Pathway Study on Solar Power in Ottawa

Presented to:

The City of Ottawa
110 Laurier Ave W
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In relation to
The City of Ottawa Energy Evolution Program

By:

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ABOUT THIS REPORT

City of Ottawa Energy Evolution Program

On July 8, 2015, Ottawa City Council approved the development of a Renewable Energy Strategy as part of the 2015-2018 City Strategic Plan. This initiative has been developed into a program entitled Energy Evolution – Ottawa's Renewable Energy Strategy. A main goal of Energy Evolution is to develop a baseline analysis of energy supply and demand within the City of Ottawa and assess options, in collaboration with community partners, for all such partners to advance energy conservation, energy efficiency and renewable energy generation within their respective areas of control and influence. The Energy Evolution program has interacted closely with community stakeholders from local utilities, the federal government and other government institutions, the development sector, academia, the non-profit sector, and the private sector at large. Leidos Canada was engaged by the City to support analysis in the energy supply domain, including research reports and facilitation of discussion with stakeholders.

The Purpose of this Report

This and other "Pathway Study" documents are focused technical notes describing how the specific energy technology may develop in Ottawa. The document considered the overall technical potential for implementation, and then further considered the constraints (economic, regulatory, etc.) that are likely to reduce uptake. It suggests opportunities to influence uptake rates and catalyst projects that may be attractive to consider further. Results of the Pathway Studies are intended to be used along with the Baseline Study of energy data towards an overall assessment of future energy strategies within the City of Ottawa Energy Evolution program.

A draft form of this Pathway Study was circulated to key stakeholders and experts in the topic during the summer of 2017. Meetings were also undertaken during this period, where these representatives contributed their insights and ideas towards the development of leading project opportunities in relation to the topic of the Pathway.

Other documents in this series are:

Baseline Study on Energy Use in Ottawa in 2015
Pathway Study on Waterpower in Ottawa
Pathway Study on District Energy in Ottawa
Pathway Study on Wind Power in Ottawa
Pathway Study on Heat Pumps in Ottawa
Pathway Study on Biogas Energy in Ottawa

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Key Units

MW_{AC} Megawatts is 1,000,000 watts, and is a measure of power, used here in the context of the power rating or the capacity of a solar generation facility during high sun conditions. The AC subscript indicate alternating current (AC) electricity output.

MW_{DC} Megawatts of direct current (DC) power, used to quantify the capacity of all of the PV modules of a system.

TJ Terajoules is a measure of energy, base unit of joules, and used here in the context of total energy delivered over one year. A medium-sized commercial rooftop could host a 0.5 MW solar facility and produce 3 TJ of energy in a year; the entire City uses 114,000TJ of energy annually.

kt CO_2eq kilotonnes of carbon dioxide (CO_2) and other equivalent greenhouse gases, which is the common unit for quantifying the greenhouse gas emissions related to a process.

Pathway Study on Solar Power in Ottawa

EXECUTIVE SUMMARY

There has been tremendous growth in photovoltaic solar to produce electricity in Ontario as a response to the procurement contracts offered under the Feed-In-Tariff program. In Ottawa, as of 2015, there were 78 MW_{AC} deployed, which were spread across the residential, commercial and utility-scale sectors in approximate percentages of 17%, 23%, and 61%, respectively. This contributes approximately 400 TJ/year of electricity, or 1.2% of Ottawa's annual electricity use.

The cost of PV technology has fallen substantially over the past decade, and will show further small price declines in the future; non-equipment soft costs are becoming a larger portion of project development costs. Presently, considering local pricing and the solar resource, solar generation in Ottawa can be cost competitive, in particular for commercial and utility-scale systems when considering the long lifetime of the equipment. In the short-term, growth is expected to be constrained by the mechanisms to sell electricity. The Ontario net metering program, as released in 2017, limits the size of projects to self-consumption (no net generation on an annual basis). To enable development of large, economic projects to be built as net energy generators requires the adoption of a new set of market mechanisms, such as corporate purchasers and virtual sales mechanisms which are quite popular in other jurisdictions. In the medium to long-term, the cost competitiveness of the technology will bring about growth in all market circumstances.

This Pathway examined the hosting potential for three sectors: residential rooftops, commercial rooftops, and ground mount utility-scale projects. Using a combination of approaches to determine the area which would be viable for solar, as well as estimations of typical solar production parameters and constraints, values for net potential were estimated to be 320 MW_{AC}, 740 MW_{AC}, and 620 MW_{AC}. In the residential sector, this amounted to 30% of viable rooftops. In the commercial sector, the percentage of viable rooftops that participate is expected to be double that of the residential sector, due to the improved logistics and economics of larger systems. The proposed land area for utility-scale solar is the equivalent to lands used by golf courses in the region, and would be distributed in both rural and urban areas with features suitable to each. Commercial is estimated to be the largest sector. The daytime production of solar is also a best match to demand profiles on grid lines that serve

commercial areas. Solar projects and grid capabilities both have several means of being able to support high levels of solar on the distribution grid. Overall, assuming aggressive uptake scenarios, solar could provide approximately 29% of the electricity needs of Ottawa.

Solar Power Summary Table

Energy Type	**Local renewable electricity**
Pathway Potential – in 2050 under an aggressive scenario (other timeframes and scenarios are detailed in Section 2 of the report)	
Electricity Generation	1680 MW_{AC} (9,300 TJ)
% of Electricity Supply(1)	29%
GHG Reductions(2)	130 kt CO_2eq
% of GHG Emissions(3)	2.5%
Other Impacts	• Local economic development. • Grid modernization and provisioning of local electricity to help offset new electricity demands of other pathways.

(1) **As a % of Ottawa's 2015 electricity usage (32,200 TJ), as per the Baseline Study.**
(2) **Assumes the 2015 Ontario grid average emissions levels.**
(3) **As a % of Ottawa's 2015 total emissions (5,200 kt CO_2eq), as per the Baseline Study.**

SECTION 1 – PRESENT ASSESSMENT OF SOLAR POWER IN OTTAWA

Pathway Description

This Pathway examines the potential for solar photovoltaic (PV) systems within Ottawa. The types of technology to be considered includes conventional and emerging PV technologies, with or without associated electrical storage (e.g. batteries). The systems generate conventional alternating current (AC) power, are grid connected and could include all types of accounting and metering options:

- as **power generation** projects with their own account;
- in association with electricity consumption of a building, either using bi-directional meters for **net metering**, where excess electricity can be sold to the grid; or
- as **self-consumption** projects, where there are no sales of electricity to the grid, typically because the system generates much less power than the building consumes.

Pathway Boundaries

The following types of projects are not included in this Pathway Study:

- Off-grid solar installations of all types (e.g. cottages and homes, telecommunications).
- Solar thermal systems.
- Residential ground mount systems – these are nominally included in the residential sector, but not explicitly calculated since they are considered to be a very small market in the future. They were particularly popular during the very early stage of the FIT program when contract prices were very attractive. This assumption could change depending on various market conditions.
- Parking lot awning structures – these are popular in the US for providing shading, but it is unclear if there is a development path for parking space awnings within the high snow environment of Ottawa, particularly with respect to parking lot snow clearing requirements. Fully covered parking lots are however equivalent to a commercial building with a rooftop project.
- Net-zero residential housing construction, which is likely to include the use of rooftop solar, is an emerging field that may increase uptake in *new* residential housing. It has been suggested that such approaches might be integrated into the Ontario Building Code by 2030. This report has not specifically speculated on the impacts of the future program – if it were very successful and influential (extending to all new construction and a significant portion of renovation

projects), it would likely lead to higher uptake rates than presently proposed in the residential sector analysis.

This report does not directly study where or when electrical storage (e.g. batteries) might be integrated into solar projects. As the prices of electrical batteries and other storage come down, it is anticipated that solar plus storage systems will become affordable and attractive, and this will likely be a tool to enable the growth of solar at high penetration levels.

Sector Classifications

It is common to classify PV installations into three general sectors: residential, commercial, and utility-scale. These sectors do not have absolute differentiation, but common traits are related to the location of deployment rather than a strict categorization by size. In this analysis, the sectors are defined as follows:

Residential - both rooftop and ground mount systems of less than about 30 kW_{AC} and installed on residential properties – excluding large multi-unit residential – are typically considered as residential. In urban environments, these projects are certainly rooftop, but in rural regions, ground mounted installations can be found.

Commercial - any rooftop system on buildings significantly larger than detached homes are considered commercial rooftop (regardless of the purpose of the building). Generally, they are generally between 10 kW_{AC} and 2 MW_{AC}.

Utility-scale - are typically large (>1 MW_{AC}) ground mounted systems, though in this report, the sector is inclusive of slightly smaller sized ground mount systems (0.5 $MW_{AC)}$ integrated into the urban environment.

For the purposes of this study, building integrated PV (BIPV) systems – where the PV modules are integrated into a building structure and replacing a building cladding component (e.g. wall cladding, roof shingles, windows, awnings) - have not been specifically considered. These types of systems are expected to be a niche segment of the residential and commercial markets.

It should be noted that these classifications are delineated as much by their business aspects as their technical differences. Utility-scale systems usually seek low cost property (purchased or leased) within a short distance of medium- or high-voltage power lines, and are generally more economical the larger they are; ownership is typically by large companies who are active in the electric utility industry, or by investment firms. While individual commercial rooftop systems are reasonably common, they are often installed as portfolios on buildings with common ownership of multiple buildings (e.g. school boards, big box retailers); ownership is most often by a professional investment firm or by the building owner. Residential systems are occasionally installed on a group of new homes by a housing developer, but the vast majority are individual "sales" to individual homeowners; system ownership is frequently by the homeowner. There are also examples of specialty residential PV development companies that own several hundred or several thousand systems, effectively leasing the roof space from the individual homeowners via a variety of contract methods.

Background

System Components

The most important part of a solar PV system is the PV module, which consists of high purity material which is able to absorb light and convert the energy into an electrical current. Materials that can accomplish this "photovoltaic effect" are types of semiconductors, with the most common choices for commercial products being mono-crystalline silicon, multi-crystalline silicon, and cadmium telluride thin film. Thin pieces of this material known as "cells", are fabricated with electrical contacts and built into PV modules (also commonly called panels). Most modules on the market are extremely stable and tested for long-term robustness; product warrantees typically guarantee 80% of start-of-life performance after 20 or 25 years, while product lifetimes of 30 to 40 years are often considered reasonable projections. Products on the market today have efficiencies (for converting light energy into electricity) in the range of 16 to 22%. The output current is in direct current (DC) form, and is fed into power conditioning inverter(s) to convert it into AC current. Other components of a solar project include racking to hold the modules in place, wiring to connect the modules together into "strings" for input into the inverters, electrical fuses and disconnects, monitoring sensors, and a meter to record energy output.

Plant Power Capacity Rating

The size, or capacity, of a solar facility is described in terms of the power output during bright sun conditions. Typically, it is the maximum power rating of all inverters in the plant. Within this study, capacities are reported in units of MW_{AC}. The actual output of the plant will vary between zero and this maximum rating depending on the intensity of the sun. The average annual output by a solar plant (its capacity factor) is typically 14 to 18% of its MW_{AC} rating[1] in Ottawa. Though this percentage may sound low, the net energy production is still substantial. It should also be noted that PV plants are also sometimes rated by the total nominal power rating of the modules; this is known as the MW_{DC} rating, and is typically 20 – 50% greater than the MW_{AC} rating.

Solar Resource in Ottawa

The solar resource in the Ottawa Valley is good, equivalent to many parts of the northern U.S. and better than some countries with large solar installations such as Germany and Japan[2]. The solar resource fluctuates only slightly year-to-year (normal deviation is less than 10%) and historical weather data can be used to provide predictions of energy production of a plant over its life. Intermittency (hour-to-hour variability) can be a challenge, but moving forward this can be mitigated with more advanced systems and grid management methods (discussed in a later section). Furthermore, the intermittency due to cloud motion is reduced for a portfolio of projects which are distributed over a geographic region.

Deployed Systems in Ottawa

In Ontario, PV plants of capacities ranging from 1 kW_{AC} to 100,000 kW_{AC} have been deployed in significant numbers since the introduction of 20-year tariff rates first offered under the Renewable Energy Standard Offer Program (RESOP, introduced in 2006) and then the Feed-in Tariff (FIT) programs (introduced in 2009).

The Baseline Energy Study for Ottawa in 2015 determined that there was an installed solar generation capacity of approximately 400 TJ/yr. This is spread across the Hydro Ottawa Limited (HOL) and Hydro One Networks Inc. (HONI) systems, and across all three market segments, and represents 1.2% of Ottawa's electricity usage in 2015 (32,200 TJ). An approximate breakdown of the solar projects by size and by local distribution company is provided in Table 1.

The systems are nearly all power production facilities connected and selling 100% of the power generated to the grid under a RESOP or FIT contract. It should be noted that the three categories in this table are system sizes as defined by the FIT program, and are similar but not the same as the three sector definitions of residential, commercial and utility. In particular, the totals contained in the first two rows include both rooftop and ground mount installations.

Table 1 – Approximate breakdown of the installed solar capacity for different sizes of systems in Ottawa, using 2015 data provided by the utilities[3].

	# facilities	Total Capacity (MW_{AC})	Total Capacity (TJ)[(3)]	% of total on HOL grid	% of total on HONI grid
<10 kW_{AC}	1,450[(1)]	13	70	7%	10%
>10 kW_{AC}, <500 kW_{AC}	110[(2)]	18	90	14%	9%
> 500 kW_{AC}	4	47	240	13%	48%
Totals	**1,564**	**78**	**400**	**34%**	**67%**

(1) Value includes some estimations based on total capacity data provided and an assumed average system size for residential systems in the HONI grid of 10 kW_{AC}.
(2) Value includes some estimations based on total capacity data provided and an assumed average system size for commercial systems in the HONI grid of 375 kW_{AC}.
(3) Estimated energy production based on an estimated capacity factor of 0.16.

More than half of the capacity is associated with just four utility-scale projects, and which we have identified to be in Arnprior (20 MW_{AC}), Burritts Rapids (7 MW_{AC}), Edwards (10 MW_{AC}), and Greely (10 MW_{AC}). Nearly a quarter of the capacity is in the commercial sector, which includes a wide number of participants, including as some examples:

Schools: The Ottawa-Carleton District, the Ottawa Catholic and the Ecoles Catholiques du Centre-Est School Boards have had solar installed on a number of their schools.

Retail: Dymon Storage has installed PV on the majority of their buildings, Home Depot has PV on the roofs of two of their six area stores (Kanata and Orleans), but Canadian Tire, which has installed PV systems on many of their buildings across Ontario has not reported any installations on their Ottawa stores.

Government: the City of Ottawa has eight buildings with commercial PV systems.

System Design

The orientation which *maximizes* energy production is south-facing at a tilt of approximately 25-30 degrees. But the decrease in production as designs deviate from this maximum are not severe, therefore most projects proceed with the design that integrates with the roof and has the best overall economics and logistics, such as:

- When being mounted on a sloped roof, modules are placed "flush-mount", using racking attached to the roof structural elements and holding the modules parallel to the roof; thus the modules follow the roof design, as can be seen in Figure 1.
- When mounted on a flat roof, system design has tended towards low tilt angles, such that the modules do not catch too much wind and create "wind loads" on the roof. It also results in less row-to-row shading, allowing for packing more rows of modules onto the roof.
- Ground mount projects in large open fields usually do orient themselves optimally, though site specific factors can influence this. Tracking systems increase the energy collected, but at the cost of more complex equipment. For the Ontario market, trends have moved away from dual-axis trackers to fixed-tilt, though recently single axis trackers are showing uptake.

Figure 1 - Images of example existing residential rooftops in Ontario illustrating how non-south facing and multiple roof sections may be employed (images obtained from Google Earth).

Both the RESOP and FIT programs contained multiple restrictions and requirements that shaped certain features of the systems installed under their auspices, and some of these restrictions and requirements differed between RESOP and FIT, and even changed over time (or by system size) within the same program. Hence the systems installed in Ottawa (and elsewhere in Ontario) may have certain features which are not inherent to the technology, and may not represent best practices in future years. Examples of these types of features include:

a) a lack of PV systems on new buildings;

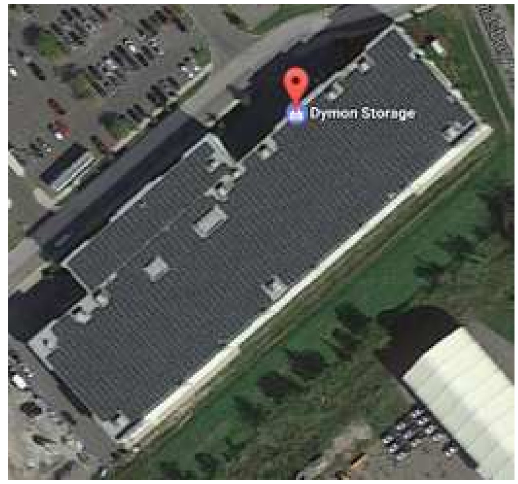
b) a lack of PV systems on structures which are not “buildings” under the FIT definition (e.g. transit station roofs, highway sound barriers, large awnings, etc.);
c) a tendency to design rooftop systems on commercial buildings which cover a relatively small portion of the rooftop, in order to qualify for higher tariff rates available for smaller systems; and
d) a maximum AC capacity of 10 MW_{AC} for utility-scale systems and 500 MW_{AC} for commercial systems (the maximum permissible value under both RESOP and FIT, but which are smaller than is common in the industry at large).

Of the systems installed in the commercial sector, there is wide variation on what percentage of the roof is actually occupied by the solar modules, including due to point c), structural limitations, connection capacity limitations, owner’s intent and investment interest, etc. Figure 2 provides some samples of existing rooftops, showing the wide disparity. Since there is a basic cost to add and maintain each grid connection point, high density roof coverage should be strongly encouraged in the future.

Figure 2 - Images of example existing commercial rooftop solar sites in Ottawa (images obtained from Google Earth).

Merivale High School, 1755 Merivale Road

(Note all the unused roof space)



Dymon Storage, 110 Didsbury Road

(Note the very high space utilization)

Home Depot, 10 Frank Nighbor Place

(Note wide border around roof edge)

Tippet Richardson, 5499 Canotek Road

(Note large central area with no solar)

Utility-scale systems are built using large regular rows, and formed into semi-regular arrays, each with a sizable inverter. Arrays are connected together with AC lines to the plant's central electrical substation, which includes a transformer to boost the power to high voltage for connection to a major grid line. It is possible to have multiple non-contiguous sections to a plant.

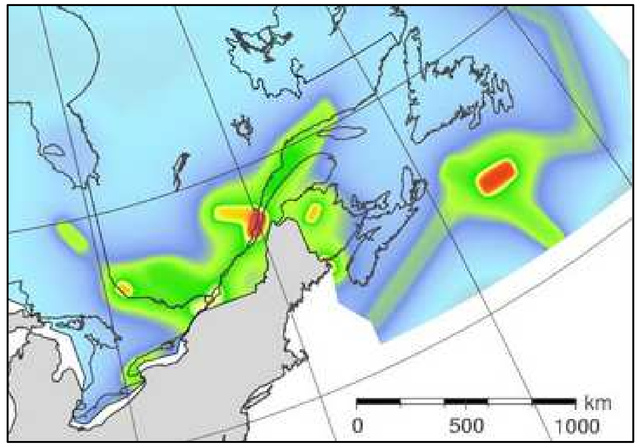
Figure 3 - The Arnprior 20 MW solar plant situated on 200 acres of land at the western edge of Ottawa. The aerial photograph is looking west at the plant, with Highway 417 and Lake Madawaska seen in the background (source EDF-EN website).

Structural Requirements

Virtually all residential and commercial buildings in Ottawa have the structural capacity to support a rooftop PV system, if the PV array is properly designed, because the building code has historically required Ottawa buildings to have sufficiently strong roofs to support substantial snow loads, and because rooftop PV generally adds less weight than an equivalent volume of snow. However, taking full advantage of the innate strength of some roofs may require creative designs (lightweight modules flat on roofs), and the willingness of both designers and regulators to work through issues (e.g. agreeing that a specific design will prevent snow from accumulating beneath the modules, thus subtracting that volume of snow from the total roof load). There will undoubtedly be some roofs where innovative approaches will prove sufficiently costly that they are not financially viable.

For ground mounted systems of all capacities, a wide range of foundation types have been developed by the industry and are already installed in Ottawa and across Ontario. Suitable foundations are available for most subsurface conditions.

Figure 4 - Excerpt from seismic hazard map, NBCC 2015.



Solar arrays must be constructed to withstand wind forces or “wind loads”, which increase with the tilt angle of the panels therefore increasing the ballast or anchor requirements. High anchor strength is generally easy to accomplish for ground mount systems (enabling tilt angles of 30° or greater), but are typically not feasible for commercial rooftop systems, thus limiting most of these systems to a tilt of 10 to 15°. Because Ottawa is located in a designated seismic zone per the National Building Code of Canada (NBCC), as shown in Figure 4, rooftop PV arrays must further be constructed to withstand forces during an earthquake, in particular they must prevent lateral movement (sliding) of the array. Traditionally this is accomplished via additional ballast or seismic anchors, which fasten the PV array to the building. In Ottawa, added ballast weight is commonly sufficient when the tilt angle is low and the roof has available capacity, but anchors are generally required for higher tilt designs or roofs with low excess structural capacity.

Daily Production Profiles and Match to Grid Peak

Solar production is a reasonably good match to daytime summer grid peaks, which are caused by high air conditioning use. Since commercial buildings consume peak power during daylight hours, specifically on weekdays, solar generation directly at these buildings and these times could be effective at reducing demand peaks in the distribution system. West-facing systems offer a slight advantage, as they peak in the late afternoon.

Because residential systems are built following the existing orientations of the roofs, and thus have multiple tilts and azimuths, the hour-by-hour production profile for the aggregate of the residential systems is smoother than for large utility-scale solar, albeit with a large number oriented generally to the south. But high penetration of solar in a purely residential area (where most people are absent during the day) can cause electricity generation to exceed demand on the grid’s “feeder” line, as will be further discussed in the next section.

In the winter, solar production is quite a bit lower, mostly due to the fewer hours of sun, and it does not provide a good match to winter peaks, which tend to happen in the morning and after sunset.

Overall, there is some value to solar as a means of reducing overall grid peaks – a detailed analysis is required in order to validate its average and minimum capacity contributions for the Ottawa grid or on particular power lines (it will depend on the type of consumers on that line).

System Costs and Electricity Prices

The costs of systems have fallen dramatically over the past decade. The most significant factor is the global growth of PV module manufacturing, resulting in module costs declining at double-digit rates. In the medium term, the cost of solar will continue to decline at a substantive rate, estimated at a 25% decline between 2015 and 2020[4].

Because a project has many relatively fixed costs (grid connection fees, costs of getting labour to the site, project engineering and development, etc. which collectively are often called "soft costs") larger systems will have lower costs to build, when considered on a $/W basis. Working on a roof, in particular a sloped roof, is more challenging than on the ground as well. Thus, residential systems are the most expensive to install, followed by commercial systems, with utility-scale systems being the lowest cost to build. Figure 5 provides recent data from the US market which illustrates in particular how soft costs have declined the least and now form a significant fraction of cost of residential systems. Some cost savings would be possible in new residential housing where solar is integrated directly into both house design and construction, as will be likely for net-zero building approaches.

A higher cost to build will translate directly into the price that is sought for the generated electricity. The FIT tariff rates for 20-year contracts were developed to provide a reasonable return on investment given the cost of systems at the time of contracting. Table 2 contains the price schedule that is being offered in 2017 for the last round of FIT contracts. Systems have needed to be at the top end of the size range of each category in order to secure a decent return on investment. The commercial contracts in particular were popular, with strong competition for the limited number offered in each FIT round. In the contracts for commercial systems, applications were also able to "bid-down" a lower contract price, by 4%, 8% and 12% in order to gain higher ranking in the point allotment system used for the contract competition.

Considering multiple factors (that project *costs* are lower than these FIT *prices*, the bid-down rates, tighter margins and avoidance of some soft costs in a non-FIT regime, consideration of project lifetimes longer than 20 years, continuing declines in equipment costs) the actual *costs* for solar generated electricity in the upcoming 2018 to 2020 timeframe can be expected to be at least 10% to 20% below the values in Table 2.

Figure 5 – Graphic of system cost declines over the past seven years, subdivided into three sectors. The bars also illustrate the relative cost contributions of different parts of a deployed system; prices are in US dollars, graphic adapted from the US National Renewable Energy Laboratory[5].

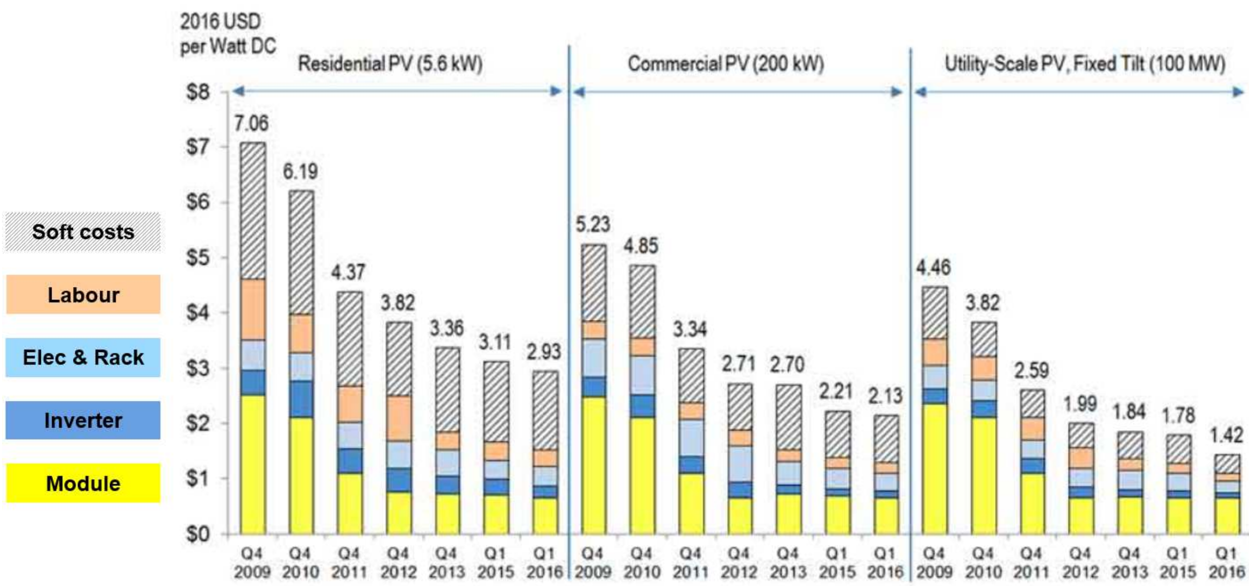


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Table 2 – Ontario 2017 Feed-in-Tariff price schedule[6] providing the guaranteed price to be paid for the solar generated electricity over the 20 year term of the contract.

System Type	System Size	2017 FIT contract price (¢/kWh)
Rooftop	≤ 6 kW	31.1
	> 6 kW ≤ 10 kW	28.8
	> 10 kW ≤ 100 kW	22.3
	> 100 kW ≤ 500 kW	20.7
Ground mount	≤ 10 kW	21.0
	> 10 kW ≤ 500 kW	19.2

In the utility sector, a recent FIT-related competitive bid procurement called the Large Renewable Procurement Round 1 (LRP1), the average bid price was 15¢/kWh for projects built by end of 2017. Furthermore, a recent study[7] estimates costs of approximately CDN$1.30/W to install in 2020, which results in a cost of electricity of approximately 11¢/kWh, At this price, the cost of utility-scale solar is reaching parity with the net cost of electricity to consumers, but not yet with the bulk purchase prices of electricity on the IESO spot market.

Near-Term Market Expectations and Financing Methods

There has been continued growth in the residential and commercial sectors during 2016 and 2017 under the FIT program, but this program is set to end December 2017, with all contracted systems expected to be installed by the end of 2018, to be replaced with a self-consumption net metering program. In this program, a system may feed unconsumed power to the grid, but it becomes a monetary credit against future consumption at that same facility. Credits expire after one year, which thus sets the maximum worthwhile energy generation will be equal to the consumption at the facility on a yearly basis; this is called self-consumption net metering. This will frequently constrain the size of systems that building owners and project developers might otherwise pursue. Credits will have a value equal to the marginal rates that the account holder pays for electricity, and at first release in 2017, the program is forcing clients off time-of-use billing and onto tiered billing structures. Rates for the two tiers in 2017 are 7.7 and 9.0¢/kWh for residential and small businesses. Fixed fees within billing (such as account and delivery charges) will not be compensated. The value is thus clearly much lower that the recently paid prices under the FIT program. Thus, the uptake in the next few years is generally expected to be significantly lower than in the past five years. A few projects at the commercial scale in Ottawa are known to be proceeding presently under net metering. The most opportune projects may be commercial systems at facilities that are larger consumers and qualify for the “Class A” rate structure[8,9].

Presently, there are no new utility-scale projects known to be under development or planned within Ottawa - this conclusion is derived from public records for FIT contract award winners and the recent ending of the Ontario procurement process for large projects. The IESO forecasts a provincial oversupply of generation for the next four years[10], though this assessment is dependent on many factors and could change quickly. The economic competitiveness of utility-scale solar electricity will surely enable new procurement at some future date.

Connection to the Grid

The capacity of a grid power line to support generation is assessed by the grid manager (Hydro One or Hydro Ottawa) during an approval to connect process. Currently, rules and guidelines are used to keep the total generation small relative to the net consumption served by that line, in order to ensure grid stability. This is to ensure there is never "excess" generation that would flow upstream from the power line into the substation equipment. In most of the grids that exist today, the substations have protection equipment that will not operate properly when power is flowing "backwards". Grid modernization and grid investment can overcome this constraint.

This percentage of solar on a power line is known as the "penetration". Various solutions exist to manage a grid with high penetration. The simplest is that utilities can require that solar plants install control systems such that the utility can signal the plant to turn down its output or "curtail" during periods that the grid has excess supply relative to use. This is already implemented on the majority of Ontario plants above 5 MW_{AC} capacity.

New Advances

There are many advances that could allow for higher penetration of solar PV on power grids. More modernized grid infrastructure and integrated electricity storage are two options. There are several solutions that can reside at the solar plant itself to make it more grid supportive:

- New regulations will enable power conditioning equipment (the inverters) to provide support and enhancement of the grid's power quality – power procurement could require or reward this.
- The integration of storage can be used to smooth power output during intermittent conditions and provide power after the sun has set.
- Modules that are more westerly facing provide some benefit to matching late afternoon peak demands - tariffs or PPAs could reward this.
- The decreasing cost of solar equipment[11] can increase the economic viability of plants that offer curtailment more frequently. The low cost of modules can further allow for plants to be built with spare DC capacity connected into the same AC inverter equipment for more frequent provision of power at the max AC power rating, even in mid-intensity sun conditions.
- The development of robust forecasting of next hour and next day solar power and the integration of storage will be useful tools to smooth output and make power production more predictable. The forecasting functionality could be "owned" by the power plant or the utility, or both.

