also be applied to natural gas systems, but are mostly used to minimize the impacts of gas shortages. Many natural gas suppliers have interruptible service contracts for large consumers that use natural gas for industrial processes, rather than heat. In signing an interruptible supply contract, natural gas customers may have their supply interrupted in exchange for lower distribution fees. Customers with over 340,000m³ of natural gas use are eligible to sign an interruptible service contract with Enbridge.[8] Natural gas DR programs can also include smaller and residential customers using energy management systems. An example program is the Advisory Thermostat Program by Southern California Gas, where participants agree to adjustments to their programmable thermostat for a $50 rebate.[9]

Natural gas DSM is critical to an energy evolution in the City of Ottawa. Natural gas consumption is a major contributor to Ottawa's greenhouse gas emissions, as most residential, commercial and industrial heating needs are met by natural gas.

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[7] Ontario Energy Board (2017). 2018 to 2021 Business Plan. Retrieved from: https://www.oeb.ca/sites/default/files/OEB-2018-2021-business-plan.pdf

[8] Enbridge. (2019). Handbook of Rates and Distribution Services.

[9] Navigant. (July 25, 2017). Natural Gas Demand Response – Current Utility Programs: Part 3. Retrieved from: https://www.navigantresearch.com/news-and-views/natural-gas-demand-response-current-utility-programs-part-3.

Energy Storage

Electricity Storage

Electricity storage technologies influence electricity supply and demand in a variety of ways, performing various grid services that benefit the electricity system.

Figure 1: Services provided by electricity storage technologies.[10]

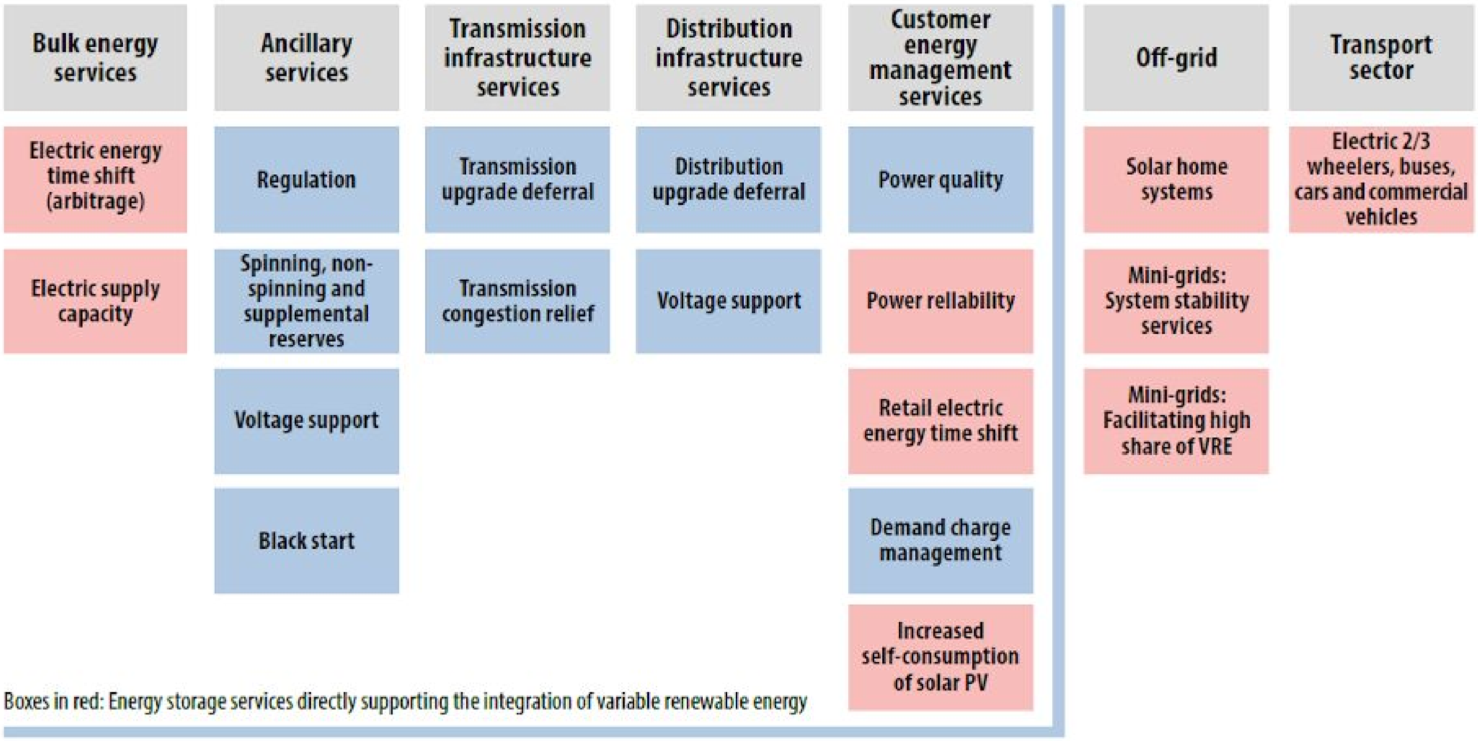

Figure 1 illustrates some of the services provided by energy storage:

- Bulk energy services refer to the role of storage in balancing energy supply and demand at a system level. As an example, seasonal storage systems store energy for days to months in order to reduce the discrepancy between seasonal supply and demand.
- Ancillary services refer to maintaining an ongoing balance between electricity supply and demand on a minute-to-minute basis, providing additional voltage support and system reliability.
- Transmission and distribution infrastructure services refers to the ability of storage to alleviate congestion in transmission and distribution infrastructure and to locally shift demand at peak hours. In this context, energy storage can be used to defer investments in transmission and distribution infrastructure.[11]
- Customer energy management uses energy storage to provide reliable supply to consumers. Generally, more relevant to larger industrial loads, it is increasingly being used at the residential level, when coupled with rooftop solar PV systems. This can allow customers to

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[10] IEA. (2017). Electricity and storage costs 2017.

[11] Department of Energy. (2013). DOE/EPRI 2013 Electricity Storage Handbook in Collaboration with NRECA. Sandia National Laboratories.

engage in time-shifting activities, often to reduce energy demand at peak times to reduce costs.[12]

- Off-grid services refer to the use of storage to provide for off-grid or micro-grid systems that provide enhanced system reliability and reduce overall system costs. Off-grid storage can better incorporate renewables services to replace diesel, natural gas and propane generators.

- Electrification of transportation refers to the use of storage to support the electrification of transportation vehicles.

The services described above can be achieved through various storage technologies, each of which has different characteristics and capabilities.

Batteries: Electricity charges chemical reactions within electrochemical cells, transferring electrical energy to chemical energy. Batteries have terminals of different chemicals, often metals. Electrolytes separate the two terminals but allow for the flow of ions between the cells. Wiring attached to the terminal connects the flow of ions to be used as electricity.

Solid state batteries are at the commercial phase, including lead-acid and lithium-ion batteries, the latter used in electric vehicles. Flow batteries are still in development and rely on chemical anodes dissolved in liquid. Flow batteries can be instantly recharged by replacing the battery liquid and are considerably more energy dense than solid state batteries.

Batteries range considerably in scale and can be placed at various points in the electricity system, depending on the service they are providing. A large-scale battery connected to the transmission system can provide time shift services controlled by the electricity system operator. Smaller scale battery storage at the distribution level is also becoming increasingly common. These smaller modules are often paired with rooftop solar PV, and can reduce overall electricity demand for electricity customers, and can increase reliability in remote areas.[13] Decentralized batteries at the distribution level can also re-inject electricity back into the distribution system, acting as distributed energy resources.

Batteries are used in transportation electrification, where electricity is used as a substitute for fuel. Deployment of electric vehicles can also act as distributed energy resources for local electricity distribution systems, releasing electricity from vehicle batteries back into the grid as required. This integrated vehicle-to-grid storage model is still in development, but greater integration of EVs both as loads and as sources could provide further flexibility to the grid, while displacing transport fuels and their associated emissions. Vehicle-to-grid storage raises concerns of battery life and degradation, as EV batteries would be charged and discharged more frequently than if used only for driving.[14] EV grid integration will also require sufficient smart grid communications to be effectively deployed.