In sum, these can be thought of as grid-supportive smart solar or “solar 2.0", which are as much related to modernization of regulations as technology development.

Net-zero building concepts, including net-zero energy and net-zero carbon, are an emerging field, including the recently released Canadian Green Building Council Zero Carbon Building Standard[12], and the possibility of a net-zero concept being integrated into a future release of the Ontario Building Code[13]. Rooftop solar will be included in most solutions. If an entire new residential housing development were to build to a net-zero approach, this would amount to high penetration on the distribution feeders, which would need to be addressed with a new community utility services design approach.

Evaluation of the Hosting Capacity for PV in Ottawa

Since the sun shines uniformly across Ottawa, there is the potential to deploy solar modules just about anywhere, though clearly this is limited by the ability to place modules in convenient locations where they can collect sun for a majority of the day. In this section, reasonable estimations of the hosting capacities of Ottawa rooftops and Ottawa land areas is undertaken. Each of the three sectors is analysed separately, since there are different deployment opportunities, constraints and energy yields associated with each. A brief summary of the methodologies, assumptions, and results are contained here, with more detailed explanations provided in Appendices 1 through 3.

Residential

The potential of residential rooftop solar is limited by the available roof space within the City, by the orientation of that roof space, by the efficiency of the solar modules, and by the amount of shading. Obviously, a detailed analysis would be complex, made more so by the fact that this work should include both existing and future buildings. The LIDAR dataset available for Ottawa did not have the necessary resolution to directly determine roof slopes and shading[14]. For the purposes of this report, Leidos made use of a new software tool provided by Google called Project Sunroof which estimates the solar energy generation potential for every rooftop of every building, including evaluation of shading from surrounding objects. While Sunroof data is not yet available for Ottawa (or elsewhere in Canada), Project Sunroof data was utilized from several northern US locations with municipal characteristics estimated to be similar to Ottawa. A detailed explanation of the analysis is contained in Appendix 2. Project Sunroof found that 70% of buildings had viable rooftops for at least some amount of generation. Two approaches were considered to translate the results into estimates for Ottawa. The first approach used the value of net annual kWh for each region, divided by its population to determine a rough average hosting capacity of 0.98 kW_{DC} per person. The second approach used more technical outputs relating to capacities for sloped roofs in combination with data on Ottawa's building stock and growth rates. Both approaches came to the approximately the same value with uncertainty, and the analyses concluded that Ottawa's residential rooftops could have the hosting capacity for 940 MW_{DC} in 2050, which could produce an estimated 3,000 TJ/yr.

Commercial

In the commercial sector, roof orientation is no longer a required piece of information, and similarly shading impacts can be assumed to be much smaller, affecting only the edges of arrays if at all. However, rooftop furniture (air handling, heating and cooling equipment) is now a factor of importance, as is overall building size, since systems are typically set-back from edges for safety and logistical reasons.

Leidos began its analysis by studying a 1 km x 1 km area in a commercial district, with support from City staff in providing LIDAR data for building square footage in the area, subdivided for three different building sizes. Various technical assumption (% of rooftop that is covered, typical PV performance in these types of systems, percent of buildings viable for hosting PV arrays, etc.) were applied to estimate the hosting capacity in this region. Then, using satellite imagery, Leidos found a total of 26 areas within Ottawa, of various sizes, that had similar densities of large buildings. The total land area in these sections was estimated to be 52 km^2, approximately 2% of the land area of Ottawa. By assuming a similar distribution of roof sizes as in the sample area, the analysis estimated that there were 2,300 buildings with 6.8 million square meters of flat or near flat roof space potentially suitable for commercial rooftop PV systems within Ottawa. The downtown core was not included in this estimate, because solar on taller buildings has additional challenges. The final result is the potential for 1,120 MW_{AC} with an annual generation of 4,440 TJ.

Utility-scale

Because of the large size of Ottawa, there is enormous potential for ground mounted solar. Land use restrictions will disallow deployment on top agricultural lands (soil classes 1 through 3), forests, wet lands, recreational areas, and a large number of other municipal land use reasons. Yet there are plenty of opportunities in unused lands, in both the rural and the urban regions. Solar installations can even be deployed and then relocated/removed on lands reserved for future development, when it is in the order of 15 or more years away. The scope of the report did not allow for extensive inventory of land types and ownership, so instead it was assumed that a collection of lands, with total area equal to 0.5% of the land area of Ottawa could easily be allocated to clean energy production for the city. This land area potential is illustrated in Figure 6. This is equivalent to 23 eighteen-hole golf courses, which is a rough match to the number of golf courses already developed in the region (the equivalent of 26 eighteen-hole golf courses were identified).

Figure 6 – illustration of the land area of Ottawa (blue border) and a circle indicating the equivalent to 0.5% of the total lands.

In the detailed analysis, as summarised in Appendix 3, many potential example locations were identified – this serves to illustrate some of the opportunities for placing solar projects, including in power line corridors, at the airport, built into the O-train corridors, and unused urban lands. This augments the utilisation of lands. Fixed orientation ground mount systems have a generation capacity of 42 MW_{ac}/km^2 for a complete utility-scale project[15]. Thus, the overall 0.5% allotted area would be able to host 580 MW_{ac} and about two times the capacity of the currently installed utility-scale projects.

Hosting Capacity Summary

Clearly each of the above analyses contain a large number of assumptions, and can thus only be considered rough guideposts for the potential for solar to be deployed. A number of niche sectors and novel approaches to PV systems were not directly contained within the analyses, but may contribute to overall growth of the solar, and for the most part are implicitly included given the many estimations involved.

The three analyses provided rough hosting capacities of 940, 1120, and 580 MW_{AC} for the residential, commercial and utility-scale sectors respectively, for a total *potential* capacity of 2,640 MW_{AC}, or average *potential* annual production of 19,000 TJ.

SECTION 2 – GROWTH PROJECTIONS FOR SOLAR POWER IN OTTAWA

Methodology of Pathway Projections

The future energy that can be produced by solar PV is defined by both the technology efficiency and the land and roof area that is available, as ascertained in the previous section. Uptake is also greatly affected by constraints, including market, economical, regulatory and logistical, as will be examined herein. The section considers all these factors and develops projections of possible uptake scenarios, as well as some near-term opportunities for positively influencing uptake.

Constraints

Regulatory Constraints

There are several regulatory processes involved in the development of solar projects, which include but are not limited to:

- land use restrictions;
- building permits (structural) for rooftop systems;
- electrical review; and
- grid connection.

Challenges in the clarity, consistency, and transparency of the domain of regulatory approvals are reported by stakeholders to impact project development costs (either directly or through costs associated with delays), development efficiency, and project capital costs. These “soft” costs have been increasing over time, and can form a measurable portion of a project’s total costs, especially as equipment costs and installation labour continue to decline.

The process of grid connection has required that a facility upgrades all parts of their service that was non-standard, including for issues not impactful on the PV system, such as meter location in a backyard and dual-voltage service, and such costs remove any payback in a small system.

The frequently changing rules of the Ontario administered programs have caused confusion. There has been a general lack of promotion of programs at all levels, which would otherwise have a positive effect on the uptake in the residential and commercial sectors.

Grid Capacity

As projects are developed and connect to the gird, they use up the hosting capacity, which can prevent future projects from proceeding on the same feeders or upstream. A community with PV on every home would generally not be possible without a specially designed distribution service. The screening criteria for the hosting capacity are determined and administered by the local distribution company and they differ from one service area to another.

Hydro One's screening criteria is a prescriptive rule where the total generation to be interconnected to a distribution system circuit line section, including the proposed generator, will not exceed 7% of the annual line section peak load[16]. Hydro Ottawa considered more closely the time of day aspect to grid use: for standard individual feeder circuits serving the buildings of Ottawa: determine the minimum load on the power line over the past three years within the 10 am to 3 pm window, and allow up to 25% of that value to connect. If the project is near to that screening limit, additional equipment solutions can be discussed.

For larger generators (> 30 kW_{AC}, connecting to higher voltage distribution lines) the rules are more complex and dependent on the grid equipment ratings, and systems must undergo a connection impact assessment. Hydro One provides an on-line tool to help determine in advance the status of high voltage line capacities, and during the latter round of the FIT program, tables of system capacities across Ontario (as a snapshot in time prior to new projects connecting) were provided. No one is providing interactive maps that can help decipher the equipment names and their capacity limitations to detailed service areas and potential locations for projects.

In jurisdictions such as Hawaii and California and in several European countries, the allowable penetration levels exceed 100% on some feeders. There are system impacts that the utilities are mitigating with smart solar (where inverters provide advanced control options) and smart grid solutions to support the growth of renewables.

Market Constraints

The current PV systems in Ottawa have been established with long-term, fixed-price power purchase agreements ("PPA"). While the IESO FIT program has ceased offering these contracts, there may be similar PPAs offered in the future. Also, in both Europe and the United States, the PV industry has successfully passed beyond this type of PPA to broader commercial arrangements. Such a transition is anticipated to eventually develop in Ontario, and cost-competitive projects are expected to be financed.

In the short term, the current rates and programs through the net metering program will attract only a slow uptake in the residential and commercial sectors. The Ottawa Renewable Energy Cooperative (OREC) undertook a study of net metering financial viability against various sectors and electricity rates. Using rates from early 2017 (prior to the latest drop in electricity prices) they found that certain types of commercial scale projects would be financially attractive to warrant close consideration. Other benefits of solar, including social corporate responsibility, points in the LEED (Leadership in Energy & Environmental Design) green building program, and role in net-zero energy building programs will also be factors that increase the adoption of solar.

For residential and commercial rooftop solar, a financing model that ties debt to the property itself, rather than the building owner may encourage more building owners to develop projects on their facilities, as may a standardized, widely offered PPA from local utilities or other agencies. It should be noted that a high proportion of residential and commercial systems (in Ontario and elsewhere) are owned by third parties with roof lease payments going to the building owners, and thus there is an opportunity for local entities to grow their generation assets through being 3rd party developers. This is the model already used by OREC (portfolio of greater than 1.7 MW on multi-sectoral rooftops) and Energy Ottawa (portfolio of 2.3 MW on City buildings).

No matter the ownership, the self-consumption restrictions of the existing net metering program will encumber project economics and uptake. A less restrictive set of mechanisms that will allow for generation at one facility to be purchased by the grid or purchased by a consumer at another location, would allow for higher uptake. This applies to potential for growth in all three sectors.

In fact, of the three sectors, the cost of electricity from utility-scale PV projects is the lowest, and is competitive against market costs of electricity; thus, it has a viable product for entities wishing to buy green power. However, projects need a mechanism for selling their power to interested consumers (or a consumer group). A whole new set of market conditions and business models that are already in use in other jurisdictions could be allowed here. The following are a few example models that could materialize:

a) Virtual net metering is where the energy produced at one location may be credited to consumers at other locations. This is a transaction of credits within the LDC billing system. The Ontario Ministry of Energy is presently engaging with stakeholders towards developing new policy and programs, and may also be willing to entertain pilot programs developed by commercial or municipal entities. OREC, Bullfrog Power and Energy Ottawa are all examining how to make this model work.

b) Community choice aggregation is a mechanism similar to the above, and which is an authorized retail electricity choice program administered by municipalities. They aggregate the buying power of individual customers within a defined jurisdiction in order to secure alternative energy supply contracts on a community-wide basis, but allowing consumers not wishing to participate to opt out. CCAs now serve nearly 5% of Americans and have the potential to drive hundreds of megawatts of new utility solar development[17].
c) Difference contracting between two parties, which allows a consumer to secure a fixed price for future electricity from a generator, though each still actually buys and sells with the grid. A large electricity user like the City could consider a difference contract with a supplier as a hedge and protection against escalating electricity costs.
d) Renewable energy credits (RECs) and carbon emission avoidance credits are forms of “adders” that help turn a marginally viable project into a viable one. New carbon credits are likely to be enabled by provincial or federal entities in the near future. Bullfrog Power uses the RECs as a model already: they sell green electricity to interested consumers, in the form of a 2.5¢/kWh REC adder to the customer’s consumption. Bullfrog acquires the RECs from renewable energy generators that are Ecologo certified (purchasing at a similar price point). The generators sell the electricity under a separate agreement (or could use it themselves). Large users of electricity, including the Federal Government buildings and the City of Ottawa operations could potentially be early buyers of the energy or the credits of the above mechanisms.

There are additional values to the deployment of solar, but as of yet no market means that capture this. Solar, in particular when combined with storage and other energy wise approaches, can reduce peak demands on grid infrastructure, which provides a capital cost savings to the grid; it also provides economic development, both through the local revenues and through local job creation. The value of solar has been contemplated by authorities[18], but not further evolved. Integration of local generation into transmission system planning has not yet been undertaken within the provincial Regional Planning Process[19].

In the long term, as prices become even more attractive, various mechanisms for sales are certain to blossom, and the market potential for solar in Ontario is solid.

Development Capacity

There are no challenges that are beyond the general construction services routinely operating in Ottawa, and thus a shortage of neither expertise nor manpower is expected to seriously restrict development. There are certainly lessons that have been learned, and likely some that are yet to be learned, about building and maintaining PV systems.

For the developments to be truly positive to the entire ecosystem, the following additional criteria should be incorporated:

i. generation facilities that include grid-friendly attributes;
ii. market and regulatory policies that maintain LDC business sustainability; and
iii. local development and local ownership, which supports both local economies and increases public support. This would include community ownership, City ownership, and aboriginal ownership.

Uptake Projections

Scenarios

The possible development paths for solar are challenging to predict. Leidos has developed three general scenarios that project future uptake to 2050. In all scenarios, the growth rates are based around non-linear increases of deployments per year, which is typical of an industry with declining costs. Leidos estimates these rates, as well as values for the initial deployment volumes between 2015 and 2020 (which are lower than in years prior to 2015 due to the transition and uncertainty over net metering and large project procurement mechanisms).

- The “conservative” uptake scenario assumes a slow rate of growth with no specific local effort to encourage rooftop PV, either by the City, the local LDCs or on federal properties. It does assume that during the period sometime soon after 2020, conditions again become favourable, when Ontario’s need for new generation sources is expected to increase[10], and the decreasing cost of solar projects[4] hit grid parity in a wide number of applications. It also assumes that LDC’s and regulatory bodies gradually tackle any issues that would unnecessarily limit the growth of PV, particularly in new communities, where it is anticipated that rooftop PV will achieve higher penetration rates. The long-term annual growth rates are approximately 3% for residential and 8% for commercial and utility-scale, starting in 2025.
- The “moderate” uptake scenario assumes that, in addition to global factors, there are some local efforts to encourage deployment at the residential and commercial sectors. These efforts could take the form of lowered LDC fees for grid connections, development of simple, speedy processes for integrating rooftop solar into new builds, targeted programs by the federal government to install solar on their owned and leased buildings. It also supposes some limited market mechanisms that enable procurement of power at the utility-scale. The long-term annual growth rates are approximately 6% for residential and 8% for commercial and utility-scale, starting in 2025.

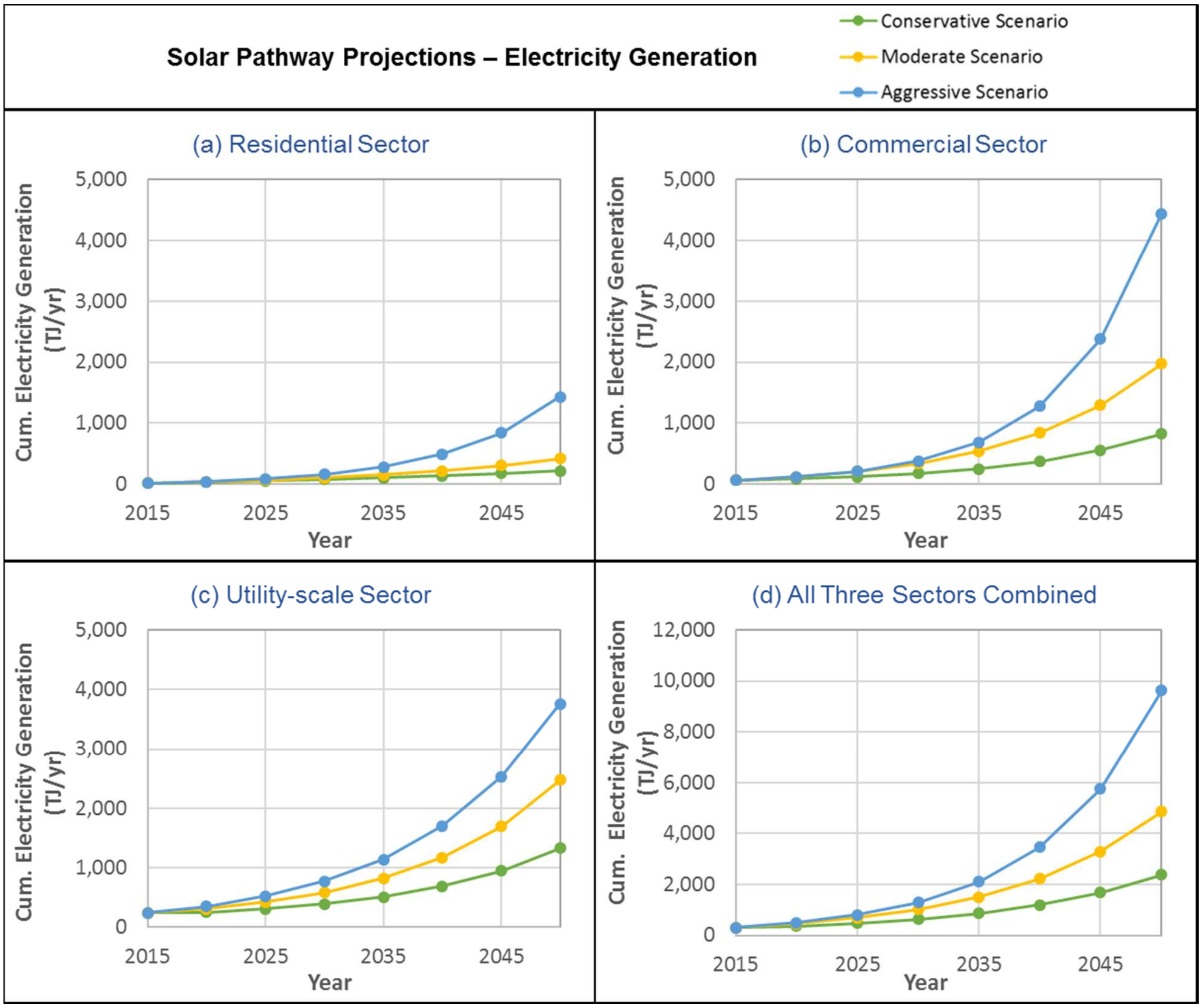
- In an “aggressive” uptake scenario, early deployment is similar to the moderate scenario, but a combination of more aggressive policies, improved system design, more aggressive actions by the LDCs in identifying and encouraging connections and more favourable financing opportunities all act in combination to encourage a move to rapid, sustained growth. This scenario also assumes a substantive catalyst project for utility-scale production, amounting to 50 MW by 2025, is enabled by innovative purchase agreements. The annual growth rates are approximately 11% for residential, 13% for commercial, and 8% for utility-scale.

Projected outcomes for new capacity and new energy generation, on five-year intervals between 2020 and 2050, for each of the sectors are included at the end of their respective Appendices (i.e. Appendix 1 through 3). Table 3 provides the rolled-up values for all three sectors. Figure 7 (a)-(c) show graphically the projections for each of the three scenarios, while Figure 7 (d) shows graphically the combination of the three, as per the values in Table 3.

Table 3 - Projected impact of total solar development in all three sectors combined, and under three different uptake scenarios.

	2015	2020	2025	2030	2035	2040	2045	2050	Total New
Conservative Scenario									
MW new	60	10	20	30	40	60	80	120	370
TJ/yr new	70	50	120	160	230	330	480	690	2,070
TJ/yr cum.	310	370	480	640	870	1,200	1,680	2,370	
Moderate Scenario									
MW new	60	30	40	60	90	130	190	280	810
TJ/yr new	70	150	230	330	490	720	1,060	1,570	4,540
TJ/yr cum.	310	460	690	1,020	1,510	2,230	3,290	4,860	
Aggressive Scenario									
MW new	60	40	50	90	150	240	410	700	1,680
TJ/yr New	70	200	300	490	810	1,360	2,280	3,890	9,330
TJ/yr cum.	310	510	810	1,300	2,110	3,460	5,750	9,630	

Figure 7 - Projections of total solar generation for each sector (a)-(c) and combined (d) and for three different uptake scenarios.



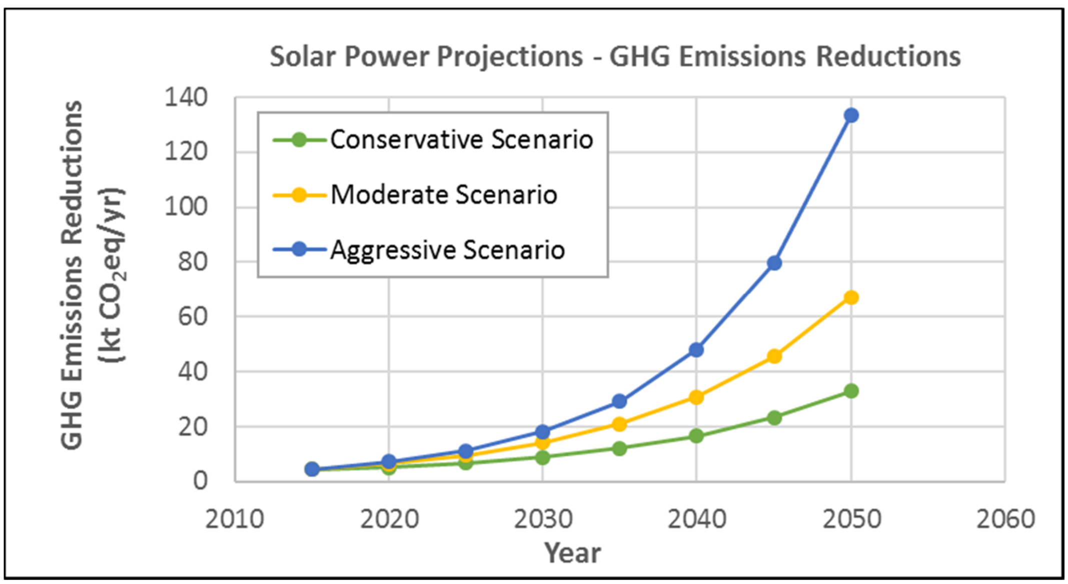
In the residential sector analysis, the aggressive scenario ends with 320 MW_{AC} of residential rooftop PV, generating 1,430 TJ (approximately 5% of Ottawa's 2015 electricity). This would require that approximately 20% of all residential buildings with pitched roofs in Ottawa have operating PV systems by 2050. This is only 30% of the "solar viable" roofs that were ascertained in earlier analyses, since it is assumed that various constraints and marginal economics restrict growth in this sector. Dramatic growth in new net-zero homes with solar could alter these numbers.

In the commercial sector analysis, the aggressive scenario ends with 740 MW_{AC} of rooftop PV, generating 4,440 TJ (approximately 14% of Ottawa's 2015 electricity). This would amount to 68% coverage of the currently *existing* roof space, but a lower percentage when growth is included.

In the utility-scale sector analysis, the aggressive scenario concludes with 620 MW_{AC} of new capacity, resulting in a total solar generation of 3760 TJ (approximately 12% of Ottawa's 2015 electricity). The area required would be approximately equal to 0.5% of the land area of Ottawa.

Figure 8 provides an estimate of the greenhouse gas (GHG) emissions reductions for the combination of all three sectors. It considers that solar production displaces electricity from the Ontario grid, and assumes the 2015 average emissions levels of the Ontario grid[20]. This is a rough estimate, since future emissions values and marginal offsets may be different. Since Ontario's electricity generation consists of mostly low carbon supplies, the GHG emission reduction value of solar power and all other renewable electricity generation technologies are low.

Figure 8 - The GHG reductions potential for solar power in Ottawa, considering the sum of residential, commercial and utility-scale sectors, and for three different uptake scenarios.



Opportunities to Advance Solar

Applicability to all Sectors

- Encourage and advocate for programs for PV systems that allow *net generation*, which removing the present "self-consumption" limitation and thus paying for generation amounts that are in excess of the building's consumption. This allows for owners to make the appropriate use of their entire roof space regardless of their usage levels.

- Ensure all regulations are clear and well understood, with fast response times. Review all regulatory fees in consideration of making them right-sized for project economics and thus supportive of uptake.
- As with many other energy-wise actions that are disregarded by building owners because of their lack of certainly of long-term ownership, financing mechanisms that provide financing tied to the property as opposed to its owner, would enable higher uptake.
- Third party ownership has been proven to be successful and popular, and opportunities to encourage and enable such models should be supported.
- Incentivize solar and smart solar systems in areas with capacity constraints as this could be cheaper than upgrades to the grid. To encourage high penetration in new developments, consider providing incentives, such as reduced connection costs or priority access to capacity, as well as design and development initiatives.
- The City and Hydro Ottawa could advocate strongly through the IESO regional planning process for provincial support of programs that develop capacity that can offset future transmission infrastructure investments (such as lines and transformers).
- A recognition that cities need electricity and can now integrate generation of electricity into land and infrastructure planning. Consider the economic development advantages of local generation, in particular for projects that involve local ownership.
- Aggressive uptake rates will require participation from a large number of Ottawa residents and businesses. The City and Hydro Ottawa can play a key role in promoting and encouraging uptake, ensuring clarity and information availability, including by:
    - Developing a quality, informative website, using leading web-interactive approaches that contain everything an interested party may need to be aware of, from general purpose information, FAQs, and local case studies.
    - Communicate with the public that today's large-scale solar is roughly grid competitive. Count on Ontarians' 83% support for solar[21].
    - Promote via Hydro Ottawa's customer base.

Residential Sector Opportunities

- Hydro Ottawa could set a fixed, low-cost connection fee for all residential solar below a specified capacity.
- With the Ontario Building Code's possible move to net-zero by 2030, there is an opportunity to work with local homebuilders to encourage the successful adoption of this requirement in new homes.

Commercial Sector Opportunities

- The City can encourage that every roof has solar developed on it, as well as actively deploying solar on all City owned buildings where feasible.

- Evaluate planning for electricity feeders to commercial areas, in particular those that have generation capacity constraints, high demand peaks, or forecasts for substantial new growth, and integrate solar and smart solar into the grid planning processes for the area. Seek community partners interested in participating in the deployment of new approaches (such as through a request for information).

Utility-Scale Sector Opportunities

- Work with other government entities present in Ottawa to enable solar development opportunities on some of the large areas of land available in Ottawa.
- Large electricity users could consider direct purchase contracts with Energy Ottawa, OREC and/or other community partners for fixed electricity price.
- Engage in the IESO's regional planning process and advocate for funding mechanisms by the IESO to incentivise local solutions, including well-designed solar, which avoid transmission infrastructure spending.
- The local grid operators, Hydro Ottawa and Hydro One, can play a substantive role in the rate of uptake of the solar, through support such as:
    - Providing and maintaining a map of grid connection capacity.
    - Proactively undertaking approaches to increase connection capacity. Some suggested areas to consider are:
        - advanced modeling of grid performance with solar
        - grid modernization and planning that supports RE as well as demand growth;
        - actively seek solar plants that provide grid supportive services (e.g. reactive power support, voltage regulation, storage and peak mitigation).
- Energy Ottawa Ltd. may be able to be a catalyst for larger deployment rates in the community through partnership opportunities and co-development of new market mechanisms.

Catalyst Projects

Catalyst Projects that Apply to All Sectors

- Develop a new innovative structure for ownership and electricity sales, such as a virtual sales mechanism, and that includes a local ownership aspect. Ontario has been considering whether to fully enable virtual net metering, and Ottawa could undertake a pilot project of this nature.
- Engage with the "smart city" initiatives that are emerging, including initiatives with upcoming federal funding, to integrate smart energy and smart solar into these programs.

Residential Sector Catalyst Projects

- Look for opportunities to work with one or more developers and homebuilders to encourage a “solar community” where all or a high percentage of homes in a new development come equipped with rooftop solar.

Commercial Sector Catalyst Projects

- Seek new partnerships to enable projects that provide advantageous grid services or that demonstrate new business opportunities, such as virtual net metering.

Utility-Scale Sector Catalyst Projects

- Investigate a large-scale project with one of the agencies that owns substantial lands around Ottawa. This could include:
    - federal research facilities
    - Hydro One and Hydro Ottawa transmission line corridors
    - the MacDonald Cartier International Airport. Several other airports in Ontario and other jurisdictions have developed solar within the active grounds of the facility, and in fact, it had already been considered by Ottawa airport management.
- Development of a net-zero electric rail transit system through deployment of solar along the transit corridors.
- Installation of a substantial PV system on a “non-building” structure (e.g. roadway sound barrier, parking garage roof, parking lot awning).

APPENDIX 1 – EVALUATION OF RESIDENTIAL ROOFTOP CAPACITY AND POWER GENERATION POTENTIAL

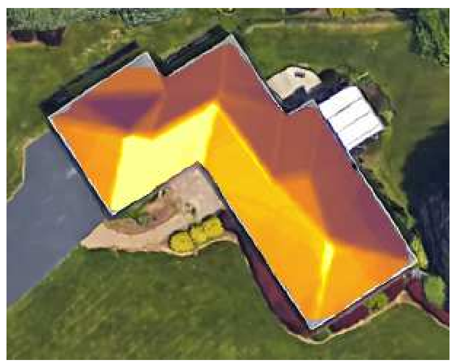
Ultimately, the potential of residential rooftop solar is limited by the available roof space within the City, by the orientation of that roof space, by the efficiency of the solar modules, and by the amount of shade. Obviously, a detailed analysis would be complex, made more so by the fact that this work should include both existing and future buildings. It is noted that not only will the amount of roof area change in the future, but so will shading, from growth and removal of trees, and from future construction of mid-rise and high-rise buildings. Any detailed estimate of potential will likely need to rely on the processing of digital images.

Google Project Sunroof

Google started their Project Sunroof[22] with the intention of estimating the solar energy generation potential for every rooftop of every building. While Sunroof data is not yet available for Ottawa (or elsewhere in Canada), Sunroof data from several northern US cities was useful to derive parameters in order to estimate Ottawa's residential rooftop potential.

Monroe County, NY which includes the city of Rochester, NY, is one location that is similar to Ottawa in that it encompasses both rural and urban lands and has a similar population, weather and latitude, and presumably also a similar distribution of building types and sizes as Ottawa. Figure 9 shows two sample images from Sunroof, with the upper image showing a collection of buildings, and the lower image showing a close-up of a single home within this area. The bright yellow areas show roof segments with the highest solar potential, with colours getting darker and eventually shifting to purple for roof segments with lower potential. In the upper image, note that buildings surrounded by large (tall) trees are darker, and south-facing segments are brighter than other orientations. Note also the larger flat roofed building in the lower left corner; buildings such as this have been excluded in our analysis. The image of the single home clearly shows the differentiation of the solar potential on individual roof segments (with different slopes and orientations). The spatial resolution of the data is not reported, but is almost certainly better than 1.0 m, and is likely in the range of 0.1 m.