The wide range of applications and declining module costs have created momentum for the application of batteries in electricity storage. Batteries make up a considerable portion of the projects already developed in Ontario, as procured by Ontario's Independent Electricity System Operator (IESO), including a lithium ion module that was installed by Canadian Solar for Hydro Ottawa at the Ellwood Energy Storage Project.

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[12] Weniger, J., Tjaden, T., & Quaschning, V. (2014). Sizing of Residential PV Battery Systems. *Energy Procedia*, *46*, 78–87. https://doi.org/10.1016/j.egypro.2014.01.160

[13] IRENA. (2015). Battery storage for renewables: market status and technology outlook.

[14] Uddin, K., Dubarry, M., Glick, M. (2018). The viability of vehicle-to-grid operations from a battery technology and policy perspective. Energy Policy, 113, 342-347.

Batteries are suitable for deployment in Ottawa for a variety of reasons. First, there are few geographical limitations, and batteries can be scaled up and down, depending on the service it is providing. This means that batteries can be placed in various places in Ottawa, from rooftop storage to large grid storage applications. Rural and vacant industrial lands can provide suitable locations for grid scale projects. Ongoing declining costs also makes battery deployment increasingly viable.

There are some concerns that widespread deployment of batteries may have adverse environmental and emissions impacts from mining and manufacturing battery components.[15] Successful decarbonization of energy systems will mean that life cycle emissions will become an increasingly important contribution to total emissions over time.

Power-to-thermal energy: This approach uses electricity during low cost periods to generate thermal energy using either a boiler or air or ground source heat pump. A relatively small volume of storage, which is typically hot water, can displace subsequent periods when natural gas is lower cost than electricity. Additional benefits include redundancy in the building heating system, the simplicity of the technical approach and the ability to act as a bridge to a broader electrification strategy. The system also provides flexibility for capturing the surplus power from renewable electrical generation in periods of low demand, thus encouraging additional renewable generation. Power-to-thermal is currently feasible in Class A accounts with real time response to hourly prices and the payback can be under ten years.[16]

Hydrogen: Electricity can be used to produce hydrogen through electrolysis. Hydrogen can be used directly in transportation, injected into the natural gas grid, or can be re-converted back to electricity. North America's first grid scale hydrogen storage project is in Mississauga, a collaboration between Hydrogenics and Enbridge. Electricity is converted to hydrogen gas at periods of low demand, which can be injected into local natural gas networks, for use in heating and industrial processes. This process is an example of power-to-gas technology. Hydrogen power-to-gas systems can displace a portion of natural gas use, which can reduce the associated GHG emissions. However, safety and feasibility studies are still required prior to widespread deployment.[17] It is estimated that local natural gas distribution networks could safely accommodate hydrogen injection rates of 5%-15%, with local case by case variation.[18]

Hydrogen storage can also be used in passenger vehicles, using fuel cell technology. Hydrogen vehicles are only just reaching commercialization, with one available model in Canada, the Hyundai Tucson Fuel Cell Electric Vehicle (FCEV). Major automakers are pushing forward on hydrogen FCEV models, but vehicle availability and filling station networks are sparse. There are also safety concerns associated with hydrogen storage, and safety standards have not been widely established.

Hydrogen storage and power-to-gas have important relevance in Ottawa. There are no geographical constraints, and power-to-gas applications target GHG emissions reductions from natural gas use, which are a critical lever for Ottawa. As one of the first commercial operations is in Ontario, there is opportunity to leverage expertise from project successes within a similar regulatory environment.

Ice Storage: Ice storage systems use electricity to create ice during periods of low demand, to be used for cooling in periods of high demand, often in the summer. This approach is often used in commercial air conditioning systems, with approximately 1,000 MW of ice storage capacity in the United States.[19] Ice storage can also be classified as thermal energy storage because it influences heating and cooling systems. Ice storage has relevance to power-to-thermal applications by

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[15] Rohmare, M. Dahllof, L. (2017). The Life Cycle Energy Consumption and Greenhouse Gas Emissions from Lithium-ion Batteries. No. c243.

[16] Personal communication with the City of Ottawa, 2018.

[17] Melaina, M., Antonia, O., Penev, M. (2013). Blending Hydrogen into Natural Gas Pipeline Networks: A review of Key Issues. National Renewable Energy Laboratory.

[18] Ibid.

[19] IEA. (2014). Technology Roadmap: Energy Storage.

providing short term storage for cooling resources, and time shifting electricity demand from cooling.

Pumped storage: Pumped storage uses electricity to pump water from a lower elevation reservoir to a higher elevation reservoir in periods of electricity surplus, storing electrical energy as gravitational potential. In periods of electricity demand, the water is then released back down to the lower reservoir to spin a turbine, to produce electricity to be re-injected back into the electrical grid. Pumped storage is the most mature energy storage technology, and accounts for over 99% of global energy storage capacity in 2014.[20] There is only one pumped storage facility in Canada, located on the Niagara River in Southwestern Ontario. The Sir Adam Beck Pump Generating Station is a 174 MW storage facility.[21]

Pumped storage is limited by regional geography, requiring an elevation differential of at least 100m and a large surface area for effective system design, and therefore is limited in the City of Ottawa.

Compressed Air Energy Storage (CAES): CAES uses electricity at periods of low demand to compress air in underground or pressurized storage tanks or caverns. When electricity is needed, air is released to a combustor to generate electricity. As air is pressurized, it must be cooled, releasing waste thermal energy; the air must be reheated (often by natural gas) in order to be used, which results in lower system efficiency and thermal energy loss. Advanced adiabatic compressed air energy storage (AA-CAES) addresses the use the of natural gas during heating phase by using waste heat generated during the initial air compression, resulting in greater efficiency and lower associated emissions. Simple CAES technology has a much lower system efficiency, with estimates at approximately 25-40%, while adiabatic CAES can see efficiencies of up to 70%.[22]

One of the world's first underwater AA-CAES storage facility is operated by Toronto Hydro, NRStor and Hydrostor in Lake Ontario. Electricity is used to compress air into accumulators at the bottom of Lake Ontario. When electricity is required, the pressure of the lake water forces air back up to the surface into an expander, which drives a generator.[23] Hydrostor is also moving forward on a similar system in an abandoned mine in Goderich, Ontario.

CAES is also limited in the City of Ottawa because it has few, if any, accessible underground or deep-water resources for tank pressurization. Hydrostor's Lake Ontario AA-CAES system is at a depth of approximately 54m.[24] The Ottawa River could be a potential site for an underwater CAES, with the deepest point of the river at 90 m, although feasibility studies would be required to assess site viability.

Other electricity storage technologies are more suited to ancillary services and electricity system regulation. These include flywheels, supercapacitors and other electricity storage technologies that provide short bursts of energy. These projects are generally associated with transmission infrastructure. While these can potentially have relevance to the City, they do not directly influence emissions reductions.

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[20] IEA. (2014). Technology Roadmap: Energy Storage.

[21] Ontario Power Generation. Sir Adam Beck Pump Generating Station. Retrieved from: https://www.opg.com/generating-power/hydro/southwest-ontario/Pages/sir-adam-beck-pgs.aspx

[22] Elmegaard, B., & Brix, W. (2011). Efficiency of Compressed Air Energy Storage. In The 24th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems: The 2011 conference motto: International Smart Energy Networks of Cooperation for Sustainable Development.

[23] Toronto Hydro. Compressed Air Energy Storage Project. Retrieved from: https://www.torontohydro.com/sites/electricsystem/gridinvestment/powerup/pages/compressedairenergystorageproject.aspx

[24] Tweed, C. (November 25, 2015). Toronto Hydro Pilots World's first Offshore Compressed Air Energy Storage. Greentech Media. Retrieved from: https://www.greentechmedia.com/articles/read/toronto-hydro-pilots-worlds-first-offshore-compressed-air-energy-storage#gs.6ohWI0s

Thermal Energy Storage

With the exception of some buildings in rural areas which are outside the natural gas grid, most heating needs in Ottawa are met by natural gas, an inherently storable fuel. Thermal energy storage technologies are used to reduce supply variability from low carbon sources of heat, which can displace natural gas use. Thermal energy storage is effective when included in district energy systems, and there are examples of thermal energy storage technologies at the building level. Renewable heating sources such as industrial waste heat, biomass, solar thermal, geothermal and renewable electricity can be combined with storage in district energy systems. District energy with thermal storage is well developed in Denmark, Netherlands, Sweden and Germany, and there are a growing number of successful projects in Canada. The following thermal energy storage technologies have relevance to emissions reductions in Ottawa.

Underground Thermal Energy Storage (UTES): A heated or cooled working fluid, often water, is pumped underground into aquifers or boreholes for later use. Underground thermal energy storage is most applicable to medium temperature thermal requirements, such as building heat. UTES can effectively store heat seasonally, by collecting solar thermal energy for use in the winter. It can also improve the efficiency and feasibility of ground source heat pumps by improving system feasibility in the winter. The technology is well developed in Sweden, where 20% of heat demand is associated with borehole thermal energy storage.[25] UTES systems are used in both individual buildings and in district energy systems.

The Drake Landing Solar Community in Okotoks, Alberta is a key Canadian example of UTES. In this district energy system, solar thermal energy is generated in periods of high solar insolation. The heated water is pumped below ground in boreholes, to be used later and throughout the year. The system provides enough space heating for 52 detached high efficiency homes. Five years into its operation, the system is still performing at high efficiency.[26] The Drake Landing example represents an important example for Ottawa, because it experiences a similar annual temperature profile, and has similar residential development patterns.

In addition to a solar thermal storage operation, a system which stores excess thermal heat in the ground from a variety of energy sources such as low-cost electricity, solar thermal and waste head can be used to increases the performance of a geothermal system. University of Ontario Institute of Technology developed such a system to heat eight buildings on campus with three hundred and eighty-four boreholes.[27]

Pit storage: Heated or cooled water is pumped into shallow pits filled with gravel and covered in insulating materials. Pit storage is frequently used in conjunction with district energy systems. It has been deployed successfully in Denmark, storing solar heating during the summer for use in the winter. In Denmark, pit storage is fairly simple to build and is relatively low cost, making it an attractive option.[28] Pit storage could be feasibly introduced in Ottawa with a connection to district energy systems or large buildings if there is sufficient surface area. The space requirements for pit storage limits this type of system in urban areas.

Snow storage: Snow storage systems use waste snow to provide cooling to buildings. In Ottawa, snow is collected and left to melt in disposal sites and facilities. Because snow is considered a waste stream, snow storage can have lower operating costs, while displacing energy for cooling. The first

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[25] Harris, M. (2011). Thermal Energy Storage in Sweden and Denmark Potentials for Technology Transfer. Lund University, thesis.

[26] Sibbit, B., McClenahan, D., Djebbar, R., Thornton, J., Wong, B., Carriere, J., Kokko, J. (2012). The performance of a high solar fraction seasonal storage district heating system – five years of operation. Energy Procedia, 30, 856-865.

[27] University of Ontario Institute of Technology (2003). Canada's newest university has one of North America's largest geothermal well fields. Retrieved from: https://news.uoit.ca/archives/2003/11/20031107_1.php

[28] Ibid.

commercial snow energy storage operation is a cooling system at a hospital in Sundvall, Sweden.[29] Collected snow is stored in an insulated tank, and as it melts, the water is fed through a heat exchanger, which cools circulating air in the building.

Snow storage is technically feasible in Ottawa, as the City receives 175 cm of snowfall annually.[30] However, there are technical concerns with declining or variable snowfall in relation to changing climate conditions.

Hot water storage: Insulated tanks are used to store hot water on a short-term basis. A common example of this technology is domestic hot water heaters, which are commonly used across Ottawa and North America. Natural gas hot water heaters do not contribute to GHG emissions reductions. However, when heat is generated using low carbon or renewable energy sources, such as solar insolation and waste heat, short term storage can maintain hot water supply, avoiding the need for natural gas and the resulting greenhouse gas emissions.

In particular, hot water storage has applications in power-to-thermal electric heating. Hot water can be generated by electricity in low demand periods and stored to provide thermal energy for heating, reducing the need for natural gas. The City of Ottawa has successfully pioneered this approach with a mock operation study, which predicted reduced GHG emissions and costs.

Costs

Capital costs for many electricity storage technologies are high, but are rapidly changing and are expected to decline with further uptake. The International Renewable Energy Agency (IRENA) estimates that by 2030, stationary battery costs could fall by 50-60%.[31] Actual project costs are very site, technology and jurisdictionally specific, which makes cost estimates difficult to apply at the local level.[32] The costs of grid-scale batteries range based on the technology, system and size of application.

The most cost-effective electrical energy storage technologies are those that can provide multiple applications. Under IESO planning, DSM and energy storage technologies are procured based on the services the storage provides, rather than the technology type and the cost of the solution. This principle fits in within the IESO's Market Renewal Initiative, in which generation, storage and DR compete in one market auction.

Once installed, grid scale electricity storage can provide economic benefits. The avoided costs of purchasing electricity at peak times is dependent on the time of system charge and discharge times. When storage is used to defer investments in new transmission or distribution investments and development, or defer the development of new generation infrastructure, energy storage often presents financial savings from a grid operation perspective. The avoided costs of purchasing electricity at peak times can also provide financial benefits for system owners.

In contrast, thermal energy storage technologies are generally more mature, and have lower capital costs.

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[29] Region Vastlnorrdland. Snow Cooling in Sundsvall. Retrieved from: https://www.rvn.se/v1/In-english1/In-english/Environment-and-energy/Energy-Factor-2/Snow-cooling-in-Sundsvall

[30] Environment and Climate Change Canada. 2018. Canadian Climate Normals 1981-2010 Station data. Retrieved from: http://climate.weather.gc.ca/climate_normals/results_1981_2010_e.html?searchType=stnName&txtStationName=Ottawa&searchMethod=contains&txtCentralLatMin=0&txtCentralLatSec=0&txtCentralLongMin=0&txtCentralLongSec=0&stnID=4333&dispBack=0

[31] IRENA. (2017). Electricity Storage and Renewables: Costs and Markets to 2030.

[32] Ibid.

Technologies examined in this report are summarized in Table 1. It should be noted that system costs are case specific, and the values shown are for illustrative purposes.

Table 1: Characteristics of sample energy storage technologies.[33, 34]

Technology	Location	Suitable storage duration	Output	Energy Capital Cost ($USD/kWh)	Efficiency	Maturity
Pumped Hydro	Supply	Long term; hours-months	Electricity	$5-100	50-85%	Mature
CAES	Supply	Long term; hours-months	Electricity	$2-120	27-70%	Commercial (AA-CAES in demonstration)
Lead-acid batteries	Supply, Demand	Minutes-days	Electricity	$50-400	75-95%	Mature
Lithium-ion batteries	Supply, Demand	Minutes-days	Electricity	$600-3800	75-95%	Commercial
NaS batteries	Supply, Demand	Long term	Electricity	$300-500	75-95%	Early Commercial
Hydrogen	Supply, Demand	Hours-months	Electricity	$15	22-50%	Demonstration
Underground Thermal Energy Storage	Supply	Long term; hours-months	Thermal	$2.6[35]	50-90%	Mature
Pit Storage	Supply	Medium term	Thermal	$1-7[36]	50-90%	Mature
Ice / snow storage	Demand	Short term; hours-days	Thermal; low temp	$2-5[37]	75-90%	Commercial
Hot water storage	Demand	Short-term; hours-days	Thermal	--	50-90%	Mature

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[33] Luo, X., Wang, J., Dooner, M., Clarke, J. (2015). Overview of current development in electrical energy storage technologies and the application potential in power system operations. Applied energy, 137, 511-536.

[34] IEA. (2014). Technology Roadmap: Energy Storage.