Figure 9 - Sample Images from Google's Project Sunroof Monroe County, NY.



In addition to providing building-by-building analyses and estimates of solar potential, Sunroof also provides estimates for specific areas, such as by municipal boundaries. When estimating the solar potential of a neighbourhood or municipality, the application:

1. Estimates solar radiation on a surface based on “typical weather year” estimates.
2. Assumes all modules are mounted parallel to each roof segment.
3. Estimates the pitch, azimuth, shape and size of every roof segment, from data in a digital elevation module.
4. Accounts for shading from obstructions such as trees and buildings up to 150 m away.
5. Assumes conventional 250 W_{DC}, 60-cell, silicon PV modules, approximately 15.3% efficient.
6. Excludes any roof segment that receive less than 75% of the solar energy falling on an optimally oriented, shade-free roof (in that municipality).
7. Excludes any roof segment that is too small to hold at least 4 modules.
8. Excludes any building that cannot host at least 8 modules (2 kW_{DC}) with adequate solar exposure.

9. Estimates net AC energy injected into the grid as 85% of the DC capacity, adjusted for temperature at -0.5%/°C.

Sunroof estimates the technical potential for rooftop solar based on the above parameters. An example of Sunroof's technical potential estimate, for Monroe County (Rochester), NY is shown in Figure 10. A key outcome of the analysis is that Sunroof data indicates that approximately 70% of all buildings in these municipalities have sufficient exposure for viable rooftop PV systems.

Several parameters from Figure 10 (and similar outputs for three other example locations) are used to determine estimated "residential" hosting capacity. Note that while Sunroof data includes all buildings and does not explicitly break out the number of installations or energy generation potential of residential buildings, the software did provide information on whether the building had a pitched or flat roof, and its PV capacity. To determine the total residential capacity in each location, the analysis assumed "residential" roofs included 100% of roof systems smaller than 10 kW_{DC}, plus 50% of roof systems from 10 to 15 kW_{DC}. Table 4 summarizes key outcomes of this analysis, where the first five rows are directly from the Sunroof results, and the remainder are based on estimated calculations. Other approaches using other Sunroof data from Figure 10 produced similar findings.

Note that all four municipalities have populations in the range of Ottawa's population, and that they consist of an urban centre surrounded by substantial rural areas, similar to Ottawa's. A first method to estimate Ottawa's solar hosting capacity was based on the relative populations. The average capacity per person from the four example locations (the average of the bottommost row) is 0.982 kW_{DC}/person. Multiplying by the population of Ottawa (967,757 in 2015) yields an estimation of physical hosting capacity of 950 MW_{DC} for residential solar installations.

Figure 10 – Various estimated solar potential parameters for Monroe County, NY (Rochester) - data that is used in the analysis is indicated with a red bar; source Google Project Sunroof.

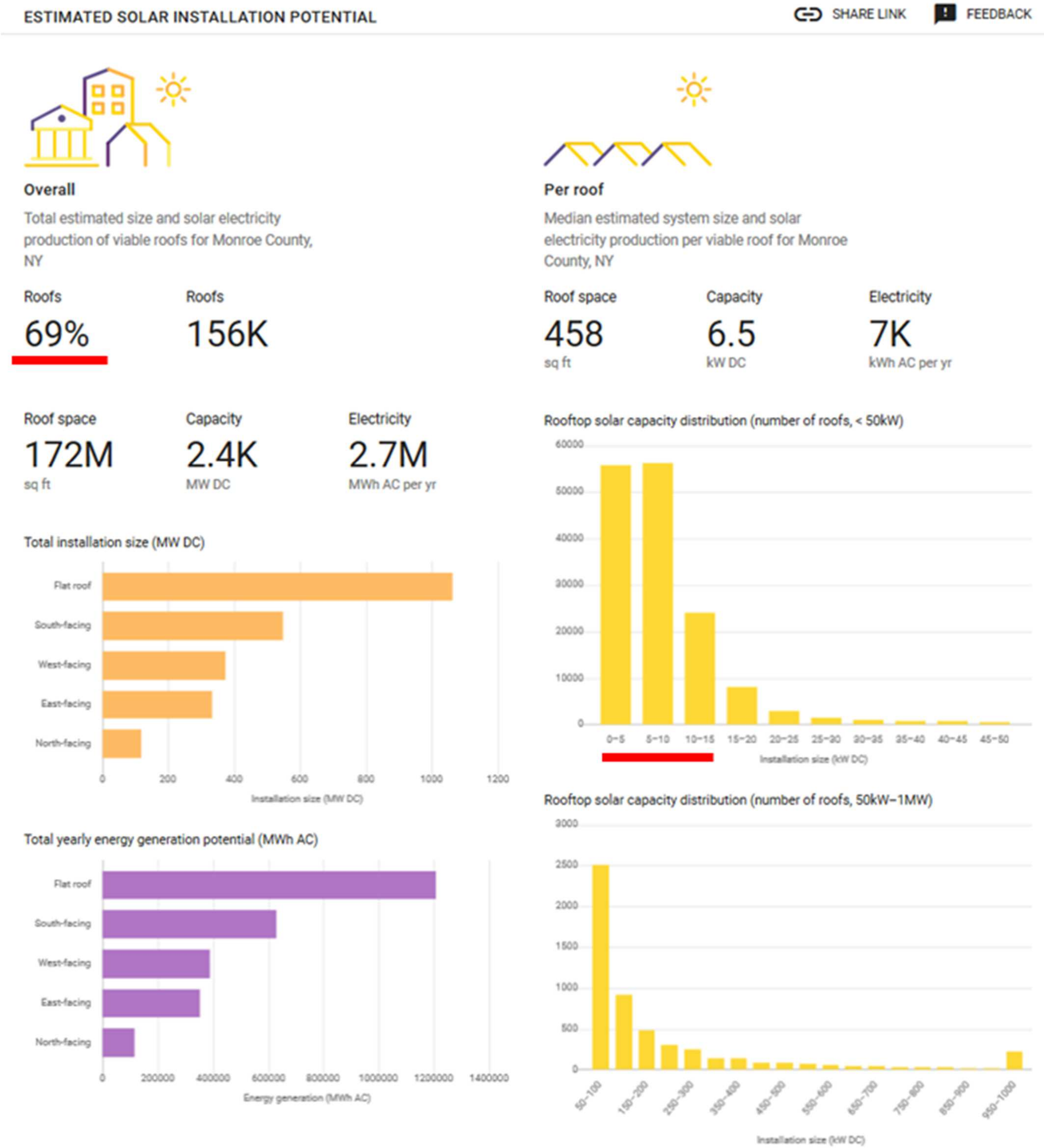


Table 4 - Summary of key results from analysis based on Project Sunroof data for four northern US municipalities.

Location	Monroe County, NY	Milwaukee County, WI	Hennepin County, MN	Erie County, NY
Population	749,857	947,735	1,212,000	992,835
Latitude	43.2	43.0	45.0	42.8
Number of Viable Roofs (including flat) 2 - 5 kW_{DC}	55,600	85,700	73,000	77,600
Number of Viable Roofs (including flat) 5 - 10 kW_{DC}	56,000	65,700	71,300	92,200
Number of Viable Roofs (including flat) 10 - 15 kW_{DC}	23,900	18,500	26,200	30,800
Extracted DC Capacity on residential roofs [MW_{DC}]$^{(1)}$	764	908	954	1,156
Extracted DC Capacity on residential roofs, per person [kW_{DC}/person]	1.019	0.958	0.787	1.164

(1) Calculated assuming 100% of roof systems 2 to 5 kW_{DC}, 100% of systems 5 to 10 kW_{DC}, and 50% of roof systems from 10 to 15 kW_{DC}.

Ottawa Residential Building Inventory

A second approach to estimating the Ottawa hosting capacity for solar is to scale the building hosting values obtained from Sunroof with information on Ottawa's residential housing stock. Statistics Canada data reports that there were 256,000 housing units in Ottawa in 2015 that are likely to have pitched roofs (detached, semi-detached and row houses), and thus be within the scope of this Pathway[23]; the other 111,000 housing units in Ottawa are primarily apartment buildings, generally with flat roofs. Table 5 shows the expected number of residential buildings with pitched roofs in 2050 assuming a growth rate of 0.3%[24]. In estimating these values, Leidos assumed an average of 5 units per row house, and 2 units per semi-detached dwellings.

Table 5 – Ottawa estimated residential building stock with pitched roofs (thus excluding apartment buildings) in 2015 and 2050.

Building type	Households (2015)	Buildings (2015)	Expected Annual Growth Rate (%)	Buildings (2050)
Single Detached	169,500	169,500	0.3%	188,200
Semi-Detached	21,600	10,800	0.3%	12,000
Row House	79,500	15,900	0.3%	17,700
Total	**270,600**	**196,200**		**217,900**

This analysis assumes that half of the detached homes can support systems from 2 to 5 kW_{DC}, that the other half of the detached homes and all of the semi-detached homes can support an array from 5 to 10 kW_{DC}, and that all of the row houses can support an array from 10 to 15 kW_{DC}. Assuming that within each of the three categories the average capacity of all systems is equal to the mid-point capacity, that is 3.5, 7.5 and 12.5 kW_{DC} respectively, then the technically viable capacity of the buildings listed in Table 5, in 2050, is 1,346 MW_{DC}. Multiplying this by 70% - in line with the percentage of buildings with viable rooftops reported by Project Sunroof for the northern US cities – yields a potential capacity of approximately 940 MW_{DC}. This generally agrees with the value obtained above based on population. Thus, it is assumed a valid value for the physical potential for residential rooftop solar in Ottawa, in 2050, is 940 MW_{DC}.

A rooftop PV system in Ottawa can be expected to produce annually approximately 900 kWh per kW_{DC} of modules[1]. This is a net energy yield after many loss factors are considered, including shading, a blend of orientations, snow losses, less than 100% uptime, degradation over life, etc. Combining this energy yield value with the capacity above indicates that Ottawa has the *potential* to generate 850 MWh/yr or 6,000 TJ/yr of solar electricity.

There are constraints which will limit the potential deployment, as discussed in detail in Section 2, with conservative, moderate and aggressive uptake rates proposed. The overall deployed sums for all three sectors of solar are provided in Section 2, while herein, Table 6 provides the values just for the residential sector.

Table 6 - Projected impact of solar development in the residential sector, and under three different uptake scenarios

	2015	2020	2025	2030	2035	2040	2045	2050	Total New
Conservative Scenario									
MW new	3.5	4	5	5	6	7	8	10	50
TJ/yr new	15	20	20	20	30	30	40	40	200
TJ/yr cum.	15	30	50	80	110	140	170	220	
Moderate Scenario									
MW new	3.5	5	6	8	11	15	20	27	90
TJ/yr new	15	20	30	40	50	70	90	120	400
TJ/yr cum.	15	40	60	100	150	210	300	420	
Aggressive Scenario									
MW new	3.5	6	10	17	28	48	80	135	320
TJ/yr New	15	30	40	70	120	210	350	590	1,410
TJ/yr cum.	15	40	80	160	280	490	840	1,430	

In the aggressive scenario, the total deployed solar attains a value of 320 MW_{AC}, which is approximately 1/3 of the total potential capacity found above. This is a relatively low percentage based on many constraints, including lower financial returns, in this sector. Aggressive uptake of net-zero housing with PV panels, in particular during in the construction of new homes, could help achieve higher uptake.

APPENDIX 2 – EVALUATION OF COMMERCIAL ROOFTOP AREA AND POWER GENERATION POTENTIAL

The potential of commercial rooftop solar is limited by the available viable roof space within the City, and the efficiency of the solar modules. Ignoring roof furniture and all other obstructions and details, the current (2016) total estimated roof space is 6.8 million square meters on approximately 2,300 buildings. Accounting for typical packing densities of modules on flat surfaces[1], a total PV module area in excess of 5 million square meters is potentially possible (especially considering future buildings in Ottawa). Assuming modules with efficiencies in the 17 to 18% range, this would lead to nearly 1 GW of potential generation capacity. In the next paragraphs, a more constructive estimate of rooftop potential is provided which considers roof capacities.

As a test case, City staff completed a building-by-building analysis of a 1 x 1 km area centred on the intersection of Merivale Road and Meadowlands Drive, an area that includes a number of larger buildings, as well as single and multi-unit residential buildings. The buildings larger than 500 m^2 were divided into three size ranges by roof area. The total roof area of all the large buildings in this selected area was 131,700 m^2, divided reasonably evenly among the three ranges of building sizes, with details provided in the first three columns of Table 7.

Using satellite imagery, Leidos found a total of 26 areas or zones within Ottawa, of various sizes, that had similar densities of large buildings. The total land area in these zones was estimated to be 52 km^2, approximately 2% of the land area in Ottawa. Assuming a similar distribution of roof sizes in all zones as in the sample area, this leads to an estimate of 2,300 buildings with 6.8 million square meters of flat or near flat roof space potentially suitable for commercial rooftop PV systems within Ottawa. These derived Ottawa values are contained in the last two columns of Table 7, still subdivided into three size categories.

Table 7 - Summary of buildings and sizes within the sample 1 x 1 km commercial area, subdivided into three size categories, and estimated equivalents for all of Ottawa.

	Analysis of 1 x 1 km sample area		**Estimates for all of Ottawa**	
Roof size category (m^2)	Number of buildings	Total roof square footage (m^2)	Number of buildings	Total roof square footage (m^2)
500 – 2,500	30	36,000	1,560	1,870,000
2,500 – 10,000	11	44,700	572	2,326,000
greater than 10,000	3	51,000	156	2,651,000
All	**44**	**131,700**	2,288	**6,847,000**

The downtown core was not included in this estimate, because solar on taller buildings brings different challenges than those on the primarily lower buildings in the identified areas. One issue is that tall buildings are often found in clusters, such that the tallest buildings may frequently shade the roofs of neighbouring ones. Tall buildings also often have a higher proportion of roof "furniture" (HVAC equipment, elevator equipment, etc.), lessening the space usable for PV. In addition, winds on taller buildings are generally higher than for one- and two-storey buildings, and may require individualized engineering to design an approved mounting structure. Finally, roof anchors, used to support window washing platforms or similar equipment, can be distributed across the roof; the building code requires that any area where cables from these anchors to the edges of the roof must be kept clear of all obstructions, effectively eliminating large areas of the roof as possible sites for PV modules. This estimate also does not include large buildings that are scattered outside of the selected 26 high-density commercial zones.

To estimate the amount of solar generation that can be accommodated on these roofs, assumptions were developed for:

- the % of buildings that can accommodate PV;
- the % of usable roof space on each building;
- the % of area within the array that is covered with PV modules;
- the PV module efficiency; and
- specific production of 1,100 kWh/kW_{DC}[25].

Table 8 provides estimates developed by Leidos, with slightly differentiated values depending on building size. The values are used, along with the total roof area developed in Table 7, and assumptions about the PV module performance parameters to determine the overall net capacity. Commercial rooftop PV systems in Ottawa can be expected to annually produce approximately 1,100 kWh per kW of rated power. Because of the low tilt angles of most rooftop systems, this value is largely independent of building orientation, and no dependence on building orientation was included in the analysis. Generation of such low tilt systems is substantially higher in summer compared to winter. The final result is the potential for 1,120 MW_{AC} with an annual generation of 4,440 TJ.

Table 8: Estimated capacity for commercial rooftop solar in Ottawa.

Parameter	**Building size, by roof area**			
	500 - 2,500 m²	**2,500 - 10,000 m²**	**>10,000 m²**	**Sum**
Total roof area (m²)	1,870,000	2,326,000	2,651,000	6,848,000
Percentage of buildings that can accommodate PV	90%	100%	100%	
Percentage of usable roof area on each building	75%	85%	85%	
PV coverage ratio	85%	85%	85%	
Total PV module area (m²)	1,073,000	1,681,000	1,916,000	4,670,000
PV module efficiency	24%	24%	24%	
PV array capacity (MW_{DC})	258	403	460	1,120
Annual electricity production (TJ)	1,020	1,600	1,820	4,440

There are constraints which will limit the potential deployment, as discussed in detail in Section 2, with conservative, moderate and aggressive uptake rates proposed. The overall deployed sums for all three sectors of solar are provided in Section 2, while herein, Table 9 provides the values just for commercial sector.

Table 9 - Projected impact of solar development in the commercial sector, and under three different uptake scenarios

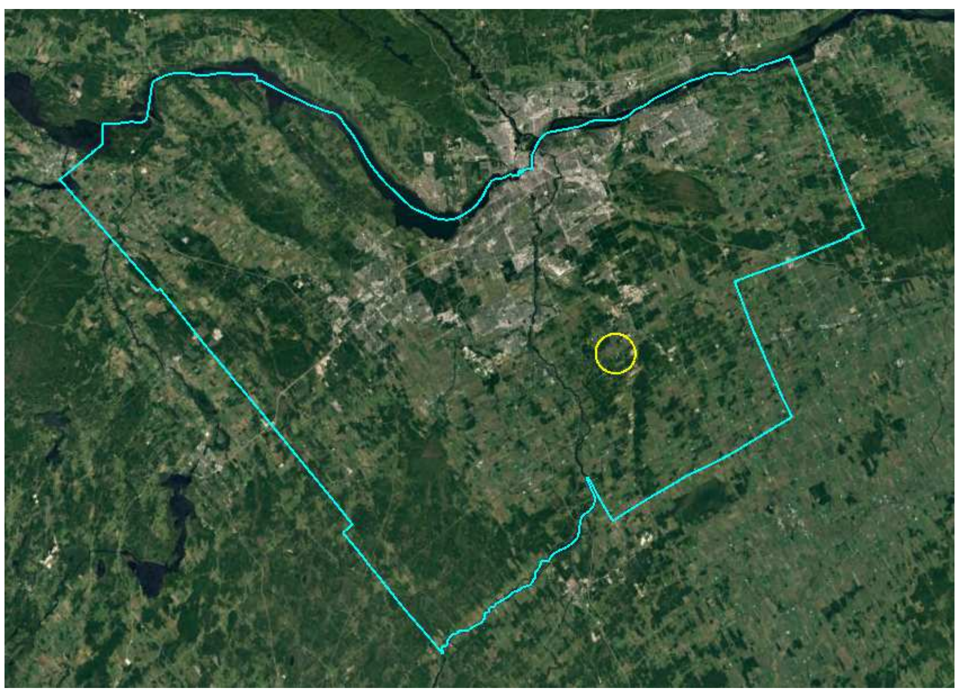
	2015	2020	2025	2030	2035	2040	2045	2050	Total New
Conservative Scenario									
MW new	10	4	6	9	14	20	30	46	130
TJ/yr new	59	20	40	50	80	120	180	270	760
TJ/yr cum.	59	80	120	170	250	370	550	820	
Moderate Scenario									
MW new	10.0	10	15	23	34	51	76	114	320
TJ/yr new	59	60	90	130	200	300	450	680	1,910
TJ/yr cum.	59	120	210	340	540	840	1,290	1,970	
Aggressive Scenario									
MW new	10.0	10	15	28	53	99	185	348	740
TJ/yr New	59	60	90	170	310	590	1,100	2,060	4,380
TJ/yr cum.	59	120	210	370	690	1,280	2,380	4,440	

The aggressive scenario ends with 740 MW_{AC} of rooftop PV, generating 4,440 TJ (~14% of Ottawa's 2015 electricity). As indicated above, the current estimate of commercial rooftop space in Ottawa is approximately 6.8 million square meters, so the aggressive scenario would amount to 68% coverage of the currently *existing* roof space. Considering that there will be significant growth of new buildings in Ottawa by 2050, and that technology advances should permit both usage of more roof space and more generation per unit of roof area, this aggressive scenario appears to be substantially lower than the technically achievable limit for this time frame. Furthermore, the potential for parking lot awning structures and building integrated technology could further enhance the overall potential.

APPENDIX 3 – EVALUATION OF LAND AREA AVAILABILITY FOR UTILITY-SCALE PROJECTS AND THEIR GENERATION POTENTIAL

The production capacity of a ground mount plant is directly related to the surface area it occupies. Because the sun shines equally across the whole region, there is the potential to deploy 1,000's of MWs of solar across the broader Ottawa region. Leidos will propose an allotment of 0.5% of the total surface area of the municipality as a possible and viable goal for 2050 – this is substantial enough for a significant amount of electricity generation, and though it certainly would be noticeable, it can be deployed such that it is not a more onerous use of land than many other land uses. It would also result in local economic development. This 0.5% allotment amounts to 14 km^2, as illustrated in Figure 11. This area is, for example, the equivalent of approximately twenty-three 18-hole golf courses which is fewer than the twenty-five 18-hole equivalent golf courses that presently exist in the Municipality[26].

Figure 11 - Map of the Municipality of Ottawa, boundary shown in blue, and with a yellow circle indicating a land area of 14 km^2 which is approximately 0.5% of the Municipality total land (Google Earth imagery).



Energy Potential per square km or land

This analysis assumes a generation capacity of 42 MW_{AC}/km^2 for a complete utility-scale project and capacity factor of 0.18 for new plants - these values are based on typical values from utility-scale projects in Ontario[27]. A summary of some example land areas and their equivalent solar capacities are provided in Table 10. The land area the size of one 18-hole golf course can host a 26 MW_{ac} plant and produce enough energy for 4,500 houses[28]. The overall 0.5% allotted area would be able to host 586 MW_{ac} and produce 3,300 TJ/yr, which is equivalent to 10% of Ottawa's present electrical energy consumption (Hydro Ottawa and Hydro One combined).

Table 10 – Some example land-use sizes and their typical solar power and energy generation potential.

Example Areas	Surface Area (km^2)	Supply Capacity (MW_{AC})	Annual Energy Production (TJ)	Equiv # Houses Electricity Use[(1)]
Cdn. football field	0.0060	0.25	1.4	44
3-acre estate	0.0121	0.51	2.9	90
18-hole golf course	0.61	26	146	4,500
0.5% of municipality surface area	13.95	586	3,300	102,700

(1) Assumes 750 kWh/month for a typical household in Ontario[4].

There are a large number of potential locations for utility-scale projects. It is anticipated that they will be initiated by a number of different developers, and will include different sizes and be placed in a range of urban and rural locations. Locations where land is already impacted by human activity can be preferentially sought. For example, this can include transmission line corridors, next to transportation corridors, land at airports, end-of-life quarries, landfills, etc. Fallow, non-agricultural lands can also be considered (environmental approvals prevent development on top agricultural lands); and certain environmental benefits can be obtained from utility-scale projects, such as pollinator friendly ground coverage. Mounting structures that do not penetrate the ground may also be considered, which may allow for the flexibility to deploy and later move equipment using lands allotted to future long-term development. Table 11 contains a list of some possible or example locations that could be considered – the selections are intended to be illustrative of potential, but not definitive in any way of the use of these sites. Other similar or alternative sites are also available, but a detailed survey was outside the scope of this report. A satellite view of these example locations is provided in Figure 12.

Table 11 – A listing of the example lands that have areas large enough for solar generation to meet 0.5% of municipal land area.

	Example Lands	Solar Potential (MW_{ac})
Western Urban Lands		
	416 at Baseline[(1)]	1.8
	Corkstown at Moodie[(1)]	3.7
	Prince of Wales near Rideauview Terrace[(1)]	2.0
	Greenbelt Complex at Woodroffe & Hunt Club[(1)]	1.9
	Golf course at suburban edge[(1)]	26
	Airport - undeveloped lands to the south[(1)]	31
Western urban subtotal		66
Eastern urban subtotal[(4)]		66
Western and Eastern urban subtotal		**132**
Transportation and Energy Infrastructure Lands		
	Trail Road landfill site[(1)]	14
	Transmission Line Corridor[(2)]	72
	Southern route of the bus transit way along Woodroffe[(3)]	1.7
	O-train Confed. Line above ground segments[(3)]	6.0
Total in urban and suburban regions		**226**
Lands in rural areas (e.g. 14 golf courses)		360
Net Total		**586**

(1) Assumes 42 MW_{ac}/km^2 for large polygon area solar farms.

(2) Assumes 2 continuous rows of racks, holding modules arranged in landscape 5 high.

(3) Assumes 1 continuous row of racks, holding modules arranged in landscape 5 high.

(4) Assumes that in the eastern urban area of Ottawa, an equivalent area of land to that in the western urban area could be identified for development of large solar projects.

(5) This represents the quantity of land located in the rural areas of Ottawa, that when summed with urban lands, will reach 0.5% use of municipal lands.

Figure 12 – Aerial view of example lands in the urban regions of Ottawa that could be developed for utility-scale solar (developed using Google Earth), with insets shown for two of the possible areas.

The conclusion of this illustrative exercise is that there is potential for more than 226 MW_{AC} of solar power built on lands that already have some form of development in the urban area. In addition to this, undeveloped lands in the broader rural regions of the City could easily support more than 360 MW_{AC} of capacity. The total of these two lists is 586 MW_{AC} of capacity, in-line with the suggested 0.5% land allotment.

In consideration of this potential, and the constraints and uptake scenarios that are detailed in Section 2 of the report, the forward project uptakes were estimated. The overall deployed sums for all three sectors of solar are provided in Section 2, while herein, Table 12 provides the values for just the utility-scale sector. The aggressive scenario attains a total of 621 MW_{AC}, slightly exceeding the above capacity either through improved technology efficiency or through slightly more deployment.

Table 12 - Projected impact of solar development in the utility-scale sector, and under three different uptake scenarios

	2015	2020	2025	2030	2035	2040	2045	2050	Total New
Conservative Scenario									
MW new	47	2	3	6	12	24	49	97	190
TJ/yr new		10	20	30	70	140	280	550	1100
TJ/yr cum.	240	250	270	300	370	510	790	1340	
Moderate Scenario									
MW new	47	3	6	12	25	49	98	197	390
TJ/yr new		20	30	70	140	280	560	1120	2220
TJ/yr cum.	240	260	290	360	500	780	1340	2460	
Aggressive Scenario									
MW new	47	20	30	18	37	74	148	295	622
TJ/yr New		110	170	100	210	420	840	1680	3530
TJ/yr cum.	240	350	520	620	830	1250	2090	3770	

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1 Based on Leidos' experience in reviewing a substantial number of operating projects in Ontario and northern US states.

2 Global Solar Atlas; http://www.globalsolaratlas.info, accessed June 12, 2017.

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9 Ottawa Renewable Energy Cooperative, "Technical Report for the City of Ottawa Review of Net Metering Opportunities, Barriers, and Implications for Solar Projects in Ottawa", June 19, 2017.

10 IESO, "Ontario Planning Outlook A technical report on the electricity system prepared by the IESO" Figure 13, September 1, 2016, http://www.ieso.ca/en/sector-participants/planning-and-forecasting/long-term-energy-plan; accessed Dec. 4, 2016.

11 PV Magazine reported module prices as low as $0.30 US per watt in July 2017 (https://www.pv-magazine.com/features/investors/module-price-index/). Leidos, from confidential sources, is able to confirm that this is a reasonable estimate.

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14 Communication with City Staff and in relation to preliminary efforts they undertook with University of Ottawa Geography Department.

15 The value of 42 MW_{AC}/km^2 is both Leidos Canada's files for large Ontario projects with fixed, south facing modules, and it is also the value found in: "Land-Use Requirements for Solar Power Plants in the United States", National Renewable Energy Laboratories Technical Report 6A20-56290, June 2013.

16 Hydro One, "Technical Interconnection Requirements for Distributed Generation - Micro Generation & Small Generation, 3-phase, less than 30 kW", DT-10-20, 2010; accessed August 2017;
https://www.hydroone.com/businessservices_/generators_/Documents/microFIT_TIR_for_Distributed_Generation.pdf

17 Local Power, http://www.localpower.com/CommunityChoiceAggregation.html, accessed Dec. 11, 2016.

18 Ontario Ministry of Energy, "Net Metering/Self-Consumption In-Person Engagement Sessions", Ottawa Session September 15, 2015.

19 Direct experience by Joan Haysom through membership in the IESO Ottawa Region Local Area Committee.

20 Derived from data in the Independent Electricity System Operator, Ontario Planning Outlook – a technical report on the electricity system prepared by the IESO, September 1, 2016.

21 Gandalf Group survey results contained within "Canadian Solar Industry Association - Distributed Generation Task Force Recommendation Report", March 17, 2016. http://www.cansia.ca/uploads/7/2/5/1/72513707/cansia_dgtf_recommendation_report.pdf; accessed Oct. 10, 2017.

22 In February 2017 Google's Sunroof project has published some preliminary data on a website (https://www.google.com/get/sunroof#p=0), with information covering approximately half of the buildings in the United States. At the time of writing, no data for any Canadian locations had been released publicly.

23 All flat roof buildings, including residential apartment buildings, are included in the "Commercial Rooftop Solar" Pathway document because, in apartment buildings the roofs are owned corporately rather than by individual homeowners, and the design of rooftop PV for these buildings is akin to commercial and industrial buildings.

24 From information provided by City of Ottawa Research and Forecasting Group, including the document "Projections 2036 – Avg Annual Dwellings.xlsx"

25 Based on Leidos' extensive experience in reviewing commercial rooftop systems in Ontario. When taking into consideration the Ottawa solar resource, impacts of snow, a mixture of array

orientations, impacts of shading, and equipment degradation over life, this is a reasonable estimation of specific energy production.

26 Canadian Golfer – Golf course guide; http://www.ontgolf.ca/courselistings/ottawa-eastern-ontario-golf-courses/, accessed Dec. 16, 2016.

27 The value of 42 MWac/km2 is both Leidos Canada's files for large Ontario projects with fixed, south facing modules, and it is also the value found in: "Land-Use Requirements for Solar Power Plants in the United States", National Renewable Energy Laboratories Technical Report 6A20-56290, June 2013.

28 Calculated using 750 kWh/month as the monthly electricity consumption of a typical residential customer, as taken from "Defining Ontario's Typical Electricity Customer", Report of the Ontario Energy Board EB-2016-0153, April 14, 2016.

Pathway Study on Waterpower in Ottawa

Presented to:

The City of Ottawa
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Ottawa, ON K1P 1J1

In relation to
The City of Ottawa Energy Evolution Program

By:

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October 17, 2017

ABOUT THIS REPORT

City of Ottawa Energy Evolution Program

On July 8, 2015, Ottawa City Council approved the development of a Renewable Energy Strategy as part of the 2015-2018 City Strategic Plan. This initiative has been developed into a program entitled Energy Evolution – Ottawa's Renewable Energy Strategy. A main goal of Energy Evolution is to develop a baseline analysis of energy supply and demand within the City of Ottawa and assess options, in collaboration with community partners, for all such partners to advance energy conservation, energy efficiency and renewable energy generation within their respective areas of control and influence. The Energy Evolution program has interacted closely with community stakeholders from local utilities, the federal government and other government institutions, the development sector, academia, the non-profit sector, and the private sector at large. Leidos Canada was engaged by the City to support analysis in the energy supply domain, including research reports and facilitation of discussion with stakeholders.