[35] Lanahan, M., Tabares-Velasco, P. (2017). Seasonal Thermal energy Storage: A Critical Review on BTES Systems, Modelling, and System Design for Higher System Efficiency. Energies, 10, 743, doi:10.3390/en10060743

[36] IEA. Task 45: Seasonal pit heat storages - Guidelines for materials & construction. IEA-SHC TECH SHEET 45.B.3.2. Retrieved from: http://task45.iea-shc.org/data/sites/1/publications/IEA-SHC%20T45.B.3.2%20TECH%20Seasonal%20storages%20-%20Water%20Pit%20Guidelines.pdf

[37] Lanahan, M., Tabares-Velasco, P. (2017). Seasonal Thermal energy Storage: A Critical Review on BTES Systems, Modelling, and System Design for Higher System Efficiency. Energies, 10, 743, doi:10.3390/en10060743

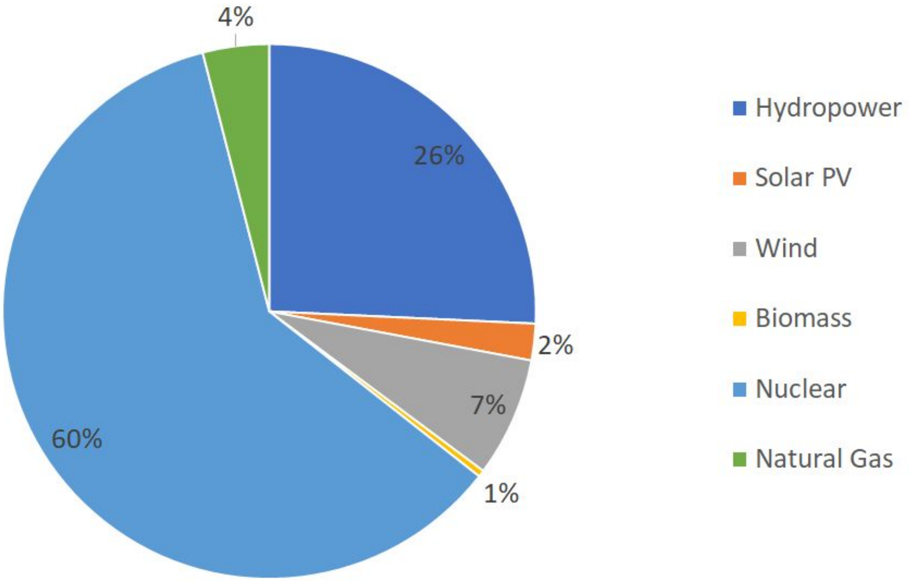
Evaluation of Current Pathway

The following section outlines the ways in which DSM and energy storage can contribute to emissions reductions in the City of Ottawa. Electricity pathways are examined first, followed by thermal energy pathways. Ongoing developments in DSM and energy storage are also considered, highlighting major opportunities for emissions reductions in Ottawa.

Electricity pathway

Ontario's electricity mix is made up primarily of nuclear, followed in order of prominence by, hydropower, natural gas, wind, solar and biomass, displayed in Figure 2. While Ontario is increasing its capacity of renewable electricity, it is also adding increasing amounts of natural gas fired generation to address electricity peaks and system reliability.[38]

Figure 2: Ontario electricity generation mix in 2017.[39]



Ontario's electricity baseload comes primarily from carbon-free sources. During peak periods when demand is greater than Ontario's baseload generation, natural gas fired generators are deployed because natural gas generators can ramp up quickly and can provide stable supply. As a result, marginal emissions factors can be nearly four times the average emissions factor for electricity.[40] Peak demands occur daily, with critical peaks in the summers and winter, due to heating and cooling needs. Ontario's annual average hourly electricity demand in 2016 is displayed in Figure 3. Electricity demand increases over the course of the day, with the greatest demand in the early evening.

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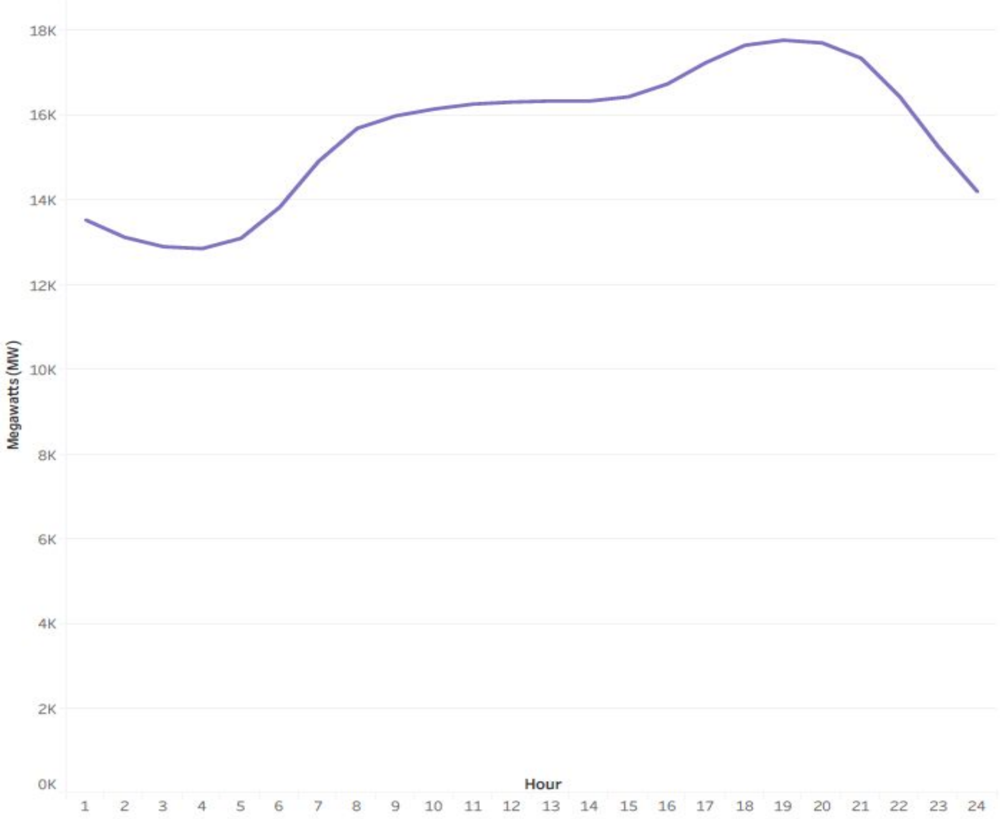
[38] IESO. (2016). IESO Report: Energy Storage.

[39] Ontario Energy Board. 2018. Ontario's System-Wide Electricity Supply Mix: 2017 Data. retrieved from: https://www.oeb.ca/sites/default/files/2017-supply-mix-data.pdf

[40] The Atmospheric Fund. (2017.). A clearer view on Ontario's emissions: Practice guidelines for electricity emissions factors. Retrieved from http://taf.ca/wp-content/uploads/2017/08/TAF_Guide_Ontario_Emissions_Factors_Digital_2017-08-03.pdf

Figure 3: Average Annual Hourly electricity demand.[41]



Electricity storage and electricity CDM can displace the need for natural gas peaking generation. If energy storage technologies can store variable renewable energy over the day or seasonally, and that storage technology can quickly inject power into the grid at peak demand periods, then there is some opportunity for displacing natural gas use.[42] Electricity conservation and DR programs can also reduce electricity demand, which decreases the need for natural gas fired generation. However, Ontario's ramping requirements can be as high as 10,000 MW, which will make the complete elimination of natural gas use difficult.[43]

Baseload supply is often greater than electricity demand for many hours of the day, and at multiple times of the year.[44] This is referred to as surplus baseload generation (SBG). Ontario is in SBG 66% of the time, most frequently in the spring and fall seasons.[45] In these periods, electricity is often exported, wind and solar generation are curtailed, or water spillover is enabled at hydropower stations.[46] Electricity storage presents an opportunity to mitigate differences in supply and demand in SBG periods. Seasonal storage technologies in particular will be useful to store excess electricity in the spring and fall, for use in the summer and winter.

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[41] National Energy board (2018). Market snapshot: Why is Ontario's electricity demand declining? https://www.neb-one.gc.ca/nrg/ntgrtd/mrkt/snpsht/2018/03-03ntrlctrctdmnd-eng.html

[42] IESO. (2016). IESO Report: Energy Storage.

[43] Ibid.