The Purpose of this Report

This and other "Pathway Study" documents are focused technical notes describing how the specific energy technology may develop in Ottawa. The document considered the overall technical potential for implementation, and then further considered the constraints (economic, regulatory, etc.) that are likely to reduce uptake. It suggests opportunities to influence uptake rates and catalyst projects that may be attractive to consider further. Results of the Pathway Studies are intended to be used along with the Baseline Study of energy data towards an overall assessment of future energy strategies within the City of Ottawa Energy Evolution program.

A draft form of this Pathway Study was circulated to key stakeholders and experts in the topic during the summer of 2017. Meetings were also undertaken during this period, where these representatives contributed their insights and ideas towards the development of leading project opportunities in relation to the topic of the Pathway.

Other documents in this series are:

Baseline Study on Energy Use in Ottawa in 2015
Pathway Study on Wind Power in Ottawa
Pathway Study on Solar Power in Ottawa
Pathway Study on Biogas Power and Energy in Ottawa
Pathway Study on District Energy Systems in Ottawa
Pathway Study on Heat Pump Technology in Ottawa

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Key Units

MW	Megawatts is 1,000,000 watts, and is a measure of power, used here in the context of the power rating or the capacity of a generation facility. A typical wind turbine has an electrical power production of approximately 2 MW (at a predefined wind strength), which is equivalent to the power required to operate approximately 1,800 microwaves simultaneously.
TJ	Terajoules is a measure of energy, base unit of joules, and used here in the context of total energy delivered over one year. As a simplistic example, a wind turbine producing on average 1.5 MW of power for 100 hours will deliver 150 MWh of energy, which can be converted in to units of joules as 0.54 TJ.
kt CO_2eq	kilotonnes of carbon dioxide (CO_2) and other equivalent greenhouse gases, which is the common unit for quantifying the greenhouse gas emissions related to a process.

Pathway Study on Waterpower in Ottawa

EXECUTIVE SUMMARY

There are a substantial number of developed waterpower projects already in existence in Ottawa, predominantly along the Ottawa River: there are 9 projects in total, with a net capacity of 260 MW, which produce 6,780 TJ of electricity per year. These presently contribute 4.4% of Ottawa's electricity consumption needs. These facilities are all considered "small" waterpower facilities, and all are run-of-the-river. Given the long history and maturity of waterpower generation, there is little untapped potential for new generation. In fact, the largest source of new generation capacity is through the refurbishment and modernization of facilities along the Ottawa River, as is being undertaken between 2015 and 2018 by Energy Ottawa. The available new locations are all smaller and considered "mini" waterpower facilities; they are predominantly along the Rideau River. A large number of similarly small undeveloped sites also exist along the many small rivers in the region to the west of Ottawa. The economics of developing smaller sites is less favourable, yet technological improvements aimed at optimizing their development are under active interest, including by commercial and government entities located in Ottawa. The total capacity that could be developed through both refurbishment and new facilities, under an aggressive scenario, is 36 MW with an associated energy production of 790 TJ. Thus, the future growth of waterpower is much more limited than its existing presence, but benefits such as technology and economic development can foster modest growth within Ottawa and further afield.

Waterpower Summary Table

Energy Type:	Local renewable electricity
Pathway Potential - cumulative to 2050, under an aggressive scenario (conservative and moderate scenario projections are contained in Section 2 of the report)	
Electricity Generation	36 MW (790 TJ)
% of Electricity Supply(1)	2.5%
GHG Reductions(2)	11 kt CO_2eq
% of GHG Emissions(3)	0.2%
Other Impacts:	Economic development through locally developed projects and development of expertise.

(1) As a % of Ottawa's 2015 electricity usage (32,200 TJ), as per the Baseline Study.
(2) Assumes the 2015 Ontario grid's average emissions levels.
(3) As a % of Ottawa's 2015 total emissions (5,200 kt CO_2eq), as per the Baseline Study.

SECTION 1 – PRESENT ASSESSMENT OF WATERPOWER IN OTTAWA

Pathway Description

Development of new waterpower generation that provides electricity to the Ottawa grid. While there is no universal definition, small waterpower typically refers to power capacities in the range of 1MW to 50MW, mini waterpower describes systems in the range of 100kW to 1MW, while micro waterpower for those less than 100kW. There are no new large waterpower resources (>50 MW) available in the region. This Pathway focuses on the undeveloped small and mini waterpower opportunities within Ottawa, which include refurbishment of small waterpower plants and development of new mini waterpower plants. Micro waterpower is too small a contribution to track within the OttEE initiative.

Pathway Boundaries

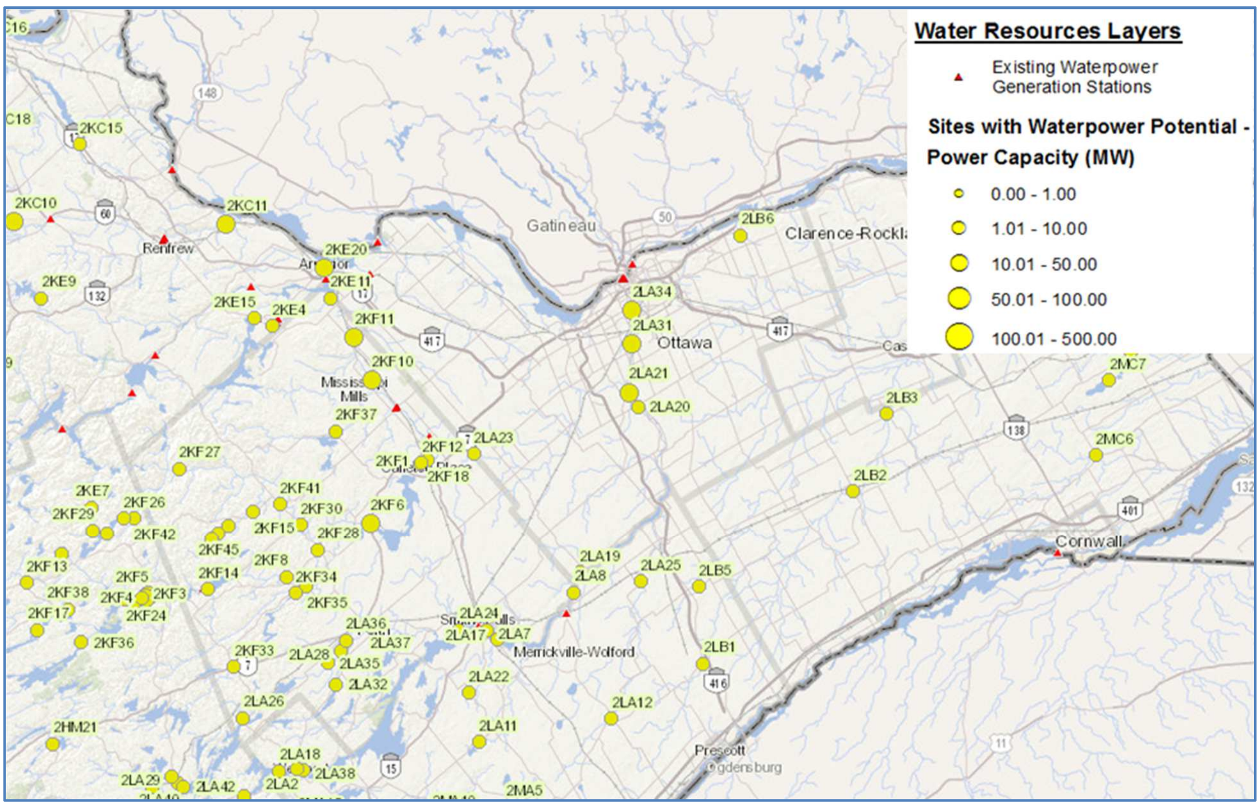
The quantitative analysis includes all waterpower sites within or on the border of the City boundary. It is worth noting that a number of small waterpower plants exist just outside the city boundaries, including many on the Mississippi and Madawaska River systems. These regions have a measurable capacity for new development, including refurbishment of small waterpower and development of dozens of mini waterpower sites as can be observed in Figure 1. These opportunities are outside of the scope of this Pathway because they are outside the boundaries of Ottawa. Such projects do however, support a greener electricity mix on the Ontario system, they may connect onto the same electricity feeders that service Ottawa, and their development may involve Ottawa area entities. In fact, in 2015 Energy Ottawa purchased ten waterpower facilities in Eastern Ontario and Upper New York State, representing 31 MW of power.

Background

Waterpower generation (also known as hydropower) has been in use for more than a century. Waterpower facilities in the small to large categories provide some of the lowest cost forms of energy, and as such, waterpower potential of all sites in Ontario with good height drops is already developed.

Weirs (a partial dam) are used on many waterways to control water levels to allow for boat navigation, including in association with canal systems. Both small and mini waterpower facilities usually include a weir to raise the water level a little and to direct water, often via a pipe or canal, towards the generator. The weirs also have a spillway, where water is allowed to flow freely downstream. There is no reservoir where the water may be stored, and as such these plants are called run-of-the-river. Production power will vary with the natural seasonal water level variations, with no capability to increase or decrease power production (i.e. they are not dispatchable). Many rivers across eastern Ontario have plants of this type, including the generation power plants along the Ottawa River in Ottawa.

Figure 1 - Map of the Eastern Ontario region indicating existing waterpower plants and potential waterpower sites[1]. The boundary of the City of Ottawa and other municipalities are shown in light grey.



All of the existing small waterpower plants within Ottawa are listed in Table 1 (information acquired from owners' websites). The capacity is the rated maximum power that the generators can produce, while the annual energy considers that power output will vary hour by hour with water conditions, for a net energy production over the year at a lower average capacity factor. Small waterpower sites tend to have capacity factors of 0.8 – 0.85.

Table 1 - Summary of existing waterpower plants within Ottawa, information found on owners websites[2,3.4]

Waterway	Project	Capacity in 2015 (MW)	Annual Energy (TJ)	Owner	Comments
Ottawa River	Chaudière #2	8	216	Energy Ottawa	Refurbished in 2001
Ottawa River	Chaudière #4	8	216	Energy Ottawa	Refurbished in 2005
Ottawa River	Grinder Powerhouse	0.7	15(1)	Energy Ottawa	Rebuilt as an electricity generator in 2007
Ottawa River	Ottawa Stations(2)	9	230	Energy Ottawa	Purchased in 2012. New 29 MW plant to be complete 2018
Ottawa River	Gatineau(3)	12	292	Energy Ottawa	Purchased in 2012
Ottawa River	Hull Central #2(3)	27	590	Energy Ottawa	Purchased in 2016
Mississippi River at Fitzroy	Galetta	2	36	TransAlta	Refurbished in 1999
Ottawa River at Fitzroy	Chats Falls(4)	192	5,147	Ontario Power Generation & Hydro Quebec	
Rideau River at Falls	Rideau Falls	1.8	40(1)	Energy Ottawa	Refurbished ~ 1980s
Total		**260**	**6,780**		

Assumptions used:

(1) For Rideau Falls, no energy generation values were available, thus energy production is based on estimated capacity factor of 0.7, which is smaller than other plants due to the smaller size.

(2) Ottawa Stations are on the Ontario side of the boundary, and in 2015 connected to Hydro Quebec system, but after refurbishment will be connected to the Hydro Ottawa system.

(3) Gatineau and Hull Central are on the Quebec side of the Ottawa River, and in 2015 were connected to Hydro Quebec, but after refurbishment will be connected to the Hydro Ottawa system.

(4) Chats Falls is half owned by Hydro Quebec, but all of the power flows into the Ontario grid.

Technology Advances

Locations with smaller height drops (lower heads) which are typical of the mini waterpower category, have been less economical to date, and many locations with heads of the order 3m are available for development. As reported for 2005, there are 45 facilities across Ontario that fit the mini category, with a total capacity of 16MW[5], some of which are within the City boundary as further detailed below. Implementation of mini waterpower plants into locations with existing weirs often have no changes to water levels and only minor changes to the built infrastructure - it may be possible to place turbines within or in-line with the weir, meaning there would not be a long penstock or substantial infrastructure to add into the site of an existing weir[6].

There have been advancements recently in small-scale waterpower technologies, relating in particular to:

- turbines that can efficiently capture energy from lower pressures typified by low-head locations;
- use of variable speed generators; and
- improved control systems to optimize parameters to the waterpower conditions.

NRCan has been actively supporting R&D and technology development of these technologies with Canadian partners, and these technologies are in the demonstration phase.

New Waterpower Resources in Ottawa

Many small waterpower plants were refurbished over the past decade, including several of the sites on the Ottawa River, as was noted in Table 1. Two refurbishments of existing plants in the Ottawa River are planned for the near future, as listed in Table 2.

Table 2 – Expected facility refurbishments.

Waterway	Refurbishment Projects	New Capacity (MW)	Annual Energy (TJ)	Owner	Comments
Ottawa River	Ottawa Stations	20 MW	547[(1)]	Energy Ottawa	New 29 MW plant to replace previous 9 MW, to be complete 2017
Ottawa River	Gatineau Plant	2	38[(1)]	Energy Ottawa	Planned refurbishment
Totals for refurbishments		22	585		
[(1)] Estimated energy production based on increased power capacity and an improved capacity factor of 0.85.					

The Ministry of Natural Resources (MNR) on-line Atlas for renewable resources[1] identifies five potential locations within Ottawa for new mini waterpower development along the Rideau River. The Atlas also provides an estimate of the capacity of each site. In addition to these sites, the outflow water from the City of Ottawa's Robert O. Picard Environmental Centre (ROPEC water treatment plant) has been identified as a viable waterpower site. Energy Ottawa has submitted an application for a FIT 5 contract for this site, but did not obtain a contract**.**

It has also been suggested that there might be additional waterpower capacity that could be harvested at Rideau Falls, and this has been estimated at 0.5 MW.

Table 3 summarizes key characteristics of these potential projects. Because these are mini waterpower projects, a capacity factor of 0.6 has been assumed to determine the estimated annual energy production. An image of one of these sites (Watson's Mill) is included in Figure 2. Resource potential on the Carp River, Jock River (Ashton Station) and Cardinal Creek (Orleans) are rated at less than 30 kW, and therefore in the micro-waterpower category, and too small to be further considered in the context of this analysis. Project development at any of these sites could be constrained by many of the factors to be discussed below.

Table 3 – Potential waterpower sites and their estimated capacities that could be developed.

Project	Waterway	New Capacity (MW)	Annual Energy (TJ)	Owner or Waterway Manager
ROPEC	Water treatment outflow	0.2	3[(2)]	City of Ottawa & Energy Ottawa
Burritts Rapids	Rideau River	0.3[(1)]	5[(2)]	BRREA[(3)] & Parks Canada
Watson's Mill	Rideau River	1.0[(1)]	19[(2)]	Parks Canada
Long Island Lock	Rideau River	2.5[(1)]	48[(2)]	Parks Canada
Black Rapids Lock	Rideau River	1.2[(1)]	23[(2)]	Parks Canada
Hog's Back Falls	Rideau River	6.2[(1)]	118[(2)]	Parks Canada
Rideau Falls	Rideau River	0.5[(1)]	10[(2)]	Parks Canada
Totals new capacity		**11.9**	**226**	

(1) Estimate provided by Ministry of Natural Resources Renewable Energy Atlas.
(2) Estimated energy generation based on an assumed capacity factor of 0.6.

Figure 2 – A picture of Watson's Mill in Manotick, looking upstream showing the existing weir and historic building (source Google Maps).

Energy Production Profile

All of these potential projects are run-of-the-river plants. As such, these projects have no ability to store water, and minimal ability to adjust their power output (i.e. they are not dispatchable). The daily profiles of the production are relatively flat, while the seasonal profiles tend to peak in the spring, and be lowest in late summer. While not a correlated match to the peak electricity demand, these waterpower systems do provide power during winter peaks which is a useful complement to local solar generation.

Greenhouse Gas Impacts

Large waterpower projects that include development of reservoirs and flooding of upstream lands generally have associated GHGs emissions due to rotting biomass, but these run-of-the-river projects that involve no change to water flows will create negligible levels of GHGs. The output energy is electricity, which feeds into the Ontario electricity mix, and thus will have a GHG emissions offset equal to the average GHG emissions associated with the Ontario supply. It has been noted by the Environmental Commissioner of Ontario[7] that when new generation is replacing natural gas generation, a larger GHG reduction can be attributed. Since waterpower plants do have a reasonable level of production during peak times, a more detailed calculation is warranted.

SECTION 2 – GROWTH PROJECTIONS OF WATERPOWER IN OTTAWA

Methodology of Pathway Projections

The future energy that can be produced by waterpower generation facilities is defined by both the technology and resources, as ascertained in the previous section, but uptake will also be greatly affected by constraints, including market, economical, regulatory and logistical, as will be examined herein. The section concludes by considering all these factors and projecting possible uptake scenarios, as well as some near term opportunities for positively influencing uptake.

Constraints

Grid Constraints

Availability of grid capacity is a potential barrier to many types of Renewable Energy (RE) projects, but the issue is more severe for waterpower development due to the long lead times to develop a project. In a recent report, the Ontario Waterpower Association stated that: "A key impediment for long lead time projects such as waterpower has been the disconnect between coordinating the availability of transmission capacity with the planned in-service date for the facility which in many cases is five (5) to eight (8) years hence. Connection availability indicated at the time of application may not be up to date or reflective of future availability." [8] The Burritts Rapids project had substantial challenges obtaining clarity and agreement between Hydro One and the IESO on the available grid capacity[9].

Regulatory Constraints

The timelines associated with the development of a waterpower facility vary greatly based on the complexity of the project and the regulatory environment. A typical waterpower facility will take from 4-8 years to develop in Ontario based on the current range of projects that are completing or have recently completed development. Much of this time is spent in environmental assessment (2-3 years), permitting (6 months - 1 year), and construction (1-2 years)[10]. This is a long lead time (in comparison to other small scale/distributed energy projects), which can be a challenge for small project financing and small developers to support.

The Rideau River waterway is managed by Parks Canada, and as such any development will need to be done in collaboration with their regulations and interests. A challenge with the potential sites on the Rideau system is that some segments are presently drained in winter, so altered practices would be required with the implementation of a generation facility. Hog's Back Falls is perhaps the most attractive in terms of capacity, but is also the most sensitive with respect to public use at and around the site.

Market Constraints

A power purchase agreement with a system operator or other energy buyer is most likely required for project development to proceed. Waterpower facilities up to 500 kW size were included in the Ontario feed-in tariff (FIT) program, with pricing in the range of 24¢/kWh and long forty-year contracts on offer. This tariff is designed to compensate for the project capital investment and provide an internal reasonable rate of return, generally in the 7 to 10 % range, at least for the larger projects. Not many projects were built, in part due to the long lead times required to develop project opportunities causing project readiness to not match with procurement windows. The FIT program is set to close after a last, fifth round (FIT5) of contracts are issued in late 2017. Both the ROPEC and Burritts Rapids proposed projects submitted for FIT5 contracts, but were not successful.

Market assessment undertaken in 2008 suggests that "low-head projects can produce energy at a cost of $0.07 to $0.15/kWh"[11], though most of the sites listed in Table 3 would be at the top end of this range due to their small head and power capacities, and possibly higher also when considering 2015 costs. However, it is also anticipated that newer technologies designed for mini waterpower sites, as discussed above, will be able to provide electricity at lower costs, and that as the market develops, technology and development costs will decrease. More detailed assessments of project economics would be warranted, but we can anticipate that mini waterpower can be competitive with distributed electricity costs.

The existing FIT program is set to end soon, though future procurements of a similar nature *may* be issued again. Except for the smallest sites, the power production is likely too large for a neighbouring building to use the energy under the presently proposed net-metering policies, thus other mechanisms to sell power, including virtual net-metering will need to be developed to support development.

Project development costs are estimated to be in the $1.5 to $5/W, depending on many factors, in particular the project size. Presently, the regulatory process is identical no matter what the size of the project, so the fixed costs can become significant to small projects. In the next ten years projects may need funding support as new low-head technologies are demonstrated. For projects that can obtain grid-competitive electricity costs, several forms of power purchase agreements (similar to those examined in the Large Solar Pathway) can be considered, either directly with the provincial system operator, or alternate avenues with green energy sellers and locally negotiated sales agreements.

Development Capacity

In 2013 Parks Canada developed a policy and stated its intent to develop new waterpower generation on Parks Canada Agency Waterways[12]. Parks Canada also issued a letter in 2013 soliciting partnerships to co-develop new generation facilities as FIT contracts; Burritts Rapids was the only one within the Ottawa section of the Rideau that was included on the list. Parks Canada sells a licence for land use (site dependent) and a licence for waterpower use (as a percentage of revenues generated). The revenue received by Parks Canada is used within its Ontario Waterways unit to support programs and infrastructure. They are generally interested to work with developers to examine more locations[13]. This could include research and development and demonstration projects for low head locations.

Ottawa is a region with a rich history of waterpower, and capacities for technology innovation and project development in this sector are very good. There are likely to be new opportunities for small and mini waterpower developments across Ontario and Canada, and the local companies can leverage experience from local development opportunities into other projects in Eastern Ontario and further afield. There are several well-established companies within the Ottawa region with solid experience in waterpower development, and at least two Ottawa companies that have new technologies for efficient small, and mini waterpower installations: Innovative Hydro Controls Inc. is developing controls and Canadian Hydropower is developing low-head turbines. Voith, a global engineering firm with a strong presence in Ontario, has a product called StreamDiver on the market[14].

Uptake Projections

Scenarios

The possible development paths for waterpower are limited by the discrete number of available sites in Ottawa. As we do not have feasibility information to know which projects are most likely to be pursued first, estimations will be made based on size and existing interests. Leidos has developed three general scenarios that project to 2050, based on the following sets of assumptions:

- The “conservative” is the most pessimistic, which assumes that the refurbishment projects will proceed by 2020, and that the two projects that have proponents will be able to develop projects (on FIT5 or other means) by 2030.
- The “moderate” scenario further assumes that two of the projects on the Rideau River (Long Island and Black Rapids), which are medium sized, will be economically viable to develop.
- The “aggressive” scenario assumes faster development of the above projects, and full build-out of all projects by 2050.

Projected outcomes for new energy generation, on five-year intervals between 2020 and 2050, for each of these three scenarios, are detailed in Table 4 and shown graphically in Figure 3.

Figure 4 provides an estimate of the greenhouse gas (GHG) emissions reductions that may be obtained assuming that the water production displaces electricity from the Ontario grid, and assuming the 2015 average emissions levels of the Ontario grid[15]. This is a rough estimate, since future emissions values and marginal offsets may be different. Since Ontario’s electricity generation consists mostly relatively low carbon supplies, the GHG emission reduction values are low.

Table 4 - Projected impact of future waterpower development for two different uptake scenarios.

	2015	2020	2025	2030	2035	2040	2045	2050	Total New
Conservative Scenario		Refurbs		ROPEC & Burritts					
MW new	260	22.0	0	3.7	0	0	0	0	26
TJ/yr new	6,780	590	0	10	0	0	0	0	600
TJ/yr cum.	6,780	7,370	7,370	7,380	7,380	7,380	7,380	7,380	
Moderate Scenario		Refurbs		ROPEC & Burritts		Long Island	Black Rapids		
MW new	260	22.0	0	3.7	0	2.5	1.2	0	29
TJ/yr new	6,780	590	0	10	0	50	20	0	670
TJ/yr cum.	6,780	7,370	7,370	7,380	7,380	7,430	7,450	7,450	
Aggressive Scenario		Refurbs	ROPEC & Burritts	Long Island		Black Rapids	Hog's Back	Rideau Falls	
MW new	260	22.0	3.7	2.5	0	1.2	6.2	0.5	36
TJ/yr new	6,780	590	10	50	0	20	120	10	790
TJ/yr cum.	6,780	7,370	7,380	7,430	7,430	7,450	7,570	7,580	

Figure 3 - Projections of waterpower generation in Ottawa under conservative, moderate and aggressive deployment scenarios.

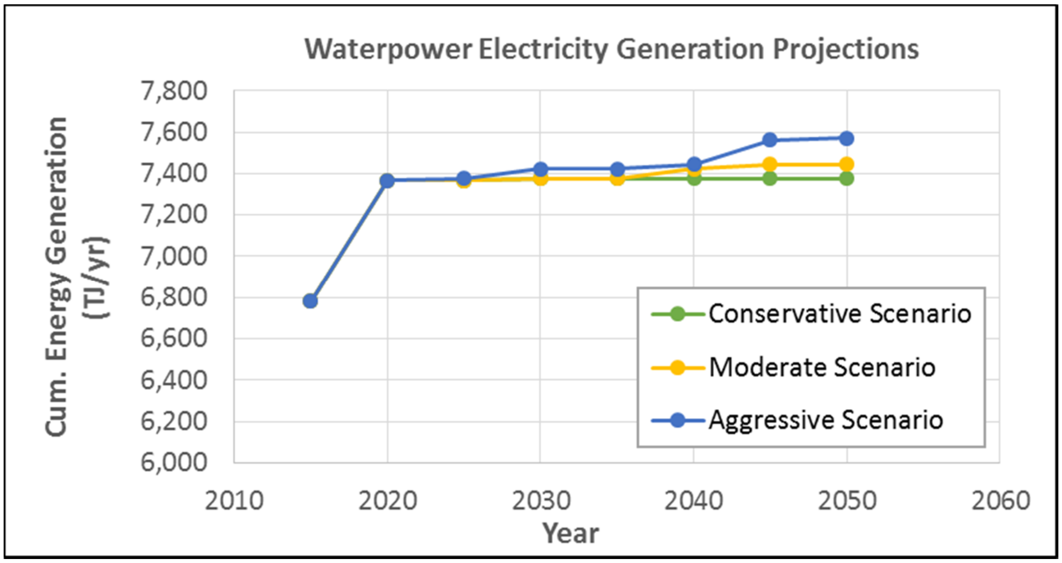


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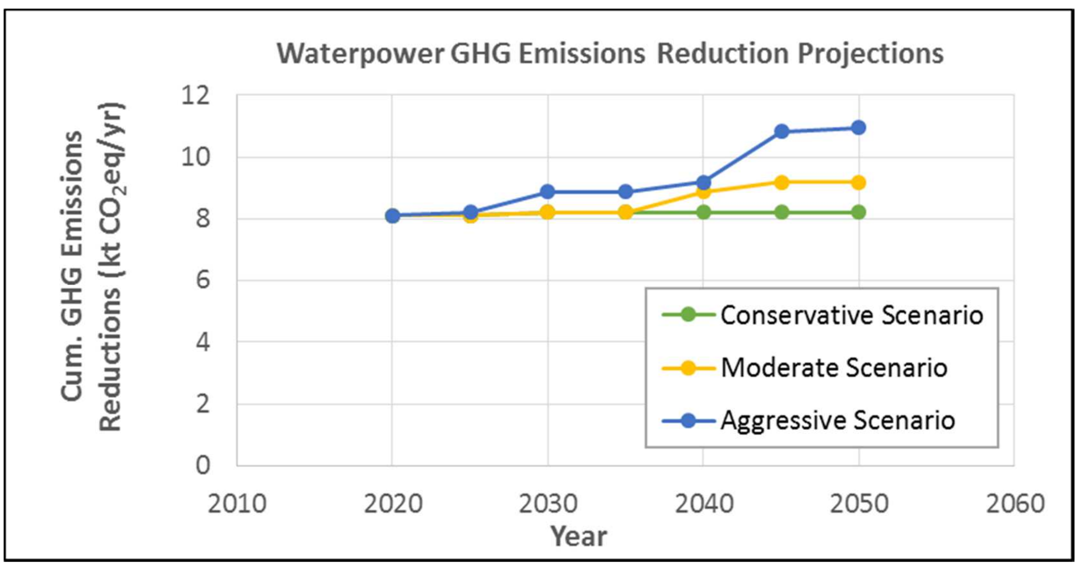
Figure 4 - Projections of greenhouse gas emissions reductions that may be realized, assuming the waterpower generation displaces Ontario grid electricity.



Opportunities to Advance Waterpower

- The City can further investigate and plan for development of a waterpower plant at the ROPEC facility.
- The City could seek a dialogue with Parks Canada to discuss how to support the development of the remaining sites along the Rideau River.
- Electricity consumers could develop a direct power purchase agreement with one or more of the waterpower sites to offset electricity consumption from their facilities.
- Energy Ottawa could consider partnering with a third party with small waterpower expertise.
- Though small from an energy perspective, development of pilots at these sites can spur economic development for local companies and in the broader Ontario market.

Catalyst Projects

- A local waterpower project along the Rideau River that develops local technology and capacity in small head waterpower.
- Development of a direct to customer power purchase agreement for waterpower generation.

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Pathway Study on Heat Pumps in Ottawa

Presented to:

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In relation to
The City of Ottawa Energy Evolution Program

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ABOUT THIS REPORT

City of Ottawa Energy Evolution Program

On July 8, 2015, Ottawa City Council approved the development of a Renewable Energy Strategy as part of the 2015-2018 City Strategic Plan. This initiative has been developed into a program entitled Energy Evolution – Ottawa's Renewable Energy Strategy. A main goal of Energy Evolution is to develop a baseline analysis of energy supply and demand within the City of Ottawa and assess options, in collaboration with community partners, for all such partners to advance energy conservation, energy efficiency and renewable energy generation within their respective areas of control and influence. The Energy Evolution program has interacted closely with community stakeholders from local utilities, the federal government and other government institutions, the development sector, academia, the non-profit sector, and the private sector at large. Leidos Canada was engaged by the City to support analysis in the energy supply domain, including research reports and facilitation of discussion with stakeholders.

The Purpose of this Report

This and other "Pathway Study" documents are focused technical notes describing how the specific energy technology may develop in Ottawa. The document considered the overall technical potential for implementation, and then further considered the constraints (economic, regulatory, etc.) that are likely to reduce uptake. It suggests opportunities to influence uptake rates and catalyst projects that may be attractive to consider further. Results of the Pathway Studies are intended to be used along with the Baseline Study of energy data towards an overall assessment of future energy strategies within the City of Ottawa Energy Evolution program.

A draft form of this Pathway Study was circulated to key stakeholders and experts in the topic during the summer of 2017. Meetings were also undertaken during this period, where these representatives contributed their insights and ideas towards the development of leading project opportunities in relation to the topic of the Pathway.

Other documents in this series are:

Baseline Study on Energy Use in Ottawa in 2015
Pathway Study on Waterpower in Ottawa
Pathway Study on Solar Power in Ottawa
Pathway Study on Wind Power in Ottawa
Pathway Study on District Energy Systems in Ottawa
Pathway Study on Biogas Energy in Ottawa

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Key Units

TJ — Terajoules is a measure of energy, base unit of joules, and used here in the context of total thermal energy required in one year.

kt CO_2eq — kilotonnes of carbon dioxide (CO_2) and other equivalent greenhouse gases, which is the common unit for quantifying the greenhouse gas emissions related to a process.