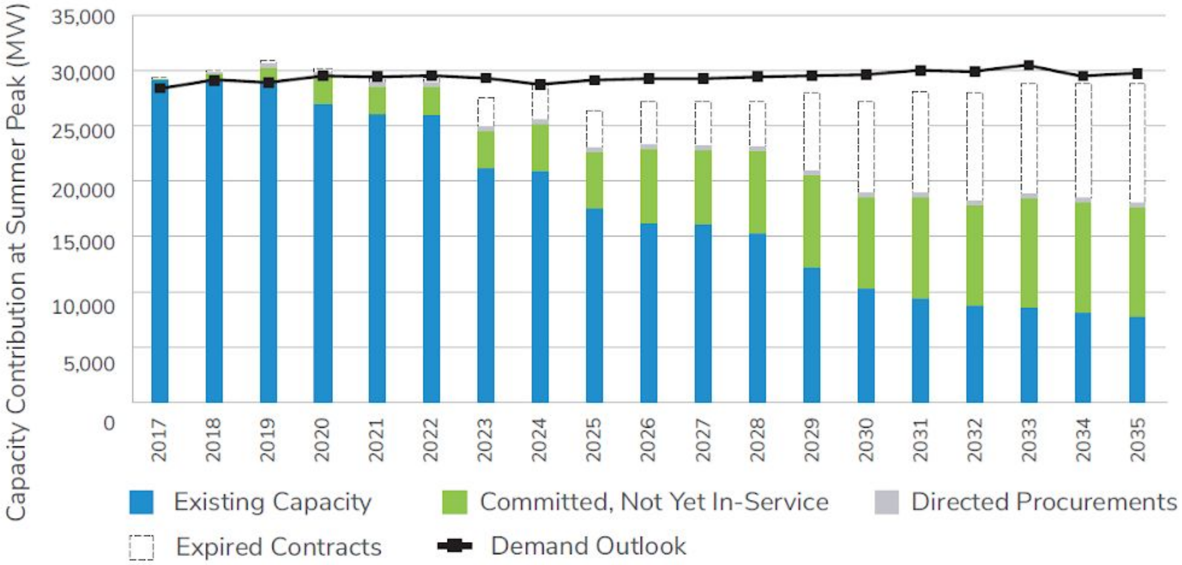
[44] Ibid.

[45] Ibid.

[46] Environmental Commissioner of Ontario. (January 20, 2017). Surplus Baseload Electricity Generation in Ontario. Retrieved from https://eco.on.ca/blog/surplus-baseload-electricity-generation-in-ontario

According to the IESO, Ontario is expecting to be in frequent SBG periods up until the mid 2020s.[47] After this, declining SBG in the coming years is partially because of planned changes in nuclear generation: the Bruce, Pickering and Darlington Nuclear Generating Stations provide the majority of electricity in province, but the Pickering station is slated for retirement and the Bruce and Darlington generating stations are undergoing refurbishments over the coming decade.[48] Future supply and demand at peak hours is shown in Figure 4.[49]

Figure 4: Supply and demand outlook in Ontario.[50]



In order to keep the emissions associated with electricity relatively low, this supply gap will need to be met with continual operation of plants whose contracts have expired, or with new renewable electrical capacity. Electricity storage will become an important tool to ensure that variable renewable energy can feasibly meet capacity requirements. The intermittency of wind and solar is a barrier to high levels of renewable electricity deployment, as energy supply must consistently match energy demand. IRENA estimates that storage will be needed to provide stable baseload electricity when variable renewable electricity exceeds 30% of system capacity, or 20% if the grid infrastructure is constrained.[51] Electricity storage technologies that can provide short term storage of minutes to hours to 'smooth' out differences between variable renewable electricity supply and demand will be important in Ontario, but because Ontario experiences large seasonal peaks in the summer and winter, IESO estimates that seasonal storage will be even more critical for the province.[52]

Additionally, the Ottawa electrical zone is considered a congested load zone, meaning that at peak demand, electricity needs to be imported from other regions of the province and transmission lines are often at maximum capacity.[53] This has implications for electricity storage technologies for multiple reasons. According to the IESO, this can potentially limit the uptake of storage technologies where electricity is not re-injected into the grid, such as EVs, power-to-gas and power-to-thermal applications, as these forms of storage can increase electricity demand if they draw electricity at peak times.[54] In relation to increasing EV uptake, this makes vehicle-to-grid two-way charging and

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[47] IESO. (2016). IESO Report: Energy Storage.

[48] Ministry of Energy. (2017). Ontario's Long-Term Energy Plan: Delivering Fairness and Choice. Government of Ontario.

[49] Ibid.

[50] IESO. (2016). Ontario's Long Term Energy Plan.

[51] IRENA. (2015). Renewables and Electricity Storage: A technology roadmap for Remap2030.

[52] IESO. (2016). IESO Report: Energy Storage.

[53] Ibid.

[54] Ibid.

vehicles as distributed energy resources an important system design feature to ensure successful EV uptake.

Ottawa's congested transmission infrastructure also presents a need for local time shifting energy storage to increase local electricity available at peak demand,[55] while DSM activities such as time of use pricing and DR programs can reduce overall peak loads when congestion is greatest.

Electricity CDM Deployment

At the highest level, the Government of Ontario has committed to a conservation first approach to energy planning in the province, a low-cost option for reducing emissions and matching electricity supply and demand.[56] The government has also required that all utilities in the province have mandatory DSM targets, in an effort to reduce consumer loads. CDM efforts are projected to cover 5% of Ontario's electricity demand by the year 2025.[57]

Demand response and time of use pricing specifically target electricity conservation at peak demand periods. Because Ontario's peaks are generated primarily by natural gas, demand response activities disproportionately reduce natural gas fired generation in comparison to Ontario's lower carbon baseload electricity.[58]

CDM initiatives at the provincial level are ongoing at multiple agencies. The Ontario Energy Board approves electricity prices and has set Ontario's time of use pricing structure. Currently, time of use pricing in the province has two separate pricing structures for summer and winter, with differing prices for off-peak, mid-peak and peak demand. Figure 5 displays TOU pricing as of May 1, 2018. The Ontario Energy Board is currently examining the Regulated Price Plan and reviewing time of use pricing structures to ensure fairness and alleviate peak demand periods.[59]

Figure 5: Time of use electricity pricing for residential customers, as of May 1, 2018.[60]

Off-Peak: 6.5 cents/kWh	**Mid-Peak: 9.4 cents/kWh**	**On-Peak: 13.2 cents/kWh**

The Industrial Conservation Initiative (ICI) is a demand response tool that encourages the largest consumers (referred to as Class A) to reduce electricity consumption at peak periods by offering financial incentive on global adjustment (GA) costs. Eligible participants must have an average monthly peak demand of over 500kW at an individual load facility, averaged over a twelve-month period.[61] Participants pay GA costs related to their contribution (as a percentage) to the largest five hourly peak demand periods over one year. This incentivizes large consumers to reduce demand, especially during critical annual peak demand periods. Global adjustment costs are paid by all customers and include charges for infrastructure, debt repayment and other charges.

In one example provided by the IESO, a Class A consumer could save approximately $31,801 in one year on GA rates by significantly reducing demand at peak load periods.[62] The ICI program is estimated to have reduced peak demand by over 1,400 MW in 2017.[63] The program has been

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[55] Ibid.

[56] Ministry of Energy. (2017). Ontario's Long Term Energy Plan: Delivering Fairness and Choice. Government of Ontario.

[57] Ibid.

[58] The Atmospheric Fund. (2017). A clearer view on Ontario's emissions: Practice guidelines for electricity emissions factors.

[59] Ibid.

[60] Hydro Ottawa. Time of Use Pricing. Retrieved from: https://hydroottawa.com/accounts-and-billing/residential/time-of-use

[61] IESO. (2018). Industrial Conservation Initiative Backgrounder April 2018.

[62] Ibid.

[63] Ibid.

successful because it combines effective cost reductions for consumers to critical peaks. Alleviating critical peaks in Ontario reduces generation infrastructure requirements.

The IESO also recently piloted 100 MW of DR resources.[64] The DR pilot engaged three large electricity consumers in the province in load-following, where the participants could adjust electricity demand on an hourly basis, in return for financial payments. Ongoing uptake of DR fits within the IESO's vision for the Market Renewal Initiative, where storage, demand response, generation and other grid operations participate in an inclusive auction, based on the service provided. IESO's market renewal initiative aligns with Order 745 by the US Federal Energy Regulatory Commission (FERC), stating that demand response is allowed to bid on the same terms as generation in electricity markets.[65]

Hydro Ottawa administers IESO funded CDM programs, including various financial incentives for conservation. For Hydro Ottawa, CDM activities conserved 414.9 GWh of electricity between 2011 and 2014, reducing the energy use of approximately 54,000 homes in the City.[66] The estimated cost of such activities is placed at $0.044/kWh, which is a lower cost than electricity generation.[67]

Hydro Ottawa is also piloting a decentralized and automatic demand response program for residential customers, outlined in Figure 6.