Pathway Study on Heat Pumps in Ottawa

EXECUTIVE SUMMARY

This Pathway Study focuses on the potential of uptake of heat pumps to provide heating and cooling in the built environment in Ottawa. It broadly considers how all aspects of technology improvements and supportive programs offered by multiple levels of government may influence increased uptake rates.

Heat pumps are major appliances akin to air conditioners that can operate bi-directionally to draw heat or cooling from the external environment. Air-source heat pumps use outside ambient air, and ground-source heat pumps use heat exchange pipes buried in the ground. By using “free” heat from the environment, they can provide multiple units of heat energy for every unit of input energy, typically in the range of 2.5 to 5 times. Most heat pumps rely on electricity for input energy; they can replace any type of heating (fossil fuel furnace or boiler, electric heating, etc.). They are understood to be an economically viable choice versus oil, propane or electric heating, but the low cost of natural gas (NG) relative to electricity poses a challenge for their economic advantages against NG heating. There are opportunities where heat pumps are reasonably economically viable, given the recent developments of cold climate air-source heat pumps (CC-ASHP), operational practices that make use of low-cost times for electricity, industry growth, and possible incentive programs at the provincial and federal levels of government. Ground-source heat pumps have a higher upfront cost of construction than air-source, but may be attractive for larger, high energy demand facilities. Use of heat pumps offer the possibility to significantly reduce greenhouse gas emissions, as long as the source of the electricity used has a low carbon content. At high uptake rates, the new electrical demand is significant enough to require new system planning. The limited understanding and awareness of the technology is an impediment to uptake, and thus opportunities to build capacity and showcase example uses are one approach that can be taken to increase uptake.

Heat Pump Summary Table

Energy Type	Local thermal energy (heating and cooling)
Pathway Potential – in 2050 under an aggressive scenario (other timeframes and scenarios are detailed in Section 2 of the report)	
New Electricity Demand **Natural Gas Displaced**	4,450 TJ 16,300 TJ
% Increase to Electricity Supply [(1)] **% of NG Displaced[(1)]**	13% 37%
GHG Reductions[(2)]	760 kt CO_2eq
% of GHG Emissions[(3)]	15%
Other Impacts	• Will be adopted in low-carbon and net-zero building construction • May impact planning of utility services.

(1) % of Ottawa's 2015 total electricity supply (32,200 TJ) and NG supplies (43,500), as per the 2015 Baseline Study.
(2) Assumes the 2015 Ontario grid average emissions levels for electricity demand portion.
(3) As a % of Ottawa's 2015 total emissions (5,200 kt CO_2eq), as per the Baseline Study.

SECTION 1 – PRESENT ASSESSMENT OF HEAT PUMPS IN OTTAWA

Pathway Description

This Pathway focuses on the potential of uptake of heat pumps to provide heating and cooling in the built environment. Heat pumps are major appliances akin to air conditioners that can operating bi-directionally, using a compression/expansion cycle to draw heat or cooling from the external environment. By using “free” heat in the environment, they can provide multiple units of heat energy for every unit of input energy. As such they can be considered as an alternative energy opportunity within energy supply or within energy efficiency policy.

There are many types and configurations of heat pumps, as are briefly discussed in the report. The overall energy use of a heat pump will depend on the technology choice and multiple details of its implementation, including the building’s energy efficiency (insulation, air tightness, duct work design, the blower fan motor efficiency), the thermostat controls and operation, and the climate in which it is operated. In addition to space heating and cooling, they can also provide domestic hot water (DHW) heating. This Pathway assumes heat pumps will use electricity as the input energy (to run the compressors, pumps and air handling).

This document focuses on *heating* aspects of heat pumps because heating has a much larger demand than cooling in Ottawa (in the order of 7 times larger) thus any savings from heating efficiency are more significant than those from cooling. Furthermore, the cooling mode of heat pumps is similar to existing air conditioner technologies, thus no significant change is expected to the cooling energy demand or cooling-related GHG reductions. In heating mode, heat pumps have the potential to significantly reduce the greenhouse gases (GHG) emissions by displacing fossil fuel with lesser quantities of electricity (as long as the Ontario electricity system provides that electricity at a low GHG content).

Heating Fuel to be Replaced

A heat pump is an alternative building heating choice to natural gas, fuel oil and propane burner furnaces and boilers, and to electric resistance heating. This Pathway Study does not directly consider the use of heat pumps to replace oil, propane, and electric resistance heating. The first two are a minor means of building energy use of existing systems (in the order of 6% each of total energy consumption for heating), while the latter is a very small fraction. Due to the higher heating costs of these energy supplies versus NG, the use of heat pumps is economically viable presently[1,2,3,4] and there are new programs from the province to encourage uptake[3,5].

Heat Pump Energy Supply Type

There is an emerging heat pump technology called absorption heat pumps that is not driven by electricity, but by a heat source such as NG, propane, solar-heated water, etc. NG-driven heat pumps will achieve some cost savings and GHG emissions reductions relative to NG furnaces, and may be attractive over electric heat pumps due to the lower cost of NG relative to electricity. The technology is not sufficiently developed for most segments of the market yet to be able to predict uptake, and thus this technology is not explicitly included in the calculations of this Pathway. The growth of this technology would drive the NG displacement and GHG emissions in similar directions but with a less substantial impact than the analysis contained in this report on electric heat pumps.

Building Types

Not all buildings can be easily retrofitted with heat pump technology. For the purpose of this discussion the target buildings shall be the following:

- Residential homes - detached low rise and townhomes;
- Apartment buildings;
- Commercial (office) buildings; and
- Institutional buildings.

The study does not include the use of heat pumps in agricultural and industrial facilities, which are considered minor energy use sectors in Ottawa.

Background

Principles of Heat Pump Operation

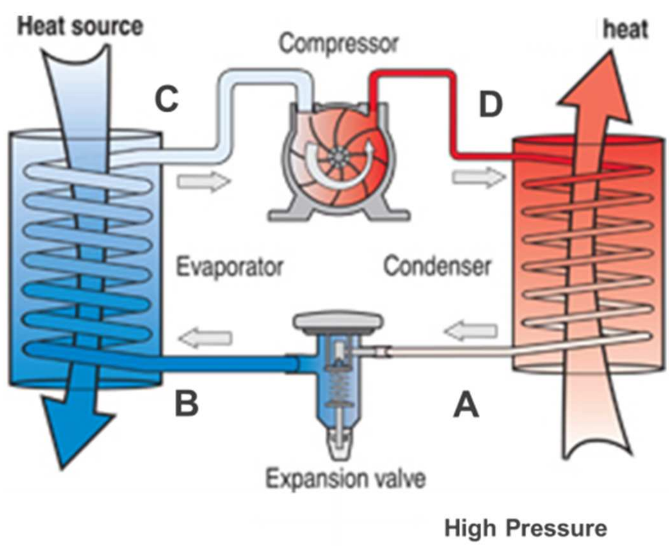
The principle behind heat pump operation is based on the thermodynamic properties of refrigerant fluids and the mechanically generated pressure difference between the heat source and the heat sink. In heating applications, the heat source could be the ambient air or the ground or other supply of low temperature heat, and the heat sink would be the interior space of our buildings. Electricity is the input “fuel” that is used to power a compressor which moves the refrigerant fluid from a point of low pressure to a point of high pressure. The main components of the heat pump are shown in Figure 1, and are herein explained for the case of an air-source heat pump functioning in a heating mode:

- First, the liquid refrigerant (point A) passes through the expansion device, changing to a low-pressure liquid/vapour mixture (point B). It then goes to the outdoor coil, which acts as the evaporator coil. The liquid refrigerant absorbs heat from the outdoor air as it boils, becoming a low-temperature vapour (point C).

- This vapour passes through the reversing valve to the accumulator, which collects any remaining liquid before the vapour enters the compressor. The vapour is then compressed, reducing its volume and causing it to heat up (point D).
- Finally, the high-pressure compressor sends the gas, which is now warmer, to the indoor coil, which is the condenser. The heat from the warm gas is transferred to the indoor air, causing the refrigerant to condense into a liquid (point A). The liquid returns to the expansion device and the cycle is repeated.

The refrigerator and air conditioner are both examples of single direction heat pumps that cool one environment and dump heat using a compressor placed in an external environmental sink. A heat pump is essentially an air conditioner that can be run in both directions - the system can be run one way to provide heating and in the opposite direction to provide cooling.

Figure 1 - Schematic of the main principles of a heat pump.



The heat pump is able to deliver the required thermal energy using a combination of electricity and thermal energy extracted from an external source. Thus, heat pump technology can be thought of as making use of free local renewable thermal energy or also as a conservation measure. Heat pumps are also part of a broader movement for “electrification” of energy demand, which can lead to reductions of GHG emissions from the traditional fossil fuel based heating systems (assuming the grid electricity supply remains relatively low carbon).

Figure 2 - Example of a central air-source heat pump system for heating and cooling (source Geothermal Valley website).

Key Characteristics

Typically, this application can displace natural gas with electricity in a ratio of 2.5 to 1 or higher[2]. This ratio is known as the coefficient of performance or COP. The value of the COP for a system depends on the heat pump, system design and operating conditions. Using a representative ratio of 3 to 1 as an example, this means 100% of the thermal energy delivered would come from approximately 33.3% electricity and approximately 66.6% conserved energy (i.e. taken for free from the ambient environment). Two main types of heat pumps are air-source heat pump (ASHP) and ground-source heat pumps (GSHP). An ASHP uses ambient air, via coils placed outside, as its source of heat and cooling, where as a GSHP uses the ground, via heat exchange pipes in the ground.

For the heating season:

The temperature of the earth approximately 6 to 8 feet below the surface is fairly steady throughout the year, and a GSHP uses this constancy to its advantage. In winter, a GSHP is pumping heat from a typical 4ºC supply to provide indoor heating, versus an ASHP that is pumping heat from outdoor winter air. Surprisingly, there is heat in below zero air, but as one would anticipate, the COP of the ASHP decreases as the outdoor air temperature drops, and so ASHPs have lower overall seasonal performance in cold climates. Older systems would not function below the minimum working temperature of approximately -8ºC, and a secondary source of heat (for example, a built-in electric heater inside the ASHP unit) was required. These secondary sources had to operate a substantial number of days, and thus the whole system was often unsatisfactory in operation. But ASHP technology has evolved in recent years such that cold climate ASHP (CC-ASHP) systems can now operate with acceptable efficiency with outdoor temperatures as low as -25 to -30°C, and are now able to provide a very high percentage of the heating at much better seasonal COP values than previously (a secondary electricity heat supply for the worst conditions is still generally recommended).

For the cooling season:

In the summer, an ASHP is essentially operating as an air conditioner would, pumping heat from the building room into a higher temperature outdoor ambient. However, a GSHP is moving heat from the building into a lower temperature sink of the ground at approximately (as a typical example) ~ 6°C, and thus, is able to operate very efficiently, possibly even with the compressors turned off, and just employing circulating or “free-flowing” fluid.

Additional Design Details

For GHSPs, the average ground temperature may slowly decrease over time over a heating season. The slightly lower ground temperature will cause the system COP to decrease slightly. During the summer it is expected that the ground temperature will rise from cooling operation and the natural warming of the shallow earth by the sun. This natural warming cycle will return the average ground temperature to a warmer level (in a properly designed system), ready for the next heating season.

GSHP systems and central ASHPs are used in combination with a forced-air or hot water/hydronic heat circulation system for distributing the heating and cooling throughout the building. These centralized systems can optionally provide heat towards domestic hot water heating, and are often able to provide 40 to 50% of DHW in the heating season, and up to 100% in the cooling season, depending on the design details. Or, ASHPs are also sold as “mini-split” units that are wall-mounted, partially outside and partially inside, to serve a room or floor directly without building ductwork. One or more units might be installed for a medium-sized house. A summary of these and related generalized characteristics are contained in Table 1.

Table 1 – Overview of the range of available heat pump technologies.

Characteristic	Variants
Heat source/sink:	Air-source heat pumps (ASHP) OR ground-source heat pumps (GSHP, which may use horizontal and vertical ground loops)
Type of heating delivery:	Single central heat exchange combined with a forced air or hydronic heat delivery to the building OR split per room/floor units ("mini-split" ASHP)
Compressor location:	indoor OR outdoor (the latter applicable to most ASHP)
Compressor design:	single capacity OR dual capacity OR continuously variable capacity (the latter being the most recent technology)
Low temperature performance:	standard OR cold-climate (for ASHPs)
External energy input:	electricity (most common) OR natural gas
Ability to heat domestic hot water:	optional for central systems, not available for mini-split ASHP
Ability to operate free-running cooling	only possible for GSHPs

Performance in the Ottawa Climate

Some of the largest global providers of heating and cooling hardware, including Mitsubishi, Fujitsu, Toshiba, Daikin, LG and Panasonic, now offer "cold climate" versions of air-to-air heat pumps; the most common configuration is the ductless mini-split heat pump system. They are incorporating what is called variable-speed compressors that allow operation at the variable capacity matched to the instantaneous conditions (versus fixed single speed or two stage compressors) and very high compression, as is required for the lowest temperatures.

Product brochures are quoting performance down to -25 or -30ºC. Still, the COP of these CC-ASHPs will decrease as the air gets colder, and the certification testing does not yet have a standard approach for rating overall seasonal performance[6]. Furthermore, the full operational costs depend on the climate where the unit is installed, and on several aspects of the building. This makes it a challenge, presently, for a decision-maker to clearly understand the performance and economic assessment of the products.

Several recent projects have aimed to build clarity and confidence in the operational performance. An overall challenge these studies face is the recently rapidly changing performance capabilities of products, the number of different products, and slow rate of experimentation that is possible for seasonal evaluations in test houses. Two studies attempted comparative studies between adjacent houses, but found that secondary aspects, such as the type of fan used in the air handling unit and the controls strategies affected the results[7,8].

In the Toronto region[7,9], seasonal COPs from CC-ASHP in the range of 2.1 to 3.4 (depending on if all system energies are included), and from GSHPs in the range of 2.4 to 3.5 (different case studies) have been achieved. Mini-split ASHP were found to meet or exceed performance expectations[9], while the central ASHP in that study generally didn't meet expectations, but older single-speed compressor products were the only units evaluated. A recent project by Ecologix[6] has installed their newest variable capacity compressor ASHPs in more than 50 houses, mostly in Ontario, and all with detailed monitoring. This, and other additional studies, (such as detailed system numerical simulations) are required to confirm what seasonal COP values are achievable for various building types in Ottawa.

Economics

The significant implementation barrier for GSHPs is the high upfront costs, where the cost for installation of ground loops are relatively high, in particular for vertical, drilled loops which are required in urban environments with space too limited for horizontal lines. GSHPs will be more attractive for larger buildings (apartments, long-term care facilities, sizable commercial buildings, etc.) with larger heat demands that can more quickly pay back the higher upfront costs, and for institutional buildings, where longer-term ownership and financial perspectives may be at play. Also, the performance advantages in the cooling season of GSHPs need to be considered in the economic advantages.

The cost for ASHP systems is significantly lower than for GSHP systems. The incremental cost over standard heating technology is presently estimated to be in the order of a few $1000. The costs have come down by as much as 25% in the past five years, and may continue to decline in the next five to ten years, though they are expected to remain at least somewhat higher in upfront cost than the conventional natural gas heating and air conditioner systems[6]. As long as the overall operational performance of a CC-ASHP can come close to a GSHP, they are likely to be the more attractive option in most situations, and the above discussed studies seem to indicate that the two technologies are close when considering the heating season values only.

The operating costs of heat pumps needs to be carefully considered – they may be higher than using natural gas based heating systems if the price of natural gas is significantly lower than the price of electricity. The Baseline Energy Study also done by Leidos for the City's Energy Evolution project found that the *average* net prices in effect in Ottawa in 2015 were $42,500/TJ for electricity and $12,000/TJ for natural gas, for a ratio of 3.5 to 1. Considering also an assumed combustion efficiency of the NG furnace of 80%, these values imply that the COP should be better than 2.8 on average for a financially positive payback during 2015 market conditions. A detailed cost comparison between natural gas furnace and heat pump operation is complex due to the typical electricity pricing structure which includes time-of-use rates and delivery costs. It is notable, however, that electricity off-peak times constituted 64% of the hours in a week, and these rates are roughly 30% less than average rates and this would imply an average required COP of at least 2, which appears to be achievable with recent products. The added value of partial heating of DHW and very low cost cooling in the summer for GSHP need to be included in a full assessment.

These economic factors are very dynamic presently, due to commercial market pressures as well as due to actions taken by the Government of Ontario:

- announcement to reduce electricity rates by 25% starting July 2017;
- the carbon cap and trade market initiated in January 2017 (which will cause an increase in natural gas prices);
- possible incentives in relation to the Climate Change Action Plan.

Economic studies done so far tend to use the simple payback metric, which is generally insufficient for long-lifetime investment of the systems. ASHP compressors are expected to last 15 to 20 years, while GSHP compressors will be more like 20-25 years[10], and the ground loop pipes should have lifetimes of 50 years or more.

Heat Pump Market Capacity

The heat pump product is now mainly supported by the Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI). Many heating and refrigeration contractors are qualified to install and maintain heat pump systems. The Canadian Geo-Exchange Coalition

(CGC) provides technical training for installers and system designers on ground-source heat pump systems. The Canadian Standards Association (CSA) has developed suitable certification standards on the design and installation of ground-source heat pump systems.

The design of heat pump systems would be best performed by experienced professionals who can evaluate the building's heat load requirements. The designer needs to understand both the opportunities and limitations of heat pump technology so that the right solution is provided. A designer short on heat pump implementation knowledge may oversize the system which may result in a substantial financial penalty in both capital and operational costs, or a poorly integrated heat pump system that leads to unhappy end users and poor market image. System design needs to consider both heating and cooling conditions, which is different than business as usual (BAU) using a NG furnace and an air conditioner.

The heat pump's output temperature range is lower than the output temperature range of combustion-based furnaces. The lower output temperature from heat pumps is not generally suitable for buildings with relatively poor envelope energy efficiency and higher air leakage. Another challenge for the GSHP is that the ground loop heat exchangers may freeze up due to poor borehole field design or imbalanced loads over a longer period of time.

There has been a general lack of builder and public knowledge and confidence in the heat pump technology, due to lack of familiarity as well as unsatisfactory results (in heating comfort and economics) with older generation systems. The Canadian Geo-Exchange Coalition has recently developed a national quality assurance program, with training, accreditation, system certification and registration.

It is suggested that the current heat pump technology lacks the backing from a large player that can create the necessary marketing presence and economies of scale. This may be in part because the air and ground are free sources of thermal energy, in comparison to traditional fuel supplies for thermal systems (fossil fuels and electricity) that have a motivated corporate supplier. However, the current climate of energy efficient houses, GHG awareness and the availability of heat pump products that function well in the Ottawa climate may provide decent market conditions for uptake, possibly even from a large-scale player. Promotion programs, as well as direct inclusion in new neighbourhood developments, can create economies of scale that would enable lower cost implementations.

New Electricity Demand

The use of heat pumps will shift energy supply use from NG to electricity, and though it is at a lower quantity of energy, it still creates a sizable additional demand for electricity. Uptake trends of heat pumps will be one of the things that IESO will build into its analysis of future electricity system planning[11].

Further Technology Advances

New technology integration concepts are continually being explored by the industry and academia to improve the overall heating/cooling system performance. Research on the possibility of pre-heating the intake air for ASHP systems are being explored. For example, the in-take air for an ASHP system is drawn from a gravel (or rock) bed under the garage which can deliver a moderating effect on the temperature as well as presenting the potential for short term solar heat storage in the gravel bed on sunny days. Combinations of heat pump and thermal storage (hot water tanks) or heat pump and solar thermal collectors are a couple of examples[12] illustrating the interest and potential for further improvements in overall system performance.

It is also possible to use ASHP in combination with low grade supplies of heat, such as 15 to 40°C waste heat from both large sources (sewage lines) or small sources (process exhausts, chilled water return) which provide a warmer source to the heat pump than winter ambient air, and thus improve efficiency.

As mentioned in the Pathway Boundaries, gas-assisted and absorption heat pumps are technologies that carry potential for uptake.

Smart interactions between electrical appliances (including heat pumps) and grid operations are an area of active development and future modalities will include the option for thermal appliances to take signals from the grid operators to time their electricity usage in ways that curb and minimize grid peak demand (e.g. preheating during periods outside of peak) and also minimize operational costs.

SECTION 2 – GROWTH PROJECTIONS FOR HEAT PUMPS IN OTTAWA

Methodology of Pathway Projections

The future impact of heat pumps is defined by both the technology and building stock. Uptake is also greatly affected by constraints, including market, economical, regulatory and logistical, as will be examined herein. The section considers all these factors and develops projections of possible uptake scenarios, as well as some near-term opportunities for positively influencing uptake.

Assessment of Ottawa Building Stock

As noted earlier, there are many building types that could be targeted for heat pump technology retrofits, and this pathway will separately consider uptake by building type sector. To analyse the impact of future growth of a sector requires data on the existing NG consumption and the number of buildings, along with the anticipated growth rates of the building stock and a number of heating system energy parameters, as summarized herein.

First, Enbridge has provided the natural gas consumption for Ottawa in the year 2015, as detailed in Table 2.

Table 2 – Natural gas consumption data for Ottawa by building sector type, as provided by Enbridge for the year 2015.

Building Sector	Natural Gas Consumption (TJ/yr)
Residential (low rise)	21,522
Commercial	16,946
Apartment	3,678
Industrial	1,381

Second, data obtained from City staff (which was derived from a combination of Statistics Canada and Municipal Property Assessment Corporation data) provided the number of residential units in 2015, as contained in Table 3. The upcoming analyses will evaluate low-rise residential and apartment sectors using this data, while a slightly alternate method will be used for the commercial sector (recall the industrial sector is not in the scope of this report).

Table 3 – Estimated housing stock in Ottawa in 2015.

Residential Type	Estimated Total Number of Households	Estimated Number of Households constructed after 1980
Detached single	169,501	92,571
Semi-detached	21,687	7,912
Row house	79,466	55,396
Apartments – 5 or more storeys	73,380	30,890
Apartments – duplex	6,795	1,275
Apartments – less than 5 storeys	37,185	12,540

Low-rise Residential

The Ontario Building Code incorporated improvements to building envelope requirements after 1980, making them better insulated and more airtight. The implementation of heat pumps in such homes should have a greater benefit in terms of occupant comfort and a better fit with the existing heating system. Thus, target buildings for heat pump retrofits are those constructed after 1980. The total number of low-rise residential buildings constructed after 1980 is approximately 155,879 households (from the sum of the first three rows in the right-hand column of Table 3). A fixed percentage of retrofits per year for heating and domestic hot water are assumed (the percentages are discussed below for each of three scenarios) with the following other relevant assumptions:

- Growth of housing stock of 0.3% per year[13]
- Space heat intensity 0.25 GJ/m^2
- DHW intensity 0.061 GJ/m^2
- Average efficiency of older generation of NG units 75%
- Weighted average floor space 191 m^2
- COP of 3 for space heating and 2 for domestic hot water

Apartments

Following a similar data review, the number of apartment units and a fixed percentage of retrofits per year, for heating and domestic hot water, are assumed (the percentages are discussed below for each of three scenarios) with the following other relevant assumptions:

- Growth of housing stock of 0.6% per year[4]
- Space heat intensity 0.13 GJ/m^2

- DHW intensity 0.089 GJ/m^2
- Average efficiency of existing natural gas units 75%
- Weighted average floor space 102 m^2
- COP of 3 for space heating and 2 for domestic hot water

to determine the future net decrease in natural gas use and net increase in electricity use.

Commercial, Industrial and Large Users

Without specific statistics on the number of buildings in these sectors, a simpler prorated approach is employed, with reference to the findings above and natural gas consumption in Table 2, which provides estimated values for space heating and DHW energy consumption intensities. The relevant input assumptions used were:

- Growth of commercial building stock of 0.5% per year[4]
- Average space heat intensity 0.4GJ/m^2
- Average DHW intensity 0.04 GJ/m^2
- Average efficiency of existing natural gas units 75%
- COP of 3 for space heating and 2 for domestic hot water

These are used in combination with an approximated total commercial floor space of 25,340,000 m^2 to determine the future net decrease in natural gas use and net increase in electricity use.

Constraints

Market Constraints and Market Growth Opportunities

Uptake of heat pumps in Canada has been very light and also very variable thus far, following to a high degree the natural gas prices of the year and the availability of federal and provincial government grants, as shown in Table 4 for a selection of 4 of the 37 GSHP installers in the Ottawa area. A 2007-2010 market analysis for GSHP for Ontario[14] suggests that the annual average sales for GSHP units in Ottawa were in the order of 600 units per year (using a ratio of Ottawa to Ontario populations). Adding sales for ASHPs to this value puts our present local sales volumes in the range of 1000 – 2000 HP units per year. The aggressive scenario below is developed with an increase to this value. The scope of the current study did not include a comprehensive review of the heat pump market in the Ottawa area. This discussion simply serves as an illustration of the current relative market size.

Table 4 – Annual sales of GSHP in the Ottawa area for a few example contractors, indicating the impact of grants on uptake, as provided by Master Group.

Contractor	Sales with no Grant (# units/yr)	Sales with Grants (# units/yr)
A	15	55
B	10	45
C	10	42
D	3	20
Total:	**38**	**162**

GSHPs carry a higher upfront capital investment compared to BAU in the order of $20,000 to $40,000 for horizontal and vertical ground loops (for a house), respectively. If the payback period is not short, the upfront cost is a strong deterrent, in which case financing support mechanisms that tie capital costs to the building instead of the owner would help encourage uptake.

The upfront costs premium of CC-ASHPs over BAU are much more reasonable, in the order of $2,000 - $4,000. In the event of continuing relatively low natural gas prices, the operational costs advantages are uncertain. Recent (July 2017) decreases in electricity prices for residential and small business accounts will improve the economic attractiveness, as would anticipated new provincial government incentives.

Recently developing programs in net-zero energy buildings and net-zero carbon buildings will be increasing the uptake of heat pumps in *new* buildings. The high energy efficiency of heat pumps makes them a close to indispensable tool for achieving the energy and/or carbon balance requirements. The building's much more effective envelope (insulation, air tightness) and other energy system measures (passive house, heat recovery systems) mean that energy supply requirements are already quite low, making electricity usage reasonable. The Ontario government is presently reviewing and seeking stakeholder feedback of many opportunities to address climate change action within the building sector, including through the building code[15],

> *Ontario's Building Code is an important vehicle for implementing a number of the Climate Change Action Plan commitments, including:*
>
> *• Updating the Building Code with long-term energy efficiency targets for new net zero carbon emission small buildings that will come into effect by 2030 at the latest.*

• Setting green development standards, whereby municipalities would be able to pass by-laws related to certain green standards where there are technical standards in the Building Code and those standards are specifically identified for this purpose in the Building Code.

Building Code primarily affects new construction, but the intent of the government is to also address improvements to existing building stock through other related programs. The effectiveness of these initiatives will have a large impact on the upcoming market growth potential for heat pumps.

Infrastructure Constraints and Hurdles

Additional electrical demand in switching natural gas to electricity for heating may add to the strains on the aging electrical infrastructure. In high uptake scenarios, the total electricity demands rise substantially, and require careful planning from the electricity system operator to maintain supply capacities, preferably with low-carbon supply options whenever possible.

In retrofitting heat pump technologies in high density areas, thermal demand for ground-source heat pumps may exceed the heat sources available from limited surface access to the shallow earth underground. (Similarly, there may be limited space for ASHP equipment installation on the roof of high-rise buildings.)

Development and Regulator Capacity (Know-how)

Ottawa already has several installers that are knowledgeable about heat pumps, and several small builders/renovators with interests in low-energy or low-carbon homes, but overall the understanding of the building sector with respect heat pumps and low-energy home design is still relatively nascent. This further includes the extent of understanding of officials in the building permitting and inspection domains. Potential liabilities could exist for issuing building permit approvals for heat pump systems where there is very little prior operating and performance evidence (examples included the risk of “cold heat”, ground freezing and unachievable occupant comfort in retrofit buildings). Timely release of training and education can help to mitigate the knowledge gaps.

The number of brands and range of systems sizes and design variants that are available are still rather small, thus further development of products will be required for high penetration into all building environments.

Uptake Projections

Scenarios

Three possible scenarios were evaluated for heat pump system uptake. In all, the uptake is approximated as consisting of two rates: a lower uptake rate in the years 2018 to 2030, followed by a higher uptake rate in the years 2031 to 2050, when market conditions, technology cost reductions and technology improvements provide substantial advantages.

- Conservative Scenario assumes that in the first period, the market conditions are negative due to lack of substantial market economics, incentives or support for local market development. The percentage of conversions per year are assumed to be 0.3% in the years 2018 to 2030, and 0.5% in the years 2031 to 2050.
- Moderate Scenario - the percentage of conversions per year are assumed to be 1% in the years 2018 to 2030, and 1.5% in the years 2031 to 2050.
- Aggressive Scenario involves substantial incentive programs, likely through a combination of provincial price for carbon and federal incentive programs for installation, as well as the active support and promotion by multiple local entities. In this scenario, a 1.5% per year uptake is estimated between 2018 and 2030, and a more optimistic uptake rate of 3% is assumed between 2031 and 2050 when more attractive market pricing signals on-going policy and program support.

Low-rise Residential

Table 5 – Changes in the number of new heat pump units, the cumulative natural gas displaced, and cumulative new electricity usage in the low-rise residential sector under three uptake scenarios.

	2015	2020	2025	2030	2035	2040	2045	2050	Total New
Conservative Scenario									
# new HP units	0	1,000	2,400	2,500	4,300	4,400	4,500	4,600	23,700
NG displaced (TJ/yr cum.)	0	80	270	470	800	1,150	1,500	1,870	
Elec increase (TJ/yr cum.)	0	20	70	130	220	320	410	510	
Moderate Scenario									
# new HP units	0	3,200	8,100	8,300	12,800	13,100	13,400	13,800	72,700
NG displaced (TJ/yr cum.)	0	250	890	1,550	2,570	3,600	4,670	5,760	
Elec increase (TJ/yr cum.)	0	70	250	430	700	990	1,280	1,580	
Aggressive Scenario									
# new HP units	0	4,800	12,200	12,500	25,600	26,200	26,900	27,500	135,700
NG displaced (TJ/yr cum.)	0	380	1,340	2,330	4,350	6,430	8,560	10,740	
Elec increase (TJ/yr cum.)	0	100	370	640	1,200	1,770	2,350	2,950	

Apartments

Table 6 – Changes in the number of new heat pump units, the cumulative NG displaced, and cumulative new electricity usage in the apartment sector under three uptake scenarios.