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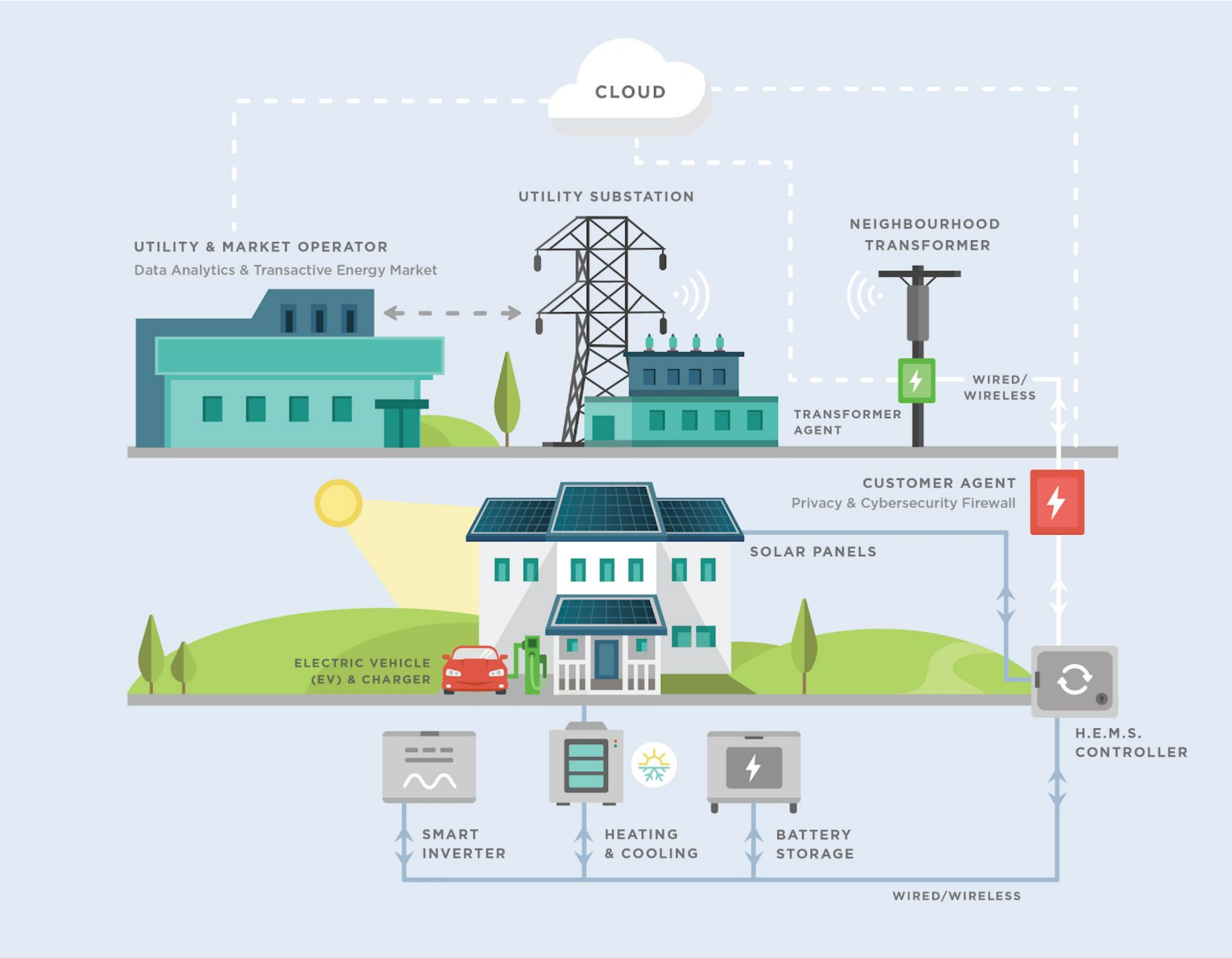
[64] IESO. (2015). IESO Demand Response Pilot Program.

[65] Hydro Ottawa. (2016). Strategic Direction 2016-2020.

[66] Ibid.

[67] Ibid.

Figure 6: Great DR program design.[68]



The Grid Edge Active Transactional Demand Response (The Great DR) program is connecting residential customers to demand response activities, including the ability to control electricity use based on periods of demand.[69] The program will optimize transformer level electricity use between customers using a device (transactive agent) placed at the transformer to allow transactions between customers. The Great DR is to have 30 participants, with each participating home receiving an energy management system, solar panel, smart inverter, lithium ion battery and a bi-directional meter. The program will provide information on optimizing local electricity loads, solar PV, stationary home batteries and EV's in one integrated system.

As a complementary approach to managing the electricity peaks, the City of Ottawa also has a power-to-thermal pilot project which takes advantage of low electricity costs during periods of surplus generation. Electric boilers are dispatched, displacing natural gas consumption, resulting in reductions in GHG emissions and energy costs. The feasibility study, Supplemental Use of Electric Water Heating for Environmental and Cost Reduction, mock operated such a system at City Hall and has demonstrated a viable opportunity in heat electrification.

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[68] Hydro Ottawa. (2018). The Great-DR. Retrieved from: https://hydroottawa.com/save-energy/residential/great-dr
[69] Hydro Ottawa. The Great DR. https://hydroottawa.com/save-energy/residential/great-dr

Electricity Storage Deployment

Agencies in Ontario are actively pursuing electricity storage development. The IESO brought electricity storage pilot projects online in 2012, through the Alternate Technologies for Regulation program. The first round procured a capacity of 6 MW, piloting a battery project and a flywheel project, which were used successfully for regulation.[70] IESO also performed a 50 MW Grid Energy Storage Procurement to investigate energy storage across multiple regions of Ontario. Technologies procured in the program included flow and solid-state batteries, hydrogen, and a compressed air project.

The Government of Ontario Smart Grid Fund provided support to 45 grid modernization projects across the province, including support to electricity storage developments. This included funding for battery energy storage projects in Niagara, Toronto, Sudbury and Ottawa. The fund also supported EV integration and automated grid developments. Hydro Ottawa is associated with multiple projects that were awarded funding under Ontario's Smart Grid Fund, including a battery storage project with eCamion, piloting a secure payment system for EV charging with the University of Ottawa, the Great-DR program as mentioned above, and a study on inverter technology.

Deployment of energy storage in Ottawa is currently small but growing. Hydro Ottawa is committed to grid innovation and sustainable energy services, as outlined in its Strategic Direction Report.[71] This is apparent in the involvement of Ottawa Hydro in projects associated with the Smart Grid Fund. Other energy storage initiatives in Ottawa include the deployment of Level 2 electric vehicle chargers across the City, as well the residential batteries in its Great DR Program. Hydro Ottawa is also involved in the Ellwood Energy Storage Project, a pilot facility for transmission-connected lithium-ion battery storage, procured through the IESO.[72]

Heating Pathway

Natural gas represents one of the largest sources of emissions in Ottawa, due to heating requirements in the winter. Natural gas DSM works by reducing overall natural gas use to reduce emissions. Thermal energy storage influences GHG emissions reductions because it allows for feasible use of renewable and waste sources of heat in district energy systems or in individual buildings.

Natural Gas DSM Deployment

Natural gas utilities are required to provide demand side management activities for customers under the Ontario energy Boards' Demand Side Management Framework for Natural Gas Distributors.[73] Enbridge Gas Distribution supplies Ottawa's natural gas.

Enbridge's programming for DSM is separated into three groups: Resource Acquisition, Low Income and Market Transformation. Resource acquisition and low-income programming are comprised of financial incentives for retrofits and efficient heating systems. Market transformation programming relates to shifting energy markets and consumer behaviour through information and support. Energy savings related to Enbridge's DSM activities are displayed in Table 2.

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[70] IESO. (2016). IESO Report: Energy Storage.