	2015	2020	2025	2030	2035	2040	2045	2050	Total New
Conservative Scenario									
# new HP units	0	300	800	800	1,400	1,500	1,600	1,700	8,100
NG displaced (TJ/yr cum.)	0	10	30	50	100	140	190	240	
Elec increase (TJ/yr cum.)	0	0	10	20	30	40	60	70	
Moderate Scenario									
# new HP units	0	900	2,500	2,700	4,300	4,600	4,900	5,200	25,100
NG displaced (TJ/yr cum.)	0	30	100	180	310	450	600	750	
Elec increase (TJ/yr cum.)	0	10	30	50	90	140	180	230	
Aggressive Scenario									
# new HP units	0	1,400	3,800	4,000	8,600	9,200	9,900	10,500	47,400
NG displaced (TJ/yr cum.)	0	40	150	270	530	810	1,100	1,410	
Elec increase (TJ/yr cum.)	0	10	50	80	160	240	330	420	

Commercial Space

Table 7 – Percentage of floor area converted to heat pump heating, the cumulative natural gas displaced, and cumulative new electricity usage in the commercial sector under three uptake scenarios.

	2015	2020	2025	2030	2035	2040	2045	2050	Total New
Conservative Scenario									
% floor space	0	0%	1%	1%	1%	1%	1%	1%	5%
NG displaced (TJ/yr cum.)	0	50	140	240	400	580	760	950	
Elec increase (TJ/yr cum.)	0	10	40	60	100	150	200	250	
Moderate Scenario									
% floor space	0	1%	2%	2%	2%	2%	2%	2%	13%
NG displaced (TJ/yr cum.)	0	170	460	760	1,210	1,660	2,120	2,570	
Elec increase (TJ/yr cum.)	0	40	120	200	310	430	550	670	
Aggressive Scenario									
% floor space	0	1%	2%	2%	4%	4%	3%	3%	21%
NG displaced (TJ/yr cum.)	0	250	680	1,110	1,940	2,710	3,450	4,140	
Elec increase (TJ/yr cum.)	0	70	180	290	500	710	900	1,080	

Overall Impact

The number of heat pump units installed in the five-year period ending in 2025 in the aggressive scenario are 12,200 and 3,800 for the low-rise and apartment sector respectively; considering also the commercial sector, this translates into the order of 4,000 units per year in that time frame, with further growth on a year-over-year basis.

In 2050, the total number of low-rise and apartments that would be using heat pumps amounts to 45% and 33%, respectively. In the commercial sector, the uptake is 21% on a per square area basis. Recall that this is considering only buildings constructed after 1980, including new growth. This hasn't directly computed the secondary path of older buildings that undertake deep energy retrofits which include heat pumps.

From the tables above, the impacts of uptakes of heat pumps in all three sectors are combined together into graphs for the Pathway's net effect on natural gas displaced and increased electricity usage, as presented in Figures 3 and 4. Note that both graphs are shown with the same vertical axis, to emphasize that the new energy demand for electricity is less than one third of that of the natural gas that is displaced, which will result in a substantial reduction in net energy use.

Figure 3 - Natural gas displaced from the uptake of heat pumps from the sum of residential, apartment and commercial sectors, and for three different uptake scenarios.

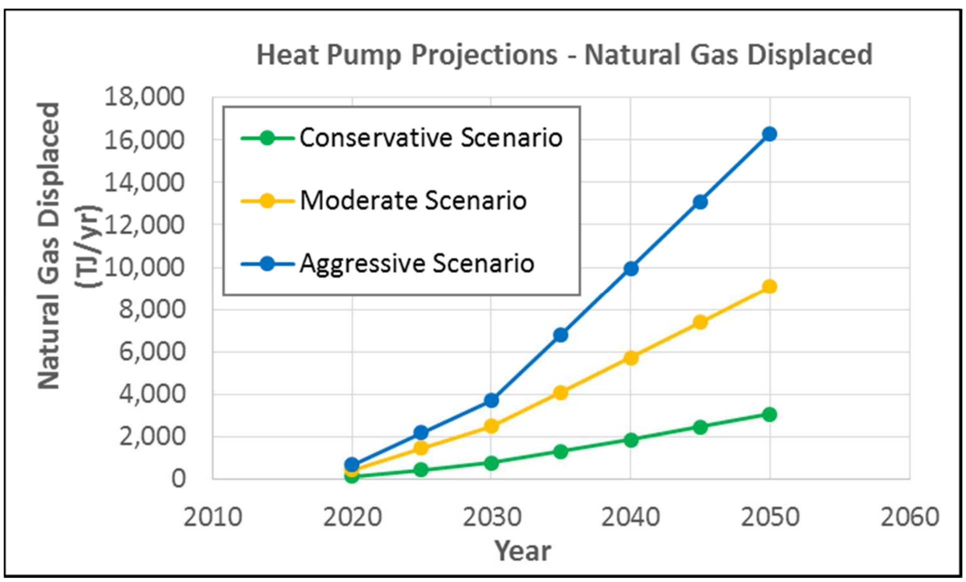
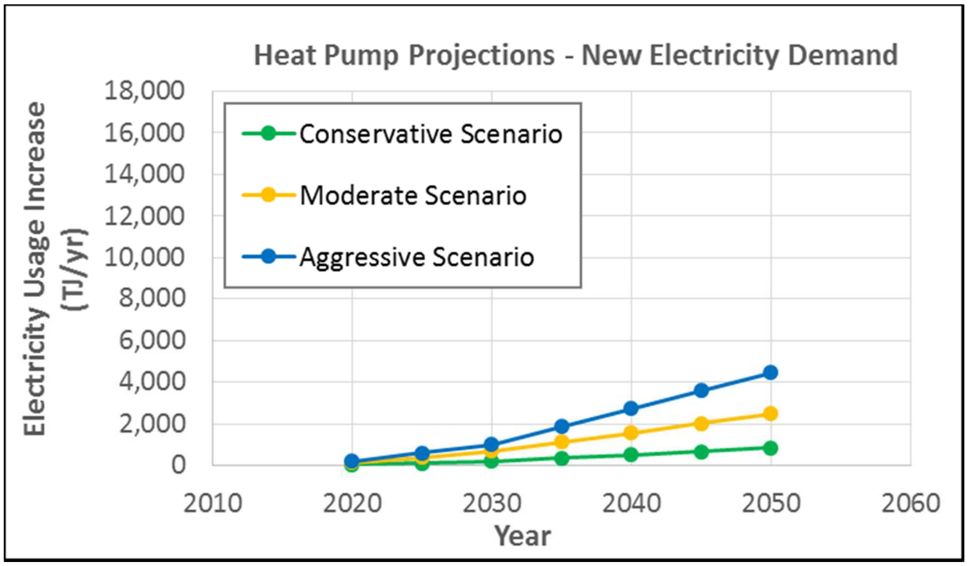


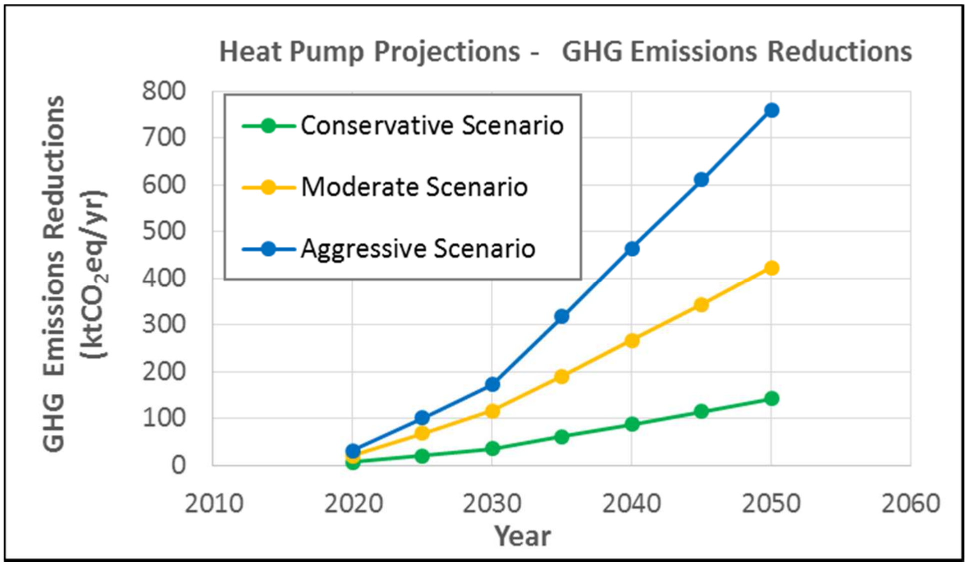
Figure 4 – The increased electricity required from the uptake of heat pumps, when considering the sum of residential, apartment and commercial sectors, and for three different uptake scenarios.



The results in Figure 3 indicate a large decrease in the use of NG. Under the aggressive scenario, the 16,300 TJ of NG that is displaced represents 37% of the 2015 consumption in Ottawa. The amount of new electricity required as a replacement is notably a smaller value, and under the aggressive scenario is 4,450 TJ. Note that these are changes to winter electricity use, and could result in winter peak power demand increases in the order of 20-40% depending on many factors, including which times in the day the heat pump is operated. The use of GSHPs for cooling in the summer will slightly reduce summer peak demands

Figure 5 provides an estimate of the greenhouse gas (GHG) emissions reductions that may be obtained considering that the emission levels for NG are replaced by those from the electricity supply. For the latter, a rough assumption is made that the new electricity required will have an emissions footprint equal to the average of the Ontario grid (using 2015 values[16]).

Figure 5 – The GHG reductions potential for heat pumps, considering the sum of residential, apartment and commercial sectors, and for three different uptake scenarios.



Whether the new electricity demand has any negative consequences, such as strain on the electricity system, or whether the GHG values will be higher than the above assumption, depends on many factors and future policy decisions in the energy system, including:

- There is a present surplus of electricity in the Ontario grid at all times, but in particular off-peak. HPs will only operate a small percentage of their time during peak, and smart controls can be incorporated to operate during the cheapest and lowest demand times.
- On-going electricity efficiency initiatives are causing a year-over year trend of slight reductions in electricity demand for other applications;
- Adoption of building envelop retrofits further reduce the energy input requirements, in particular for new builds and net-zero compliant construction.
- Several renewable electricity generation technologies are competitive with market rates, and are expected to be further developed over the timespan of this study. They further offer opportunities to develop the generation locally, to avoid new transmission infrastructure costs.
- There are emerging projects and programs for development of renewable natural gas, and could form a portion of the combustion fuel at electrical peaker plants.

Certainly, careful planning of the infrastructure would be needed, considering the street-level feeder lines all the way to the transmission infrastructure, and dynamic sub-hourly needs all the way to gross yearly demands.

Opportunities to Advance Heat Pump Use

There could be positive impacts on local economic development due to increased demand for heat pump system designers and installers. The retrofits to heating and cooling may also be accompanied by retrofits to the building envelope, leading to more local economic development and potential for reduced utility bills.

Increase in electricity demand and consumption that came from switching from natural gas to electricity may create new opportunities for local electricity generation, use and management to reduce the load on existing electrical infrastructure.

The following are suggested opportunities for the City and its partners to advance the use of heat pumps:

- The City could consider, wherever feasible, the incorporation of heat pumps in new and existing City facilities. They could install performance monitoring systems to collect useful data for learning and outreach purposes.
- A financing mechanism that assigns payment fees to the building asset as opposed to the building owner should be considered.
- Support of the local market capacity through the delivery of education and information to broad audiences, and through interaction and support of local capacities in the technology.
- Prepare general application guidelines on GSHP, ASHP and CC-ASHP technologies in the residential building sector for targeted building types, vintage of construction and acceptable energy use intensity values specific to Ottawa.
- Consider the inclusion of heat pumps in new communities and developments, where the most attractive deployment costs are achieved.
- Local utilities could become active promoters and enablers of these technologies. A model for this could involve the LDC assisting in heat pump financing in exchange for rights to dispatch heat pump equipment as guided by factors such as electricity prices and environmental conditions. Consumers could be incentivized on an ongoing basis for agreeing to allow the LDC to have some control over their heat pumps.
- A utility-related company could consider new business models that enable uptake of ASHPs, such as being the sales, financing, and service provider for the equipment, similar to existing services for standard furnaces and water heaters.
- Lobby the province for changes to the building code that would mandate the use of heat pumps where feasible, including smaller applications such as small DHW heaters and outdoor pools.

- A utility or other corporate entity could consider new business models that enable uptake of GSHPs, such as being the developer and owner of geothermal energy loops, and then selling the thermal energy to building owners.

Catalyst Projects

- Demonstrate the integration of both GSHP and ASHP technologies in City or partner facilities and collect system operating data for education and market capacity development purposes. The collection of operating data is critical to the success of this pathway as there is a lack of reliable actual performance data in the public domain.
- Stakeholder engagement of active companies, industry associations and relevant municipal offices and organizations to further advance strategies to increase uptake and literacy.
- Assemble and publish case studies on sites in Ottawa that have heat pumps. Develop and publish more robust economic models. Within the latter, consider operational control that considers variable electricity pricing and outdoor air temperatures. If there are feasible scenarios, pilot some houses employing successful set-ups.

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Pathway Study on Biogas Energy in Ottawa

Presented to:

The City of Ottawa
110 Laurier Ave W
Ottawa, ON K1P 1J1

In relation to
The City of Ottawa Energy Evolution Program

By:

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October 17, 2017

ABOUT THIS REPORT

City of Ottawa Energy Evolution Program

On July 8, 2015, Ottawa City Council approved the development of a Renewable Energy Strategy as part of the 2015-2018 City Strategic Plan. This initiative has been developed into a program entitled Energy Evolution – Ottawa's Renewable Energy Strategy. A main goal of Energy Evolution is to develop a baseline analysis of energy supply and demand within the City of Ottawa and assess options, in collaboration with community partners, for all such partners to advance energy conservation, energy efficiency and renewable energy generation within their respective areas of control and influence. The Energy Evolution program has interacted closely with community stakeholders from local utilities, the federal government and other government institutions, the development sector, academia, the non-profit sector, and the private sector at large. Leidos Canada was engaged by the City to support analysis in the energy supply domain, including research reports and facilitation of discussion with stakeholders.

The Purpose of this Report

This and other "Pathway Study" documents are focused technical notes describing how the specific energy technology may develop in Ottawa. The document considered the overall technical potential for implementation, and then further considered the constraints (economic, regulatory, etc.) that are likely to reduce uptake. It suggests opportunities to influence uptake rates and catalyst projects that may be attractive to consider further. Results of the Pathway Studies are intended to be used along with the Baseline Study of energy data towards an overall assessment of future energy strategies within the City of Ottawa Energy Evolution program.

A draft form of this Pathway Study was circulated to key stakeholders and experts in the topic during the summer of 2017. Meetings were also undertaken during this period, where these representatives contributed their insights and ideas towards the development of leading project opportunities in relation to the topic of the Pathway.

Other documents in this series are:

- Baseline Study on Energy Use in Ottawa in 2015
- Pathway Study on Waterpower in Ottawa
- Pathway Study on Solar Power in Ottawa
- Pathway Study on Wind Power in Ottawa
- Pathway Study on District Energy Systems in Ottawa
- Pathway Study on Heat Pump Technology in Ottawa

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Key Units

Mm^3	Mega cubic meters, or 1,000,000 m^3, used here to quantify the volume of renewable natural gas (RNG).
MW	Megawatts is 1,000,000 watts, and is a measure of power, used here in the context of the power rating or the capacity of an electrical generation facility.
TJ	Terajoules is a measure of energy, base unit of joules, and used here in the context of total energy delivered over one year. An on-farm biodigester with size of 0.5 MW might produce 0.54 TJ of energy in a year
kt CO_2eq	kilotonnes of carbon dioxide (CO_2) and other equivalent greenhouse gases, which is the common unit for quantifying the greenhouse gas emissions related to a process.

Pathway Study on Biogas Energy in Ottawa

EXECUTIVE SUMMARY

Biogas is naturally derived methane, produced during the anaerobic (non-oxygenated) decomposition of organic materials. The collection of biogas for energy has developed substantially in Ontario in the past decade, and includes 6 operating facilities within Ottawa with an annual energy generation of 390 TJ. This biogas has been produced at landfills (decaying organic waste) and in anaerobic digesters (AD) located on farms and at wastewater treatment facilities. These projects have used the biogas to produce electricity (through combustion), and were developed with the aid of long-term contracts for the purchase of their electricity at prices that are slightly elevated relative to market prices. When new competitive procurement mechanisms for renewable electricity may develop, biogas electricity may be less competitive than electricity from new solar and wind facilities; landfill gas projects are likely the most competitive, but are mostly developed already in Ottawa. New project development is most likely when the additional benefits of biogas facilities are tapped: the collection and use of waste heat on-site, the reduction of odours from manure, the reduction of waste volumes, and the output of a bio-waste that is an excellent fertilizer with no pathogens or weed seed.

This pathway identifies a large quantity of feedstocks that may be available within Ottawa. Substantial growth in biogas energy generation will require tapping into several potential feedstocks (including municipal solid wastes and crop and forestry residue), and will also require the consideration of new processes. Instead of combusting biogas to produce electricity, it is possible to clean the biogas for use as a direct equivalent to natural gas (NG), which is referred to as renewable natural gas (RNG). It may be injected into the NG pipelines, or used in transportation as compressed RNG (CRNG). This may be a desirable pathway, as it allows for decarbonization of fuels used in heating and transportation. CRNG may be economically viable presently compared with diesel fuels for use in fleets. In Canada, a small number of commercial facilities that are based at landfill and wastewater treatment facilities are now producing RNG. The challenge of producing RNG, when collecting a broader quantity of feedstocks, is that the costs are typically several times more than market prices for NG. Gasification (Gfn) is a new, alternate process to AD that offers much higher efficiency

of conversion of raw material into biogas, and that may be a pathway to reducing the cost of RNG. Furthermore, a number of new opportunities may develop that find economical approaches, also include expansion of existing facilities, processing of multiple sources of feedstock, partnerships for RNG purification, and use of compressed RNG in fleet vehicles.

Biogas Energy Summary Table

Energy Type:	Local renewable electricity and renewable natural gas production
Pathway Potential - cumulative to 2050, under an aggressive scenario (conservative and moderate scenario projections are contained in Section 2 of the report)	
Electricity Generation **Renewable Natural Gas**	8 MW (188 TJ) 130 Mm^3 (5,300 TJ)
% of Electricity Supply(1) **% of Natural Gas Needs(2)**	0.5% 12%
GHG Reductions(3)	275 kt CO_2eq
% of GHG Emissions(4)	5.2%
Other Impacts:	• New value and processing opportunities for solid waste streams • Economic development through locally developed projects and development of expertise.

(1) As a % of Ottawa's 2015 total electricity usage (32,200 TJ), as per the Baseline Study.
(2) As a % of Ottawa's 2015 NG supplies (43,500), as per the Baseline Study.
(3) Assumes the 2015 Ontario grid average emissions levels for electricity and 100% replacement of NG emissions for RNG production
(4) As a % of Ottawa's 2015 total emissions (5,200 kt CO_2eq), as per the Baseline Study.

SECTION 1 – PRESENT ASSESSMENT OF BIOGAS ENERGY IN OTTAWA

Pathway Description

This Pathway focuses on the potential development opportunities for biogas in Ottawa, which includes biogas for direct combustion towards electricity generation and biogas as renewable natural gas (RNG) for injection into the natural gas (NG) grid or other direct uses. The Pathway will consider biogas production via both anaerobic digestion (AD) and gasification (Gfn) processes. When the output of the biogas is used for electricity production, it is discussed in terms of capacity in kilowatts (kW) or megawatts (MW) and when it is used for RNG it is discussed in terms of megacubic meters per year (Mm^3/yr). Both are discussed in terms of the energy available in terajoules (TJ/yr).

Pathway Boundaries

Biogas is part of the larger umbrella of bio-energy that includes direct combustion of biomass and the production of biofuels. Biomass combustion generates electricity through a Rankine cycle, while biofuel results in a liquid fuel that may be used for transportation. Though biogas may share the feedstock used for biomass combustion or biofuel production, the technologies are separated because their outputs are distinctly different. Neither biomass combustion nor biofuels are included in this Pathway Study.

It should be noted that biogas can also be compressed and used as a transportation fuel, as a direct alternative to compressed NG – this report is inclusive of volumes of RNG that may be used for that purpose. However, the creation of hydrogen gas as an input to NG networks, such as through electrolysis undertaken using low cost or excess electricity, is not included in this report, though it is an alternate approach to generate renewable combustible gases that can be called RNG.

The burning of biogas in generators produces waste heat, which may be used advantageously, such as in a combined heat and power (CHP) approach; this use of the heat energy is not specifically quantified in this Report, but is a further benefit that is likely to have value in many instances.

Biogas production relies on the organic feedstock streams that often have a low energy density. As a result, if the feedstock is transported for significant distances, the energy consumed in transportation represents much of the available energy being transported, thereby offsetting the potential benefits. In this report, only feedstocks in the general vicinity of Ottawa are considered. As well, due to limitations with exchanges between provincial borders, only feedstocks available in Ontario are considered.

Due to the technology requirements, micro-generation or small scale RNG facilities are not considered viable.

Background

Biogas uses organic material as the feedstock from the following streams:

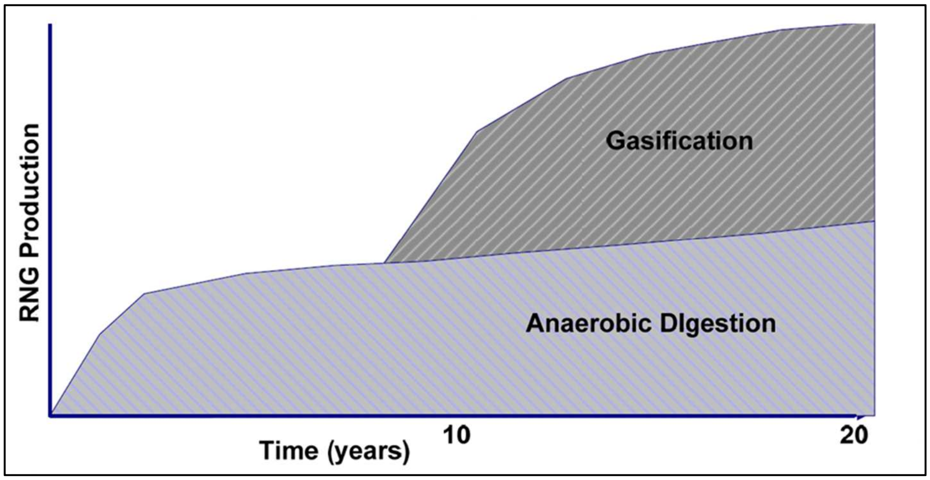
- agricultural, including crop residue and livestock manure;
- forestry waste;
- municipal waste which includes municipal solid waste (residential, commercial, industrial, institutional, construction and demolition), wastewater, and biosolids from wastewater; and
- landfills.

Depending on the choice of feedstock, biogas has the potential to increase waste diversion from landfills and decrease direct emissions of methane from decomposing material. A facility may advantageously be able to collect feedstock from more than one stream.

Biogas feedstock is used in one of two processes: anaerobic digestion or gasification. AD is a process by which the feedstock is placed in an oxygen-free container and micro-organisms break down the organic matter into methane and carbon dioxide[1]. The growth of the industry in the past ten years in North America has allowed for adaptations to an AD facility's design, with improved process and operations efficiencies.

Anaerobic digestion also occurs in landfills with the decomposition of organic waste material and is referred to as landfill gas (LFG). The gases may be directly burned for electricity generation or purified for injection into the natural gas grid. Gfn is a high temperature reaction where the organic material and a small amount of oxygen are converted to a gaseous mixture, referred to as syngas, which is composed of carbon monoxide, hydrogen and methane[2]. This gasification uses much lower temperatures and pressures than the plasma gasification process that the City investigated with Plasco, and is intended only for organic feedstocks, not complete municipal waste. Though the technology is not new (Gfn is currently done with coal), the use of Gfn with organic wastes for the manufacturing of RNG is not a common technology today[2].

Figure 1 - Projections for the development of gasification facilities (source: Alberta Innovates Technology Futures[3]). This shows the primary technology that can create a feedstock that can be burned as is or further purified into renewable natural gas.



Generally speaking, wet feedstocks are only suitable for AD. Both processes are advantaged by drier and higher energy density feedstocks, with fats, oils and greases (FOGs) being the most energy dense feedstock option. The Gfn process has advantages over AD including the suitability of a larger selection of feedstocks, such as more fibrous biomass products. More importantly, the methane production of Gfn is higher than AD. Through Gfn, the conversion of organic material to methane is between 65 and 80% while anaerobic digestion converts only about 20% of the feedstock[2]. The yield of biogas from a particular feedstock will vary according to:

- Dry matter content - food wastes in particular will vary greatly;
- The energy left in the feedstock, if it has undergone prolonged storage it may already have begun to break down;
- Length of time in the digester;
- The type of AD plant and the conditions in the digester; and
- The purity of the feedstock.

With the AD process, there is a choice between using the gas onsite for direct generation of electricity (including CHP) or purifying the gas for injection into the natural gas grid. If the biogas is used to generate electricity through a combustion engine, the efficiency of converting methane to electricity is between 35 and 40%[3]. The combustion also produces waste heat, which can be captured and used on-site, for heating of facilities or even of the AD process itself. If instead the biogas is used for manufacturing RNG the efficiency of the methane to RNG is between 80 and 90%[2]. The high energy retention in the conversion to

RNG may make it the more desirable alternative. In addition to a higher efficiency conversion, the use of RNG also results in the displacement of conventional natural gas. These estimated conversion factors are summarized in Table 1.

Table 1 – Summary of efficiencies of three different processing opportunities.

Process options	Efficiency of feedstock to methane	Efficiency of methane to energy	Comments
AD ⇒ Elec	20%	35 to 40% (or up to 80% for CHP)	Use of waste heat increases overall efficiency
AD ⇒ RNG	20%	80 to 90%	
Gfn ⇒ RNG	65 to 80%	80 to 90%	Wider range of feedstocks

Existing Facilities in Ottawa

There are currently a number of AD biogas facilities in Ontario that have been developed through the Ontario Biogas Systems Financial Assistance Program, the Ontario Feed-In Tariff (FIT) program and other mechanisms. The majority of these projects are biogas to electricity generation or CHP systems. Currently in Ontario, the only exception to this is the Woodward Avenue Waste Water Treatment Plant in Hamilton, which produces RNG from AD and injects it into the NG distribution system. Table 2 shows a list of current biogas projects in the Ottawa area, including landfill gas projects. It is worth mentioning that one project just outside of Ottawa, at Laflèche Moose Creek landfill, is a joint partnership with Energy Ottawa[4] with equivalent technology and capacity to the Trail Road LFG facility.

Table 2 - Summary of existing biogas plants within Ottawa.

Tech	Project	Capacity in 2016 (MW)	Annual Energy (TJ)	Owner	Comments
AD	Jockvalley Farms Limited	0.5	12	Jockvalley Farms Limited	FIT 1
AD	Carleton Corner Farms Limited	0.5	12	Carleton Corner Farms Limited	FIT 1
AD	Schouten Cornerview Farms Limited	0.5	12	Schouten Cornerview Farms Limited	FIT 1
LFG	Trail Road Landfill	6.0	144	Energy Ottawa	Pre-FIT contract
LFG	Carp Road Landfill	6.4	150	Waste Management	Pre-FIT contract
AD	Robert O. Pickard Environmental Centre	2.4	57	City of Ottawa	CHP / Net-metered
TOTALS		**16.3**	**390**		

The use of biogas directly for electricity generation as a local renewable energy (RE) source is a good compliment to other RE generators, since output is approximately continuous and it holds the potential to be partially dispatchable, for electrical grid demand management. With a sustained source of biomass feedstock, a biogas RNG facility can run with a capacity factor of 85 to 95%.

Market for Biogas Electricity

The Ontario FIT program supported the development of biogas for electricity generation but not for RNG. Unlike some technologies, the FIT contract price for biogas increased from the original FIT pricing in 2009. The January 1, 2017 FIT contract price list has on-farm biogas at $0.258/kWh (≤100 kW project) and $0.20/kWh (>100kW ≤ 250kW) while the initial contract prices in 2009 were $0.195/kWh and $0.185/kWh, respectively. The same has occurred for biogas projects less than or equal to 500 kW which started at $0.16/kWh and have increased to $0.165/kWh. However, the FIT program is no longer offering new electricity contracts, thus new procurement opportunities will need to be found (as is the case for all renewable electricity generators). Assuming the above FIT prices are reasonably indicative of the price to produce electricity, biogas may be less competitive than medium or large-scale wind and solar facilities. Biogas facilities slightly larger than the above FIT contracted limitations, such as 1 MW, will be more economical[5].

Market for RNG

The market for RNG is nascent. Bullfrog power has, in the past few years, begun selling RNG in a similar manner to how they have sold renewable electricity for more than a decade. They procure RNG from an accredited facility (presently only one: a landfill in Quebec that runs an LFG to RNG process), and sell it virtually at a premium of $3.92/GJ (as of August 2017)[6] to those willing to pay a price premium over regular NG, which sells at approximately $6/GJ presently, and which may rise slightly to $8 to 10/GJ in the future[7]. Costs also depend on the feedstock supply, which are "free" for landfill projects, and which may be as low as $8/GJ. However, in general, the cost to produce RNG from feedstocks is generally understood to be higher than this, likely in the $15 to $20/GJ range[2] presently. Costs will vary depending on the scale of the project, with higher costs for small projects due to the capital cost of purification and pipeline injection equipment. The technology and the market are young, thus it can be anticipated that costs will decrease, but policy supports and/or a sufficient price for carbon may be required to support future growth. These would mostly be developed by provincial governments, but development of the most opportune local projects, perhaps building on existing city biogas facilities, will benefit from municipal involvement.

RNG can also be used for transportation as CRNG (for example farm vehicles, buses, waste transportation vehicles, and other commercial fleets) if investment in suitable filling stations and vehicles is undertaken[8]. Costs for CRNG are higher than regular NG ($0.60/litre), but are presently competitive against gasoline and diesel ($1.20/litre)[9].

In certain jurisdictions, such as in California, higher renewable energy credits may be available for RNG used as compressed NG for transportation, and sales to California may be feasible, and would be brokered through the gas network.

Other Benefits

In addition to the production of electricity for RNG, the AD and Gfn processes result in a substantial decrease in the volume of residual waste, which results in a lower cost of disposal, and in most cases a low-odour, pathogen-free, weed seed free high-quality fertilizer that can be used on the farm. This creates a nutrient cycle, where nutrients in the food and crops from the local area are returned to the farm. The processes also create excess heat, which can be used locally or fed as an input into a district energy system.

Accessing the value of multiple attributes: energy, waste diversion, nutrients, heat and GHG reductions may be required to obtain economical projects.

Resource Potential

Biomass feedstocks readily exist as waste products throughout the urban environment, providing opportunities for waste diversion, while rural areas of Ottawa further contain agricultural and forestry wastes. The future potential of biogas for electricity and RNG is based on the availability of, and ultimately is limited by, the various streams of feedstock within the region.

The estimation of available feedstock resources has been based on a 2011 report by Alberta Innovates Technology Futures on the potential production on RNG in Ontario[3], which was limited to areas with access to natural gas distribution infrastructure. The report calculated municipal waste quantities based on population, while agriculture residue, manure and forestry waste quantities were based on county survey information. Leidos was able to estimate the available Ottawa municipal waste feedstock based on the population of Ottawa as a percentage of the total in the report. For agricultural residue, manure and forestry waste, the breakdown on a per county basis was not provided in the report, so as a rough estimate, Ottawa was considered to have access to 10% of the Enbridge service area's quantities of crop residue, manure and forestry waste[10]. The Alberta Innovates Technology Futures report assumed that only a portion of the total available feedstock would be directed towards AD and Gfn, with the values per feedstock type being quite conservative, as are further discussed in that report. Table 3 shows the estimated energy available from each feedstock in Ottawa. Of particular note, under municipal solid waste (MSW), only 25% of residential waste is included and zero waste from industrial and commercial is included, which means that restaurant and food centre wastes are not included. Furthermore, FOGs, such as from grease trap waste, are not included in that report, but are known to be particularly good feedstocks for AD. Rendered fats and vegetable oil grease however have value as inputs to biodiesel production and may not be available at reasonable costs for AD, though mixed composition food wastes that include FOGs may be available. A more refined assessment of these waste streams is recommended for future work. Cells in the table with "N/A" reflect the expectation that there is no potential for the specific feedstock within the given technology.

Table 3 – Potential energy available from feedstock through biogas production as RNG, as estimated for Ottawa, based on the Alberta Innovates Technology Futures Report[3].

	Production Volume (Mm^3/yr)		Production Capacity (TJ/yr)	
Feedstock	**AD (Near-term)**	**Gfn (Long-term)**	**AD (Near-term)**	**Gfn (Long-term)**
Crop Residue	6.9	32.2	260	1,212
Manure	4.1	6.4	155	241
Forestry	N/A	0.5	N/A	18
MSW	2.0	32.8	76	1,234
Wastewater	4.6	N/A	172	N/A
Biosolids from wastewater	N/A	4.6	N/A	174
LFG	43.6	N/A	1,642	N/A
Totals	**138**		**5,180**	

The estimates for energy are based on the conversion of all potential organic material into RNG either through anaerobic digestion or through Gfn. If some of the feedstock/AD outputs were used instead for generation of electricity, the electrical energy outputs would be lower due to the lower conversion efficiency as discussed in the Background section; using the median values, a relative energy output of 0.44% of the above values is assumed, which further assumes no waste heat collection of the CHP process is in place.

Energy potential

Biogas has the potential to be a consistent energy supply provided that the quantity of feedstock for a facility is sufficient and does not experience frequent disruption. For new biogas plants for RNG, capacity factors were estimated to be between 85 and 95%, with 90% used for calculations, whereas for new biogas plants for electricity generation, the capacity factor was estimated to be 70%[11]. This means that on average they will produce 90% of their rated capacity or 70% of the rated power capacity over the course of a year. If all the feedstocks detailed in Table 3 were used optimally for RNG production, there would be an estimated annual energy capacity of 5,200 TJ for Ottawa in approximately 2035. There is potential to exceed this value as there is high uncertainty in the estimated numbers, the Alberta Innovates report used conservative diversion rates and did not include food wastes (including grease trap waste), and there is the potential to draw on sources outside the City boundary that are still within a reasonable transportation distance.

SECTION 2 – GROWTH PROJECTIONS FOR BIOGAS ENERGY IN OTTAWA

Methodology of Pathway Projections

The future energy that can be produced by biogas generation facilities is defined by both the technology and feedstock resources, as ascertained in the previous section. Uptake is also greatly affected by constraints, including market, economical, regulatory and logistical, as will be examined herein. The section considers all these factors and develops projections of possible uptake scenarios, as well as some near-term opportunities for positively influencing adoption.

Constraints

Regulatory Constraints

Currently the key regulatory issues related to anaerobic digesters for electricity generation appear to be the cost and time required to achieve compliance rather than an inability to comply. Regulatory processes include, but are not limited to[12]:

- conformance to the Nutrient Management Act;
- Renewables Energy Approval (REA) for electricity projects; and
- electrical grid capacity, connection costs, and required protection equipment, as set by the LDC.

The rules and level of permitting required for waste transfer can be barriers to development. The REA process includes review of set-backs, noise and other impacts on residents, and requires public consultations. When long study and consultation processes are required for sites that are already involved in processing operations (wastewater treatment) or when applied equally to large and small projects, it may be onerous and thus a barrier for some projects[13].

Electrical Grid Constraints

One key limitation is the capacity of the grid to accept more electricity generation. Hydro Ottawa and Hydro One (the two local distribution companies operating within Ottawa) have limits on the maximum power generation that can be connected to each of their individual circuits. Over time these limits can be changed – either up or down – by upgrading LDC equipment, changes in policies which affect how the calculations are done, or by the connection of other, competing distributed generation facilities. The limits can be overcome – and have been in other jurisdictions – with appropriate grid modernization and/or changes to utility-imposed limitations. Challenges in the clarity, consistency, and transparency of the connection costs can impact project development costs (either directly or through costs associated with delays), development efficiency, and project capital costs. These "soft" costs have been increasing over time, and can form a measurable portion of a project's total costs.

Natural Gas Network Constraints for RNG Injection

Development of RNG for injection into the NG network requires proximity to the pipeline, yet the NG network does not have extensive coverage in rural areas in Ontario. Larger projects will be able to afford to run connections for longer distances to the network, but lengths likely need to be of the order of 5 km or less[14]. The injection point on the NG network also needs careful consideration for required injection pressures and other regulations. Injected RNG must meet specific minimum or maximum levels for certain gases, moisture, and other parameters in order to be added into the pipeline. It must be pressurized, and it must meet a variety of safety and metering rules. Depending on contractual models, it could be purchased by an end user, or by the gas utility. In Ontario, the process of pipeline injection is regulated by the Ontario Energy Board.

A dual stage or "hub and spoke" supply chain approach could also be considered, where "raw" biogas from multiple AD and/or Gfn facilities is transported to a secondary central facility for purification and injection onto the NG grid. Transportation of the raw biogas to the central facility could be economical for distances in the order of 100 km or less[14]. This approach adheres to the need for short transportation distances for input feedstock, but economies of scale and location constraints for the purification and gas injection infrastructure.

Feedstock Supply Constraints

It is important for a digester to have a regular and continual supply of consistent feedstock, which gives preference to stable longer-term reliable sources. But certain sources may not have long-term existence, and certain sources may not have sufficient control of the quality of the inputs. Aggregators of feedstock can serve a useful role in these regards, by actively creating and optimizing quality controlled collection, with the further possibility for pre-processing of wastes to reduce water content (reducing transportation costs) and improve consistency[15]. However, they then need to charge for the value of the delivered product, which is different than the free on-farm feedstock supply model in which the market originated. In 2012, Organic Resource Management Inc. was operating an urban organic waste collection in the Toronto region that delivered to a small number of biogas facilities, however it appears to have not expanded substantially since.

There is an overall maximum quantity of feedstock available within a region, so competition and/or commitment to existing waste management methods may limit the growth of biogas facilities. For example, the use of the City's residential green bin municipal waste is presently committed for composting with Orgaworld until 2029.

Yet, many streams of organic waste material currently carry a cost for disposal, so there may be a market opportunity to divert these streams into biogas processes that produce energy. Furthermore, there are additional motivations to increase collection rates of FOGs, as those that enter the wastewater pipes adhere to the pipe walls and cause wastewater infrastructure maintenance and repair costs.

Market and Financing Constraints

Power purchase agreements (PPAs) through the RESOP and FIT programs have been successful mechanisms for providing a stable revenue stream for generated electricity. With reference to the latest tariffs offered, the cost of electricity from AD is estimated at $0.16/kWh, which may be competitive with retail rates of certain electricity consumers, in particular as a fixed long-term price that will hedge against rate increases. The added values (fertilizer, reduced disposal costs, heat) may further enhance project viability. With the ending of the FIT program, new mechanisms to be able to sell the electricity will enable AD facilities to develop. Net metering is viable when there is a sufficient demand on-site, but virtual net metering or direct commercial power purchase agreements, (where a consumer with sizable load purchases the power or kWh credits from the biogas generator) will enable many more opportunities to proceed. It is also worth noting that the FIT program was not an ideal mechanism as it limited the size (≤ 500 kW) and the end product (electricity).

Similarly, more significant procurement mechanisms for the sale of RNG will need to develop, in particular due to the desired larger size of generation for Gfn plants. The procurement may be directly by the gas utility, or it could be another mechanism such as sales via the gas network to organizations seeking direct renewable procurement, or carbon cap and trade credits.

A second issue is the cost of high quality (energy dense) feedstock. Projects may rely on the availability of cheap feedstock to be economically feasible. This will likely limit the sourcing of feedstock to areas geographically close to the facility. Competition for feedstock could develop as the market matures, causing higher feedstock costs and the risk of facilities operating at less than full capacity.

Development Capacity

There exists good expertise on AD within Ottawa, as well as several operating facilities. However, moving towards using biogas for RNG will likely require some dependence on experienced companies from outside Ottawa to gain knowledge. For AD to RNG there are projects currently in Canada, including but not limited to: Hamilton, Ontario, Berthierville, Quebec and Abbotsford, British Columbia that could be used as study cases[2]. Future development of Gfn facilities will entail more challenges and may require demonstration projects. Though the technology is not new (Gfn is currently done with coal), the use of Gfn with organic wastes for the manufacturing of RNG is not a common technology.

Gas utilities in Ontario, Quebec and British Columbia are already accepting RNG in their pipelines, though quantities are a negligible percentage presently. In Ontario, Enbridge and Union Gas had applied to the Ontario Energy Board to increase the percentage of RNG in their networks, but at the time they were rejected as unattractive due to the increased costs of NG to consumers that would ensue[16]. New analyses as part of the Ontario Long Term Energy Plan are underway on this matter[2]. A Navigant Fuels Technology Report has forecast 155,000 TJ of RNG delivery capacity by 2035[7], which is approximately 11% of the current 2015 Ontario NG consumption[17]. These values are a total for RNG supply provided by several sources, including biogas, power-to-gas, and imports, and thus are approximately consistent with the predictions from the Alberta Futures report which found that biogas pathways could produce RNG at a quantity of 6% of the NG consumption[13]. These are aggressive uptake values, based on technical feasibility, which require good market conditions and national/provincial initiatives for project development support and carbon pricing.

Uptake Projections

Scenarios

Future projections for growth in this sector are very speculative due to the dramatic changes occurring presently, and relating to multiple factors:

a) The industry for electricity production from biogas AD at the 250 to 500 kW scale is established but has been dependent on the Ontario FIT program, which is set to end.
b) The market for RNG is in its infancy, and many of the economic and regulatory drivers are in a state of development and flux.
c) The strong potential for GHG reductions with both AD and RNG are likely to result in provincial and federal governments developing new policies over the next five years.

Leidos estimates that the sequence for the build-out of project by type and feedstock would likely transpire in this order:

- More of the existing (agricultural residue and manure used for AD producing electricity);
- Use of institutional and commercial food waste streams;
- Use of residential organic waste (once the feedstock can be diverted from composting contracts);
- Development of RNG production using AD processes (sourcing one or more feedstocks); and
- Development of gasification facilities (potentially using more than one feedstock at the same facility). This could produce electricity but optimally it would produce RNG.

Leidos has developed three possible scenarios for the future uptake of biogas facilities which consider the overall feedstock availability from Table 3, the timelines for technical feasibility of the three processes, and then further considers how market, regulatory, and economic constraints will influence uptake.

- In the conservative scenario, AD is the only process that is developed. AD for electricity production begins at 2% of the available resources and increases by 1.4 times every 5 years until 2030 when development slows to 0.5 times every 5 years as new development will be focused on RNG. RNG begins in 2025 using 2% of the feedstock available for AD and increases 1.4 times every five years. The potential growth with the use of only AD is relatively flat.
- The moderate scenario includes AD for electricity and RNG production at higher rates than in the conservative scenario, beginning with 3% of the available resources and

increasing by 1.4 times every 5 years until 2030 when development slows to 0.5 times every 5 years as new development will be focused on RNG. RNG from AD begins in 2025 using 3% of the feedstock available for AD and increases 1.4 times every five years to 2030 then it increases 1.6 times every five years to 2050. The scenario further includes the development of Gfn facilities which produce RNG starting in 2035 using 2% of the available resources for Gfn and doubling every 5 years.

- The aggressive scenario is similar to the moderate scenario but with higher uptake of both types of processes. Electricity and RNG from AD begin at 5% of the available resources and increases 1.4 times every 5 years until 2030 when development slows to 0.5 times every 5 years as new development will be focused on RNG. RNG from AD begins in 2025 using 5% of the feedstock available for AD and increases 1.4 times every five years to 2030 then it increases 1.6 times every five years to 2050. The scenario further includes the development of Gfn facilities which produce RNG starting in 2035 using 2% of the available resources for Gfn and doubling every 5 years until 2040 when the increase becomes 2.2 times every five years up to 2050. It further assumes that by 2050 facilities are developed with the highest efficiency, that being a two-stage process where biosolid output from AD is used as a source for Gfn for RNG production.

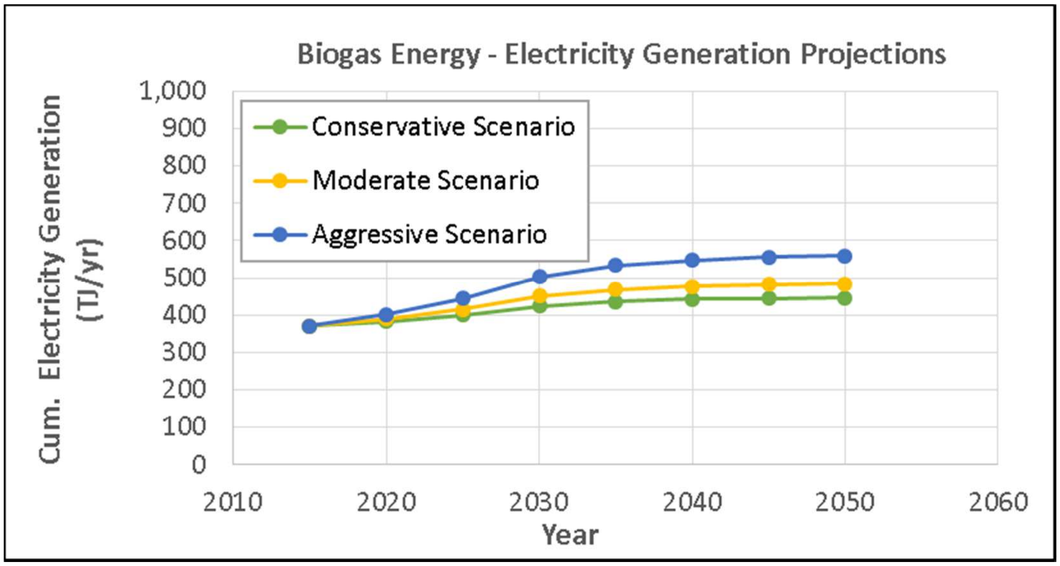
The scenario projections are summarized in Table 4, including separate tallies for the electricity and RNG production. The cumulative values for overall electricity generation and RNG generation are graphed in Figure 2. The *cumulative* (cum.) aspect of the values is the total generation capacity that will be installed and in operation by the representative timeframe, and where capacity is an annual energy generation value in TJ/yr.

Figure 3 provides an estimate of the greenhouse gas (GHG) emissions reductions that may be obtained considering that biogas electricity production displaces electricity from the Ontario grid (assuming the 2015 average emissions levels of the Ontario grid[18]) and considering that the emission levels for regular NG are fully avoided. The first is a rough estimate of actual impact, since future emissions values and marginal offsets may be different. But it is a small value in comparison to the RNG contribution to GHG emission reductions.

Table 4 - Projected impact of future biogas development for three different uptake scenarios.

	2015	2020	2025	2030	2035	2040	2045	2050	Total New
Conservative Scenario									
MW/yr new Elec	16	0.5	0.8	1.1	0.5	0.3	0.1	0.1	3
Mm^3/yr new RNG	0	0.0	0.9	1.3	1.8	2.5	3.5	4.9	15
TJ/yr cum. Elec	370	380	400	420	440	440	450	450	
TJ/yr cum. RNG	0	0.0	42	100	180	300	450	680	
TJ/yr cum. Total	370	380	440	520	620	740	900	1,120	
Moderate Scenario									
MW/yr new Elec	16	0.8	1.2	1.6	0.8	0.4	0.2	0.1	5
Mm^3/yr new RNG	0	0.0	1.4	1.9	4.4	7.6	13.3	23.4	52
TJ/yr cum. Elec	370	390	420	450	470	475	480	485	
TJ/yr cum. RNG	0	0.0	60	150	340	670	1,230	2,220	
TJ/yr cum. Total	370	390	480	600	810	1,145	1,710	2,700	
Aggressive Scenario									
MW/yr new Elec	16	1.4	1.9	2.7	1.3	0.7	0.3	0.2	8
Mm^3/yr new RNG	0	0.0	2.3	5.2	9.2	16.4	31.9	64.4	130
TJ/yr cum. Elec	370	400	440	500	530	550	555	560	
TJ/yr cum. RNG	0	0	100	330	720	1,400	2,700	5,300	
TJ/yr cum. Total	370	400	540	830	1,250	2,000	3,300	5,900	

Figure 2 - Projections of biogas generation in TJ/yr under conservative, moderate and aggressive deployment scenarios. Electricity generation and RNG are shown separately.



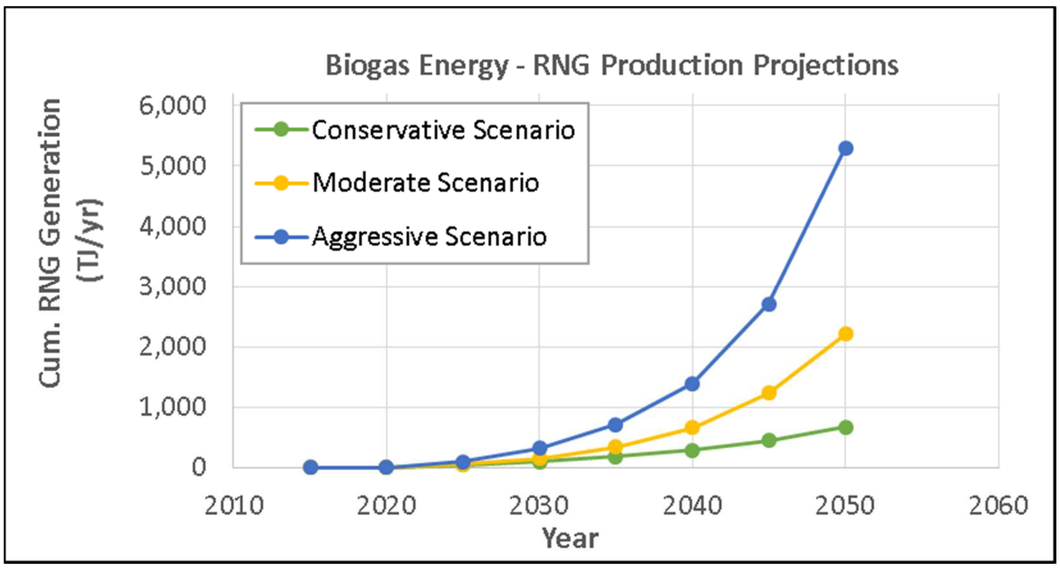
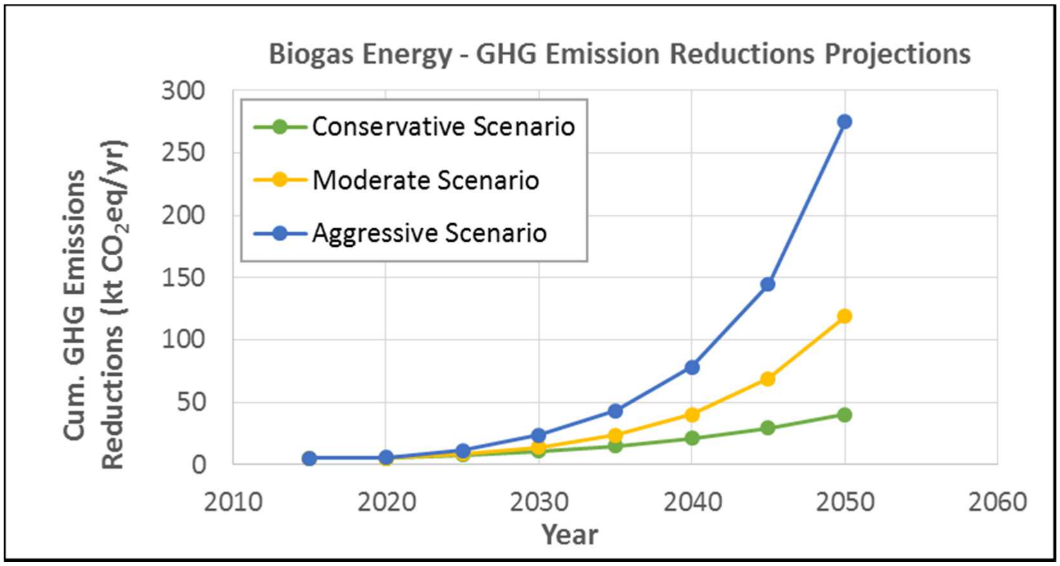


Figure 3 - Projections of greenhouse gas emissions reductions that may be realized, assuming the biogas electricity production displaces Ontario grid electricity and RNG production displaces NG.



Under the aggressive scenario, the amount of RNG that would be produced in 2035 is 700 TJ, which represents 1.6% of the 2015 NG consumption. This is lower than the Alberta Futures report value of 6% for all of Ontario, but potentially more realistic considering the constraints that will affect uptake and Ottawa's feedstock resources. In addition, some feedstocks are projected to continue to be used for electricity generation through this period. But within the model, Gfn does develop substantially between 2035 and 2050, such that by 2050 the amount of RNG that would be produced is approximately 5,300 TJ, which is equivalent to approximately 12% of Ottawa's 2015 natural gas consumption. These volumes of biogas-derived RNG will contribute substantially to the overall RNG supply that may develop. It is recommended that additional research with more stakeholders and using new market development information be undertaken in the future.

Opportunities to Advance Biogas Energy

- Work to direct valuable energy streams towards biogas production as a potential energy source. A comprehensive planning strategy may be the best way to optimize the use of the various feedstocks available.
- Work to promote the technology, including through outreach, advocacy, and partnership to enable a broad and substantial uptake across the region. It should look

to work with local companies to mutually develop expertise to spur further economic growth.

- Initiatives to increase the collection rate of FOGs from the food services industry for the purposes of directing the waste to biogas processes could be developed. The added advantage is the decreased rate of FOGS entering the sanitary system[19].
- Farms, landfill and wastewater treatment facilities can be developed into multi-technology energy and nutrient centres, that may have economic viability and economic development advantages.
  - The AD or Gfn centre may be able to intake feedstock from other sources to create a larger scale biogas facility.
  - The heat outputs should be captured and used advantageously on-site (including selling it to greenhouse growing facilities), or provided to district energy systems.
  - One grid connection could be used for multiple electricity generation technologies, i.e. biogas as well as solar or wind generation.
  - The connection of the RNG to the NG network could be further leveraged with the co-location of power-to-gas RNG generation, which could use electricity curtailed from the solar or wind project.
- The City and other large gas consumers could consider procuring RNG (directly or virtually) as a renewable energy supply.
- As FIT contracts for biogas generated electricity expire, explore the option of converting biogas to RNG where access to the natural gas grid exists. Or, the outputs from an AD can become inputs to a Gfn facility.
- Pricing and procurement that recognizes the values of the biogas, including for GHG emissions reductions, will help the economic feasibility of projects.
- Where regulatory conditions are acting as a constraint or barrier to a potential project, advocate with the appropriate levels of government and develop a pilot project that demonstrates and tests sound new approaches.

Catalyst Projects

- Review and consider possible changes of the facilities at ROPEC to optimize municipal waste managements, economical energy outputs, and GHG reduction opportunities. Consider taking-in additional feedstocks (municipal and external) for economies of scale.
- Development of an RNG production facility at existing facilities, either as a standard AD process or as a Gfn project (would need to confirm distribution gas line availability at each):

  - ROPEC
  - Carp landfill
  - Trail Road landfill
  - Taggart-Miller waste processing centre
  - other centres?
- Work with the rural areas of Ottawa to examine what partnerships might be leveraged towards:
  - how agricultural wastes could be further developed and used for energy;
  - where there may be interest to develop new biogas facilities; and
  - the option for a dual-staged approach where a centralized purification plant for RNG which receives raw biogas from multiple AD or Gfn facilities.
- Consider use of compressed RNG for a portion of City fleet needs, as this may be the most economical project in the near term, as well as also providing low-carbon transportation.

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18 Derived from data in the Independent Electricity System Operator, Ontario Planning Outlook – a technical report on the electricity system prepared by the IESO, September 1, 2016.

19 The energy of FOGs that do make it through the sanitary system do become part of the energy input to ROPEC's AD facility, but due to loss on walls and decomposition, the energy content is lower than if it was captured directly.

Pathway Study on District Energy in Ottawa

Presented to:

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In relation to
The City of Ottawa Energy Evolution Program

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ABOUT THIS REPORT

City of Ottawa Energy Evolution Program

On July 8, 2015, Ottawa City Council approved the development of a Renewable Energy Strategy as part of the 2015-2018 City Strategic Plan. This initiative has been developed into a program entitled Energy Evolution – Ottawa's Renewable Energy Strategy. A main goal of Energy Evolution is to develop a baseline analysis of energy supply and demand within the City of Ottawa and assess options, in collaboration with community partners, for all such partners to advance energy conservation, energy efficiency and renewable energy generation within their respective areas of control and influence. The Energy Evolution program has interacted closely with community stakeholders from local utilities, the federal government and other government institutions, the development sector, academia, the non-profit sector, and the private sector at large. Leidos Canada was engaged by the City to support analysis in the energy supply domain, including research reports and facilitation of discussion with stakeholders.

The Purpose of this Report

This and other "Pathway Study" documents are focused technical notes describing how the specific energy technology may develop in Ottawa. The document considered the overall technical potential for implementation, and then further considered the constraints (economic, regulatory, etc.) that are likely to reduce uptake. It suggests opportunities to influence uptake rates and catalyst projects that may be attractive to consider further. Results of the Pathway Studies are intended to be used along with the Baseline Study of energy data towards an overall assessment of future energy strategies within the City of Ottawa Energy Evolution program.

A draft form of this Pathway Study was circulated to key stakeholders and experts in the topic during the summer of 2017. Meetings were also undertaken during this period, where these representatives contributed their insights and ideas towards the development of leading project opportunities in relation to the topic of the Pathway.

Other documents in this series are:

Baseline Study on Energy Use in Ottawa in 2015
Pathway Study on Waterpower in Ottawa
Pathway Study on Solar Power in Ottawa
Pathway Study on Wind Power in Ottawa
Pathway Study on Heat Pumps in Ottawa
Pathway Study on Biogas Energy in Ottawa

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Key Units

GJ/km^2 — A gigajoule is equal to 0.001 TJ, and herein is divided by land area, in kilometers squared. This is a unit of energy *intensity*. In this report, it is used to quantify the natural gas energy consumption across regions of the city.

GJ/m^2 — Gigajoules per meter squared is also an energy intensity as above, and used in this report to discuss modeled energy consumption per building or land parcel area, for mapping of a neighbourhood.

MW — Megawatts is 1,000,000 watts, and is a measure of power, used here in the context of the power rating or the capacity of an electrical generation facility.

MWh/m — A megawatt-hour is a measure of energy (equal to 3.6 GJ), and herein is divided by a distance in meters (m) to give a *linear* energy intensity. In this report, it is used to quantify the energy delivered per length of pipework in a district energy system.

TJ	Terajoules is a measure of energy, base unit of joules, and used here in the context of total energy delivered over one year. An on-farm 0.5 MW biodigester might produce 0.54 TJ of energy in a year.
kt CO_2eq	kilotonnes of carbon dioxide (CO_2) and other equivalent greenhouse gases, which is the common unit for quantifying the greenhouse gas emissions related to a process.

Pathway Study on District Energy in Ottawa

EXECUTIVE SUMMARY

A district energy (DE) system links thermal energy use among multiple buildings using insulated pipes that deliver heat or cooling to each building. The DE system has a centralized energy centre that provides the heated or cooled fluid to the network, using one or more energy supply types. These supplies may be fossil fuel based, but an attractive advantage of DEs is the opportunity they afford to make use of alternative energies which would not be possible for individual buildings to do. Example renewable energy supplies that are in substantial practice already in Canada include waste heat, biomass combustion, ground-source heat, and combined heat and power. DEs can thus enable increased use of renewable energy on a cost-effective basis. They may be able to provide overall energy efficiency advantages as well, depending on many details.

The challenge of district energy systems is the infrastructure coordination, the majority of systems in existence relate to institutional campus environments, yet there has been recent growth in urban neighbourhood deployments that include partnerships and support with municipalities.

DE systems can offer long term financially viable energy systems in regions with moderate to high energy use intensities (energy use per square area of land); this includes many urban neighbourhoods of Ottawa, from downtown to linear areas with commercial and townhomes. The Zibi development on the Chaudière Islands is developing a carbon-neutral DE system using waste heat and waterpower generated electricity, and includes a partnership with Hydro Ottawa. The Canadian Federal Government is in the process of revitalizing its DE systems that service the many federal buildings in Ottawa, and has expressed interest in expanding the system to Ottawa buildings and neighbourhoods. The most opportune times to build new DEs is during the development phases of new neighbourhoods and/or as part of the expansion of existing systems.

District Energy Systems Summary Table

Energy Type	Local thermal energy (heating and cooling)
Pathway Potential – in 2050 under an aggressive scenario (other timeframes and scenarios are detailed in Section 2 of the report)	
Thermal Energy Load Connected **Natural Gas (NG) displaced**	7,300 TJ 6,100 TJ
% NG displaced(1)	14%
GHG Reductions(2)	310 kt CO_2eq
% of GHG Emissions(3)	6%
Other Impacts	• Local infrastructure development • Enables switching of heat supply type(s) and integration of low-carbon thermal energy opportunities • New municipal land and community planning around energy supply

(1) As a % of Ottawa's 2015 total NG usage (43,500 TJ), from the Baseline Study.
(2) Assumes that NG heating is displaced by efficiency and by zero-carbon supplies.
(3) As a % of Ottawa's 2015 total emissions (5,200 kt CO_2eq).

SECTION 1 – PRESENT ASSESSMENT OF DISTRICT ENERGY IN OTTAWA

Pathway Description

This Pathway relates to the development of district energy (DE) systems which are an alternative and more integrative means of heating buildings. A DE system links thermal energy use among multiple buildings using insulated pipes that deliver heat to each building. A DE system includes a network of supply pipes to deliver heat to the buildings, and a parallel set of cool water pipes to carry the return fluid to the energy centre. The energy centre will have one or more heat generators that reheat fluids for distribution. The hot fluid is delivered into each building, where a heat exchanger extracts the required heat for use within the building's distribution system. The building may use the heat for space heating, domestic hot water, and process applications. DE systems often also supply cooling in the summer season.