[71] Hydro Ottawa. (2016). Strategic Direction 2016-2020.

[72] Association of Power Producers. (2016). Canadian Solar Installing for Hydro Ottawa.

[73] Ontario Energy Board. (2014). Demand Side Management Framework for Natural Gas Distributors. EB-2014-0134.

Table 2: Enbridge DSM results in 2015.[74]

Program	Energy savings in 2015 (m^3)	Program Cost
Resource Acquisition		
Residential	6,762,791	$9,362,295
Commercial	25,646,715	$6,211,724
Industrial	12,289,466	$2,166,706
Low Income		
Part 9	1,129,070	$4,444,616
Part 3	3,143,515	$2,111,746
Market Transformation		
Savings by Design Residential	n/a	$2,032,022
Savings by Design Commercial	n/a	$890,464
Home Labelling	n/a	$121,241
Total	**48,971,556**	**$35,220,594**

In total, Enbridge's DSM programs saved just over 48 million m^3 of natural gas consumption in Ontario in 2015. In comparison to total natural gas consumption in the province, this represents a small reduction in energy use. With total natural gas consumption in Ontario in 2017 at over 22 billion m^3,[75] Enbridge's DSM savings makes up approximately 0.22% of total natural gas consumption in Ontario.

However, according to a report to the OEB, DSM programs have the technical potential to reduce gas consumption by 46.1% by 2030, which could reduce GHG emissions by 24.0 Mt CO2/yr. in 2030; achievable potential could see gas consumption decrease by 9-17.8%, which represents a reduction of 4.7-9.3 Mt CO2/yr. in 2030.[76]

Key barriers to natural gas DSM programming in Ontario are the total funding limit on DSM initiatives, as well as a freeze on financial incentives paid to shareholders for effective conservation, which provided incentive for effective DSM program uptake.[77]

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[74] Enbridge. (2017). 2015 Demand Side Management Annual Report.

[75] Statistics Canada. Table 25-10-0055-01 Supply and disposition of natural gas, monthly (data in thousands) (x 1,000). Retrieved from: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510005501

[76] ICF International. (2016). Natural gas conservation potential study. Submitted to Ontario Energy Board.

[77] The Atmospheric Fund. (January 23, 2015). The Good, the Bad and the Ugly: Ontario's New Natural Gas Framework. Retrieved from: http://taf.ca/good-bad-ugly-ontarios-new-natural-gas-conservation-framework-2

Thermal Storage Deployment

Currently, there is little development of thermal storage in Ottawa. Most buildings in the City use some form of hot water storage tank. However, at this time, heat needs are met mostly by natural gas. Therefore, although the technology is widely deployed, it does not contribute to emissions reductions.

Thermal energy storage has the greatest potential to contribute to emissions reductions if it is included in district energy systems in Ottawa, because district energy systems can more readily incorporate low carbon sources of thermal energy. One option is to include thermal storage in existing district energy systems at federal buildings in the downtown core, the University of Ottawa, Carleton University and other existing systems.

Another possibility would be to encourage district energy systems with thermal storage in new developments in the City. Ideally, these developments would also use low carbon source of thermal energy. One potential site for inclusion of district energy with thermal storage would be at future developments at LeBreton Flats. The site, which is overseen by the National Capital Commission, and is slated for mixed-use redevelopment. The potential for high energy intensity uses of this area makes it suitable for district energy that could use borehole thermal energy storage, similar to that deployed by University of Ontario Institute of Technology. The system could also theoretically connect to the federal buildings district energy system, or to the proposed district energy system at the Zibi development, although feasibility studies and development agreements would be required.

Other potential sites would be related to redevelopment and intensification along the new LRT corridor. Mixed-use, transit-oriented development at LRT stations could likely have sufficient density for district energy that uses thermal energy storage to use low carbon heat. Transit oriented development sites at Blair Station or around the Trainyards redevelopment could also support district energy combined with thermal energy storage. A program similar to the Toronto Green Standard could require or incentivize district energy with thermal storage as a condition of redevelopment.

Another application for thermal energy storage relevant to the City of Ottawa is the use of snow for cooling applications at City buildings. The use of snow storage was explored at the Mary Pitt Centre in Nepean, however, the City has chosen not to move forward with the project.[78] As urban intensification continues in the City, snow storage could be explored for new developments, especially for buildings with high cooling loads that are in proximity to snow storage disposal sites.

Electrification

Because of the low carbon profile of electricity in Ontario, electrification is a critical tool to reduce emissions in transportation and heat. Although there is less activity ongoing in natural gas DSM and thermal storage deployment, the role of electricity storage and demand management will play an important role in decarbonizing heat systems in the medium to long run. Electricity storage and CDM will be important to ensure there is sufficient supply to meet the increasing demand, and that the electricity supply is from and can support low-carbon sources.

Heating electrification through the use of heat pumps or district energy systems that use electric boilers or heat pumps will increase electricity demand, especially in winter and summer months, when critical electricity peaks already occur. Similarly, as electrification of transportation systems

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[78] City of Ottawa. (May 11, 2010). Planning and Environment committee Minutes. Retrieved from: https://ottawa.ca/calendar/ottawa/citycouncil/pec/2010/05-11/minutes73.htm

increases within the city and across the province, electricity demand will increase, potentially disrupting current load patterns throughout the day, week and year.

Up until the mid-2020s, additional electric loads from electrification can be advantageous in Ontario in managing surplus baseload power, alleviating the need for the province to sell electricity at a reduced cost, or curtailing renewable generation.[79] This is an important consideration for power-to-thermal applications, where electricity is used for heating and cooling, to alleviate electricity demand and displace natural gas use. This aligns closely with the City of Ottawa's power-to-thermal pilot.

If increasing electrification results in higher than expected electricity demand, especially as nuclear supply is decreased over the coming decade, electricity storage and CDM programs may be required to mitigate system demand requirements.

Large scale grid electricity storage and other CDM programming could reduce the need for additional electrical supply additions by effectively load shifting existing supply to match a new demand profile from electrification. If new capacity is required, electrical storage can also better incorporate variable renewable electricity sources to ensure that Ontario's electricity supply remains from low carbon sources. As mentioned, using EVs as distributed energy loads in two-way vehicle-grid charging systems will be important. CDM programming that effectively reduces overall heating demand from buildings will also be necessary to alleviate the impacts from heating electrification.

Hydro Ottawa is actively engaging in EV readiness for electrification disruption. In a partnership with FLO, an EV charging network, Ottawa Hydro is piloting the use of level 2 chargers at the residential level within the City, gaining data to better understand the impact of EVs on the electricity grid.[80] Other utilities in Ontario are examining vehicle charging habits to better understand the impact of EV's on distribution systems, including Burlington Hydro and Oakville Hydro. A pilot program run by FleetCarma examined the role price signals in influencing charging behaviour, as well as charging optimization based on grid availability.[81] Ottawa could continue to examine the impacts of electrification, especially as it relates to energy storage requirements.

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[79] IESO. (2016). IESO Report: Energy Storage.

[80] Hydro Ottawa. April 24, (2018). Hydro Ottawa and FLO to pilot residential charging stations in Ottawa. Retrieved from: https://hydroottawa.com/media/news-releases?nid=201

[81] Government of Ontario. Smart Grid Fund. Retrieved from: https://www.ontario.ca/document/projects-funded-smart-grid-fund/electric-vehicle-integration

Section 2: Growth Projections for DSM and Energy Storage

Methodology

There are four imperatives that support the deployment of energy storage and demand side management for the City of Ottawa:

1. To reduce GHG emissions from thermal energy consumption, primarily natural gas.
2. To optimize the use of low or zero carbon electricity within the city; using storage to match production with demand.
3. To minimize the burden (or congestion) on the existing electric grid as a result of extensive deployment of decentralized renewable electricity generation.
4. To enable the grid to support electrification of transportation and heat.

Description of approach

A key strategy in any low carbon scenario is the deployment of decentralized renewable energy. Energy storage can be installed alongside renewable energy deployment. This study models energy storage deployment as installations in tandem with decentralized renewable energy that improve the performance of the renewable energy system. There are two core strategies applied to evaluate pathways for energy storage for the City of Ottawa.

1. Thermal storage is modelled as "enhanced" geothermal as a component of district energy systems. In other words, the efficiency of geothermal is increased to reflect heat pumped into the ground during the summer. As a result, the Coefficient of Performance (COP) of the system increases from 3.0 to 5.0.[82]
2. Electrical storage is modelled as "enhanced" solar PV and hydropower, in which the capacity factor of solar PV and hydro is increased to reflect the ability of storage to capture energy that would otherwise be lost. Without storage the curtailment rate is assumed to be 15%; with storage this declines to 10%.[83] Using this calculation, energy storage capacity can be approximated to an energy storage capacity.

With this approach, energy storage is not associated with emissions reductions directly, but it influences the emissions reductions of the renewable thermal and electricity pathways.

Uptake projections

Uptake projections will be driven first by the rate of introduction of decentralized generation and second by the requirements for a seasonal storage system. The modelling approach relies on the introduction of additional actions (ground-source heat pumps, solar PV and hydropower) in order to capture GHG and energy benefits associated with storage. Table 4 describes the increase in storage capabilities associated with each energy system, assuming first the increase in decentralized energy generation. Table 5 describes cumulative emissions reductions from electricity and thermal energy systems from 2018-2050, with assumptions included.

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[82] Foulds, E., Abeysekera, M., & Wu, J. (2017). Modelling and analysis of a ground source heat pump combined with a PV-T and earth energy storage system. Energy Procedia, 142, 886–891. https://doi.org/10.1016/j.egypro.2017.12.142

[83] Denholm, P., & Mai, T. (2017). Timescales of Energy Storage Needed for Reducing Renewable Energy Curtailment. Renewable Energy, 33.

Table 4: Low carbon pathway action parameters.

Action	Conservative scenario	Moderate scenario	Aggressive scenario
Thermal storage	District energy: 16% of existing commercial buildings; 16% of apartments; 3% of residential buildings: 14% of the system low carbon Storage increases coefficient of performance to 5.0	40% of existing commercial buildings; 40% of apartments; 8% of residential buildings: 40% of the system low carbon Storage increases coefficient of performance to 5.0	80% of existing commercial buildings; 80% of apartments; 15% of residential buildings; 70% of the system low carbon Storage increases coefficient of performance to 5.0
Electricity storage: residential solar PV	3.92 MW storage by 2050	7.06 MW storage by 2050	25.10 MW storage by 2050
Electricity Storage: commercial solar PV	10.20 MW storage by 2050	25.10 MW storage by 2050	58.04 MW storage by 2050
Electricity storage: utility solar PV	14.90 MW storage by 2050	30.59 MW storage by 2050	48.63 MW storage by 2050
Electricity storage: hydro	6.80 MW storage by 2050	7.58 MW storage by 2050	9.41 MW storage by 2050

Table 5: Cumulative emissions reductions related to renewable energy deployment, with energy storage assumptions (2018-2050).

Action	Conservative scenario	Moderate scenario	Aggressive scenario
District energy	2,006	4,922	10,077
Residential solar PV	45	78	270
Commercial solar PV	112	270	620
Utility solar PV	162	329	521
Hydropower	75	83	102

Constraints

Costs are a primary barrier for uptake of energy storage. For electricity storage, the cost of most technologies prohibits widespread uptake at this point in time. However, costs are falling for technologies as they move through the development phase. Lithium-ion batteries are experiencing rapid declines in module costs.[84] Other technologies - including sodium-sulfur batteries and CAES - are also expected to see a decline in system costs.[85]

Thermal storage and natural gas demand side management are limited by the low cost of natural gas. Because natural gas prices are low, there is less incentive for consumers to engage in natural gas DSM programming, and little incentive for developers to pursue district energy systems with thermal storage. While a carbon price could help correct the impact of low natural gas prices, there is political uncertainty surrounding Ontario's carbon pricing regime. Additionally, with the recent cancellation of Ontario's Green Ontario Fund and the Cap and Trade Program, there is uncertainty in the availability of provincial funding for energy storage projects.

Other barriers to electricity and thermal storage deployment are utility acceptance, performance, safety as well as regulatory uncertainty.[86] While there is some momentum on storage uptake in Ontario, the regulatory environment differs across Canada, internationally, as well as at the utility level.[87] Hydro Ottawa has stated its intention to move forward with electricity storage, but this is not the case across all utilities in Ontario, which provides difficulties for individual companies as they progress through commercialization. Where feasible, Ottawa can act as a first mover through ongoing pilot projects and research to establish a solid foundation for energy storage and demand side management initiatives.

DR programs and many electricity storage technologies are also limited due to their maturity. Many technologies are still in the piloting phase, which cannot be widely adopted until there is greater technology and system certainty.

There are also concerns for data security. Widespread deployment of energy storage and demand response will require smart grid infrastructure that can communicate between the consumer and the wider electricity grid and natural gas networks, such as two-way electric meters, programmable thermostats, and natural gas meters. There are ongoing concerns across Ontario in the mandatory roll-out of smart-meters, and it is likely that further roll-out of communicating grid devices will be met with public scrutiny. There are similar concerns relating to the electrification of energy services with communication abilities as targets of disruption.

A final, yet critical barrier for uptake of electricity storage in Ottawa is that most energy planning falls within provincial jurisdiction. The development of large grid scale storage falls more closely into the role of the IESO. However, Hydro Ottawa has already been an active player in IESO procurements for storage as a project partner and could continue to partner on projects and bid on procurement allocation. The City of Ottawa, through Hydro Ottawa, has an influence over distributed electricity storage development. This includes the development of decentralized batteries at the building level and encouraging EV uptake. Ottawa also could encourage the use of thermal energy storage in district energy in new developments through rezoning and planning applications. The City can also actively encourage uptake of utility led electricity CDM and DSM programming in the natural gas sector.

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[84] IRENA. (2017). Electricity Storage and Renewables: Costs and Markets to 2030.

[85] Ibid.

[86] IRENA. 2015. Renewables and Electricity Storage: A technology roadmap for Remap2030.

[87] Jang, D., Lafontaine, L., Tuck, A. (2015). Developing Stronger Links: Summary Report of the Canadian Energy Storage Supply Chain Workshop, April 9, 2015, Toronto. National Research Council.

Ways to Advance this Pathway

Policy set provincially by the Ministry of Energy, Ontario Energy Board and the IESO have considerable influence on energy storage and DSM deployment, funding capacity and overarching policy direction. The City of Ottawa and Ottawa Hydro can encourage energy storage uptake through incentives, advocacy and funding.

Hydro Ottawa could continue to be an active partner in energy storage pilot projects. Hydro Ottawa's subsidiary, Energy Ottawa, is also an owner of multiple renewable energy projects, and could pursue a portfolio that could be complimented or expanded by pursuing ownership of energy storage projects in the future.[88] The City of Ottawa or Hydro Ottawa can also provide incentives or low interest loans for consumer who chose to pilot home connected energy storage projects, similar to the Great DR program.

To successfully champion energy storage pilot projects, the City of Ottawa could develop key partners in well-established industries that can help financially support projects, such as banking and communication sectors, or partners that can benefit from electricity or thermal storage projects, such as manufacturing and industrial partners. [89]

The City of Ottawa and Hydro Ottawa play a role in consumer advocacy and informing customers on electricity system operations and costs. Hydro Ottawa could continue to inform customers on electricity system information and explain the role of electricity storage to mitigate cost and security concerns. It could also continue to work proactively with the IESO and other utilities to support standardized energy storage regulations in the industry.

Finally, Hydro Ottawa could continue to make smart and resilient grids a priority, which can ensure that energy storage technologies can be easily integrated in the future.[90] Energy storage technologies have the potential to considerably impact traditional electricity systems, and Hydro Ottawa could leverage its commitment to innovation to prepare for the future.[91]

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[88] Navigant. (2015). Ontario Smart Grid Assessment and Roadmap. Prepared for Ontario Ministry of Energy.

[89] Jang, D., Lafontaine, L., Tuck, A. (2015). Developing stronger links: summary report of the Canadian Energy Storage Supply Chain Workshop, April 9, 2015, Toronto. National Research Council.

[90] Navigant. (2015). Ontario Smart Grid Assessment and Roadmap. Prepared for Ontario Ministry of Energy.

[91] D'Aprile, P. (2016). The new economics of energy storage. McKinsey & Company.