This document focuses on DE supplied heating because heating is a much larger load than cooling in Ottawa (in the order of 7 times larger) thus any savings from heating efficiency are more significant. Furthermore, DE heating may include fuel switching to low-carbon opportunities, while cooling will dominantly be electricity-based whether or not on a DE system. The document draws some comparisons to the business-as-usual (BAU) approach of using stand-alone heating units in each building, which are typically natural gas (NG) furnaces or boilers and hot water heaters using NG or electricity.

The energy supply housed in the energy centre can include conventional fossil fuel boilers and other sources of renewable and waste heat. The implementation of district heating systems, in particular modern designs with lower temperature heat delivery (hot water instead of steam), can be more efficient than BAU thermal systems, and they can facilitate the use of renewable energy supplies of heat, which is a key tool for the development of low carbon thermal energy systems for cities.

DE systems may connect only a few small buildings together, or they can be large systems that connect hundreds of buildings together. It is possible to expand a DE system's service area over time and to interconnect several DE systems together. Due to the integrated nature and sub-surface pipes, they can be substantive infrastructure projects.

Pathway Boundaries

It is possible to integrate thermal energy storage into DE systems, which can be advantageous in certain system configurations. To a certain extent, the DE system itself already provides some "storage type" capacity, in that supply loops can receive low to medium quantities of heat during opportune times of surplus energy (including surplus or low-cost electricity). These energy storage and dynamic applications depend on the specifics of a potential site and the market conditions, and are not addressed explicitly within this Pathway study.

This pathway includes DE systems that are as small as a cluster of buildings, such as a few condominium buildings within one city block[1], but the focus is on a more logistically complex integration of networks of buildings and multiple building owners.

Background

Introduction

DE systems have been in use for more than a century, in particular in environments where the long-term financial commitments required for these integrated infrastructure energy systems are well accommodated. This includes government and public-sector institutions and campuses, but also includes commercial and residential networks in countries with higher energy prices and more centralist policies for energy infrastructure, such as in Scandinavian countries. In Denmark, district heating systems supply 75% of citizens with space and water heating[2], and 98% of Copenhagen's population is served by DE systems that are fueled by waste and renewable sources[3] (where waste includes heat from combined heat and power (CHP) facilities). DE is a mature field, but it involves a higher upfront capital investment with longer term paybacks in comparison to BAU, and because they compete with low fossil fuel energy prices in North America, DE systems are not common in commercial and residential markets. As of 2014, there were 159 DE systems operating in Canada, providing approximately 1% of the national heating and cooling demand.[4] DE systems are receiving new appreciation in the context of longer term sustainability, with the use of local energy resources, and greenhouse gas (GHG) emissions reduction opportunities. Uptake has increased considerably recently, with 25% of the 159 Canadian systems in operation developed between 2009 and 2014.[1]

Though the technologies used in DE systems are well understood, their implementation requires dedicated planning. The particulars of each opportunity, including the policy, planning and social context, all have a dramatic influence on the optimized design solutions, economic viability, and the level of success. There are many similarities between district energy and public transportation: while both require substantial upfront investment, they also offer long-term cost savings and emission-reduction opportunities.

Technical Background

Energy Distribution and Building Connection

Supply pipes are highly insulated and carry a hot fluid, which can be steam or high pressure hot water (e.g. at temperatures of 145°C) but most modern DE system designs are adopting hot water supplies at temperatures less than 95°C. A study by Natural Resources Canada (NRCan)[5] indicates that medium temperature DE systems with supply temperatures between 70°C and 90°C can decrease heat loss by as much as 40% compared to high temperature systems. The study also found that low temperature systems (those operating at less than 60°C) further reduce distribution losses, but require additional capital costs for pumping or heat boosting at certain points in the network. DE systems with medium and low supply temperatures allow for the use of energy supply options that have lower supply temperatures compared to combustion supplies, such as process waste heat, geothermal and solar sources. The supply temperature of the heat in the DE network must be compatible with the designed supply temperature of each building's heating system. The temperature of the network's return pipes depends on the quantity of heat extracted by the connected buildings. Careful design of the entire network is required, considering pipe flow rates, pipe pressures, supply temperature, return temperature, variable demand needs, supply dynamic capacities, heat exchangers' needs, and efficiency.

The pipe network may include a large primary pipe backbone and secondary pipes that connect to each building. Most system designs will be based on "indirect connections", where the heat exchanger in each building transfers heat to the building's heating systems. Direct connections, where fluid in the DE system is also directly circulated in the buildings, require tight control of heating systems and coordination with the DE system operator, so are less favourable in multi-user DE systems.

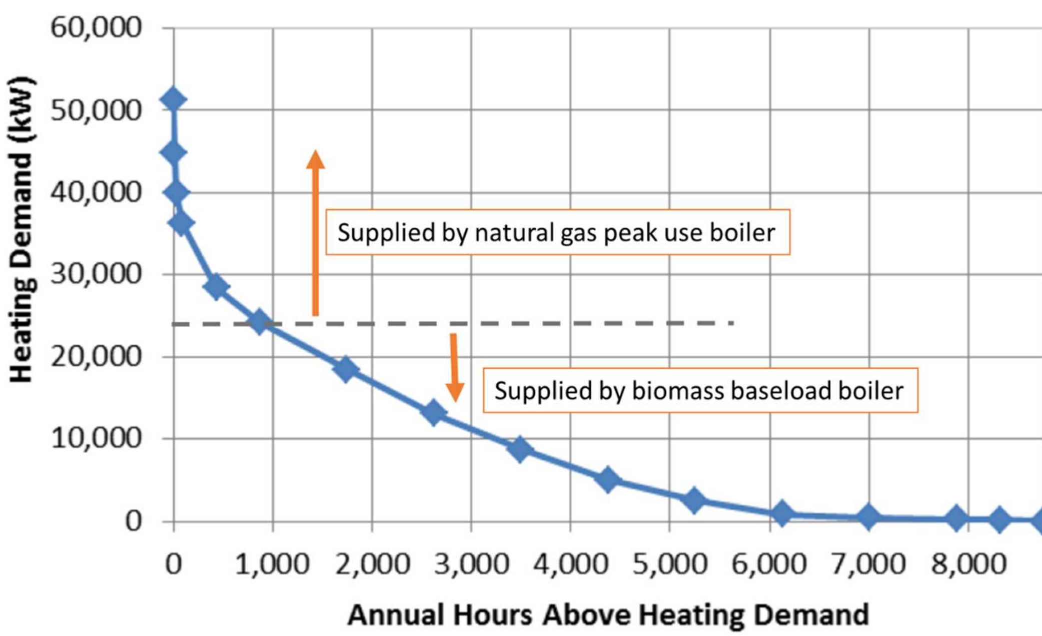
There are fixed costs associated with each connection point, as well as fixed costs per length of pipe required, thus the economic feasibility correlates with energy demand intensity.

Energy Supply Design

Two main advantages of DE systems are their ability to use local sources of energy and the ability to change the composition of the energy supply mix over time. It is substantially less work to convert the supply technology at a central energy centre rather than the heating source in every building of a network. The large central unit also allows for the use of heating technologies that are not practical at residential scale, such as biomass boilers, and for the integration of multiple low carbon options.

The integration of two or more energy supply types is feasible, and even preferred in order to economically provide heat in both peak and low demand conditions. A supply type that has higher capital costs to build, in combination with lower operational costs and/or lower GHG emissions, should be used as the "baseline" supply that always runs, while a supply type with lower upfront costs per unit of capacity, that can be run dynamically, should be used during peak periods. For example, as illustrated in Figure 1, for a system with a peak thermal demand of 50 MW, a majority of the energy (e.g. 85%) could be satisfied by a biomass boiler sized with a capacity of 23 MW, in combination with a NG boiler sized at 27 MW that only needs to run occasionally to provide the remaining 15% of energy[6]. The fractional split between the baseload and the peak supply is dependent on the local climate and building envelope. If the baseload can be satisfied by a biomass boiler, it is possible to reduce GHG emissions by roughly 85% relative to BAU heating.

Figure 1 - Example heating load duration curve of a building (in blue), which indicates the number of hours required at each heat demand value, and with an example division of the supply capacity (grey line) into two supply types; adapted from reference 7.



A CHP supply may be an attractive option for a baseload supply, based on the combustion of NG, biomass or other fuel. The combustible fuel is used to drive a generator and produce electricity, which may be used onsite to offset the amount of electricity purchased. The waste heat from electricity generation becomes a heat supply for the DE system. The electricity provides an additional revenue stream, and extracts a higher process efficiency than when NG is used for electricity generation in peak plants without capture of waste heat. However, this electricity from a fossil fuel based CHP may still have higher GHG emissions than that of the electricity from the Ontario grid which it is displacing; it is a subject of debate as to whether NG CHP is useful for GHG emissions reductions. Biomass-based CHP avoids this issue by having a low carbon footprint for all uses.

Local Renewable Energy Supply Options

Waste heat and free cooling - Harvesting of sources of waste heat wherever available, is clearly a very attractive option as a low-cost fossil fuel free opportunity. This includes CHP as described above, but also untapped sources of existing thermal energy, such as sewer lines, process exhausts, data centres, etc. Sewage pipes and treated sewage outfall contain substantive steady quantities of heat, and have been used as supplies of thermal energy in cities such as Vancouver and Halifax. Cold supplies from large bodies of water or snow piles; the former is not generally expected to be available from the Ottawa River (which gets warm in summer, in contrast to the use of deep Lake Ontario water in Toronto's large DE network[8]), but the use of cold from winter snow piles in the summer has had some preliminary analysis for Ottawa[9].

Biomass – Combustion of biomass is expected to be one of the primary renewable supply options able to displace NG, which can include material sourced from sustainable forestry, pulp and paper waste, and possibly municipal sources such as tree clippings and waste from construction. Bio-oil is another related option – this requires more processing of the bio feedstocks, but is more energy dense allowing for shipping over longer distances from source to end user.

Ground-source heat pumps (GSHP) are an attractive option, in particular for small clusters of buildings with heating and cooling loads. There are higher upfront capital costs relative to combustion heating equipment, but low operating costs and the ability to supply cooling as well. The GSHP supply temperatures are compatible with low and medium temperature DE systems.

Solar thermal – The Drake Landing Solar Community[10] in Okotoks, Alberta demonstrates that using solar thermal supply and seasonal storage is technically very feasible, but the project was developed at a time of escalating NG prices, and is not expected to be economical with the advent of low NG prices. It may still be attractive to integrate solar panels into a development, but solar's intermittency and the lower production in winter either requires storage or inclusion as only one of several sources in a DE system. Given the dramatically decreasing prices of solar photovoltaic panels, even though they are less efficient than solar thermal panels at converting sun power into energy, the use of photovoltaic panels' DC power output connected to resistive heating for the DE fluid might be a more attractive choice than solar thermal modules, for both economic and lower maintenance requirements.

Low-cost & surplus electricity – For large electricity accounts, where electricity prices follow market rates and can be very low or negative at times, it is attractive to use price signals to operate low-cost electrical heating units, which can help to displace fossil fuels for thermal needs. Similarly, grid-connected intermittent sources of renewable electricity (wind, solar) can be more grid-friendly if they are curtailed during times of low demand, at which point the energy could be diverted to thermal loads and thermal storage. Ice making using low-cost electricity in winter or at night, for summer cooling, can be viable in some situations.

Combustion of municipal solid waste in combination with modern emissions controls can provide a stable source of local thermal energy, and are in common practice in several European countries.

DE System Energy Efficiency

DE systems based around NG boilers can also be a viable option compared to BAU. When aggregating many loads on one DE system, there can be small "diversity" advantages, due to the non-simultaneous timing of each building's peak, which will result in the net peak of the system being less than the sum of all the individual peaks. Diversity factors in Canada are often around 0.9; they will be lower in a network that includes a mix of many building types and services. This allows for smaller capacity supply to meet the loads (a capital cost advantage) and allows it to run more hours at its design capacity, which will be more efficient than BAU. Furthermore, the efficiency of the DE system supply is improved with the use of multiple boilers, which are turned on in a staged manner as demand changes in order to keep all "on" units operating near their optimal capacity. These advantages, in combination with the opportunities to invest in larger, more efficient units and having dedicated maintenance staffing, can offer an operational efficiency of 0.9 or more for central DE NG boilers, versus 0.7 for many existing facilities[11]. Newer high efficiency condensing boilers in well maintained heating systems may provide similar 0.9 or higher operational efficiencies. Efficiency advantages may be substantially offset by heat losses in the pipes, such as in a distribution system with long runs, which are typically between 5 and 15%[12]; but good design and implementation can typically minimize these.

Logistical Attributes

Advantages to Building Owners

A sizable DE system may include multiple boilers (or other supply types) and have a spare unit that provides resiliency for maintenance and emergencies, which is a logistical advantage versus BAU. There are also some convenient advantages to the building owners who no longer service a combustion unit within their building. Some floor and/or roof space usually afforded to BAU thermal units will be freed, in particular for a DE system that provides both heating and cooling, leaving just the air handling equipment. Roof space can even be rededicated to hosting a green roof or solar panels.

Expandability

Most DE systems have the capacity to be expanded, allowing for the most economically feasible locations to be developed first, followed by the addition of more commercial buildings, new developments, and lower energy intensity regions. Expansion can also include the interconnection of two or more DE systems, which improves efficiency due to a larger diversity factor, and increased reliability and redundancy.

Phased Projects and Future Proofing

The staged construction of a neighbourhood may pose economic challenges to DE system development: while the entire development would support a DE system, the first phase of construction may be too small on its own to support the investment costs, leading to high initial energy costs, and the taking on of risk for the timely completion of subsequent phases. But if the developer waits for multiple phases to be completed, existing buildings will have already invested in individual BAU systems. Projects that plan on having a large number of existing entities connect need firm commitments and rules to mitigate the risks of insufficient loads. Financing support during these early phases and sound municipal planning and coordination can help to avoid issues.

General Economic Attributes

Resiliency and Security

Use of local diverse sources of energy improves the resiliency of the region against disruptive events or external market price increases. The use of CHP further provides local sources of electricity, which can help power buildings during emergency conditions.

Local Economic Advantages

There are several possible ways in which deployment of a DE system can provide economic advantages, which depend substantially on the project details, but may include:

- efficiency gains and reduced fuel costs will provide long term energy cost savings;
- replacing imported fuels with locally sourced fuels keeps energy supply profits in the community;
- decreasing the use of NG will reduce the exposure to fossil fuel price volatility and possible future price increases;
- a DE system with local (renewable) supplies will displace the costs of imported fuels, which are replaced by costs for infrastructure development and operations, both of which relate to local labour and thus an increased number of local jobs. Markham estimates this to have a local economic value of $1.37 for each $1 invested[3];
- DE systems may be a low-cost carbon abatement option; and
- a low-carbon, resilient thermal energy supply may be able to attract certain businesses[13].

Small DE systems are likely mostly influenced by calculable advantages, whereas development of larger networks may include more holistic macro-economic thinking.

Example Systems

Sustainable Neighbourhoods in Canada

As mentioned before, DE systems in Canada are most often found in government complexes and university and college campuses. But over the past decade, in both Canada and globally, a number of example sustainable neighbourhoods which include a DE system have been developed. Several Canadian examples are described herein:

Southeast False Creek Neighbourhood in Vancouver - during the development of a large piece of land from industrial land into a sustainable urban neighbourhood, the Southeast False Creek Neighbourhood Energy Utility was developed. The DE system uses waste thermal energy captured from sewage to provide space heating and hot water to buildings. “This recycled energy eliminates more than 60% of the greenhouse gas pollution associated with heating buildings.” The utility began operation in 2010 and since then has rapidly expanded to serve 395,000 m^2 of residential, commercial, and institutional space. The DE system is owned by the City of Vancouver, which requires developers to connect to the system, providing thermal energy at rates that are set annually by City Council, and which are also reviewed by an independent expert panel, and stated as being cost competitive[14].

Drake Landing Solar Community in Okotoks, AB – a DE system built in 2007 which used solar thermal collectors on each of the 52 residential properties, and underground seasonal storage to store heat during the summer months and distribute the energy to each home for space heating needs during winter months. It has achieved over 90% heating from solar over the past five years, and uses an NG boiler for the difference[10].

Alexandra District Energy Utility in Richmond, BC – a project under development which will use a ground-source heat pump system for heating, cooling and domestic hot water. At full build-out it will service 360,000 m^2 of residential, commercial, office and institutional space.

Deep Water Lake Cooling System in Toronto, ON – a unique DE system that uses cold water from deep in Lake Ontario to cool more than 150 buildings in the downtown core. It is a strategic collaboration between the City of Toronto and Enwave. It “eliminates the need for electrically-powered chillers at customers' buildings. This saves tens-of-thousands of dollars in capital investments at new constructions, while freeing significant square footage and reducing maintenance and replacement costs for retrofits at existing buildings.” The environmental benefits include energy conservation and the elimination of ozone damaging coolants[8].

Dockside Lands in Victoria, BC – features a biodiesel manufacturing facility developed by Nexterra, which received waste wood from the City operations and converts it through gasification into biodiesel for use as the supply heat to the DE system for cooling and heating. The project has had some economic challenges relating to slower than expected growth and biodiesel production[15].

Regent Park in Toronto, ON – a low-income community housing neighbourhood in old Toronto undergoing redevelopment which started in 2006 and will extend for 15 to 20 years. The primary fuel of the DE system will be NG, but the system is designed so that it can easily incorporate solar energy or ground-source heat pumps in the future.

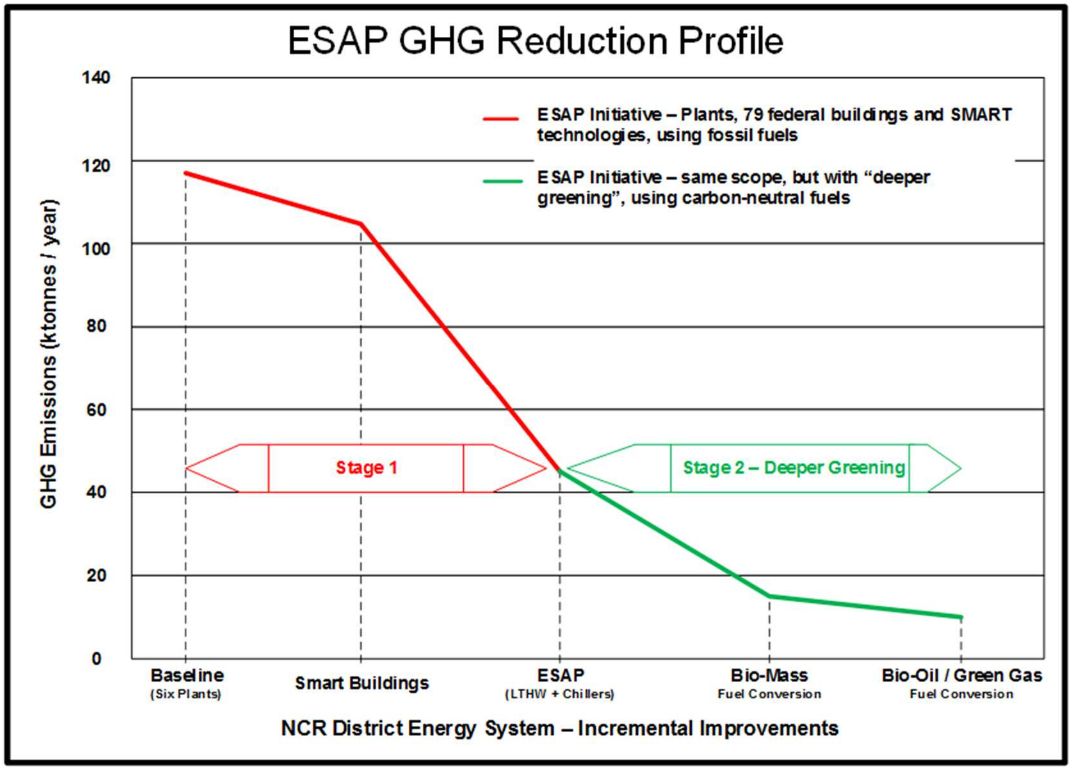
City of Markham, ON – Markham District Energy is a thermal energy utility owned by the City of Markham that developed two CHP DE systems[16] powered by multiple CHP units: Markham Centre, which serves the downtown core, and Cornell Centre, which serves the Stouffville Hospital and the surrounding area. The systems include 48.5 kilometers of piping which services more than 800,000 m^2 of commercial, residential, and recreational space.

Existing and Planned Systems in Ottawa

Zibi Sustainable Waterfront Community in Ottawa – will be built on former industrial lands on Chaudière and Albert Islands and the shores of the Ottawa River in Gatineau. It is being designed to meet the very stringent One Planet Community Plan requirements. It will include the development of a zero-carbon district energy system with a primary supply of low-grade waste heat sources from a local industrial process. Additional thermal sources being considered are biomass boilers, waste sewer heat, electric heat pumps, and free cooling from the river. It will also use zero-carbon electricity, procured from Hydro Quebec and through direct connection to the co-located Hydro Ottawa waterpower facilities. This development project is being created as a "campus" that has negotiated specific servicing and development provisions (for roads, heat, electricity, etc.) and has created a unique utility model. DREAM, Windmill, and Energy Ottawa are investing and collaborating with the development of Zibi[17].

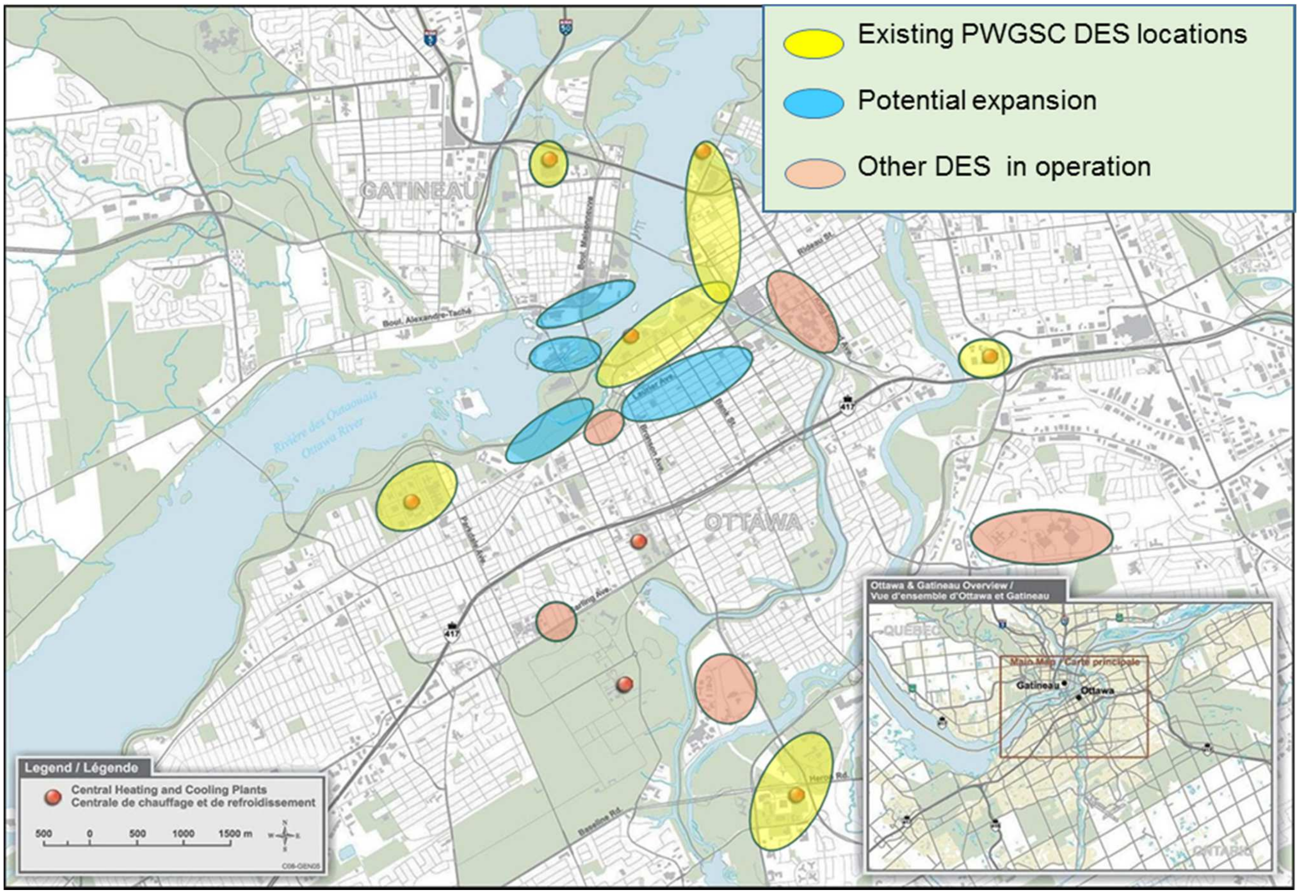
The Federal Government's Systems – the Energy Services Acquisition Program (ESAP) is modernizing its multiple DE systems, which provide heating and cooling services to over 80 federal buildings in the National Capital Region (>1.6M m^2 of floor space), accommodating 55,000+ occupants. Approval was given in December 2016 for a first phase of work, to convert the systems from steam to hot water (95°C), which will improve efficiency by at least 25%. The primary fuel will continue to be NG for heating, with conversion of the cooling supply to high efficiency electric chillers. A proposed second stage is estimated to start in 2025 to convert the heating supply to carbon-neutral fuels such as biomass, biogas, or bio-oil. Preliminary analysis and pilot work on the fuels and the conversion options are also underway in the first stage. Figure 2 shows ESAP's prediction for GHG emissions reductions in relation to each stage. Later stages may also involve increasing the number of government buildings on the network, and expansion to non-government buildings, which is a high leverage opportunity for Ottawa. For the latter, consultation and development of the business case is currently underway.

Figure 2 - Estimated GHG reductions for the Federal Government's DE systems in the National Capital Region.



Other DE Systems in Ottawa – Four of the larger systems in Ottawa, all based on NG boilers, as shown in Figure 3, are at: the University of Ottawa, Carleton University, the Civic Hospital, and the campus of the General Hospital and Children's Hospital of Eastern Ontario. An example of a smaller system owned by Centretown Citizens Ottawa Corporation (CCOC) is located at Beaver Barracks, serving the 5 buildings on that site with a geo-exchange supply[1]. Algonquin is presently developing a small distribution network with CHP on their campus.

Figure 3 - Map of urban Ottawa with approximate locations of existing DE systems and potential regions for expansion of Government of Canada systems, figure care of ESAP[18].

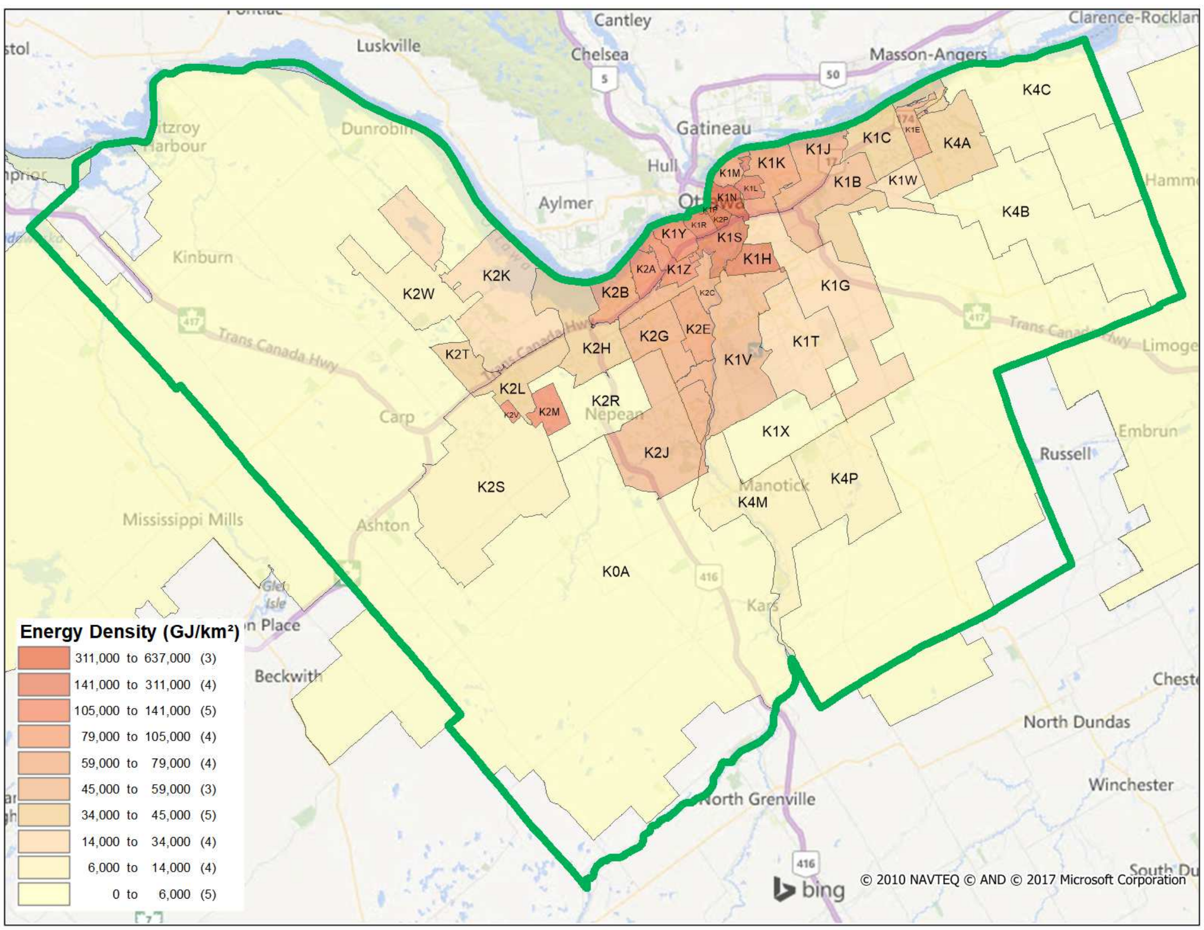


Energy Mapping

Mapping Using NG Consumption Data

Assessment of the potential for development and expansion of DE systems to service a broad range of residential and commercial buildings requires the analysis of the thermal energy needs and intensities of neighbourhoods in Ottawa. Since NG constitutes more than 90% of the present thermal energy service, the analysis undertaken herein uses NG consumption, as provided by Enbridge Gas for the year 2015. Data was provided by postal code and further identified by one of four account types: residential, apartment, commercial and industrial. For privacy reasons, Enbridge provides only the first three digits of the postal code, or forward sortation area (FSA) code, for large users that could be otherwise be directly identified if their full postal code was provided. This report uses this three-digit FSA granularity. If an FSA has less than five accounts, privacy is further protected by not providing postal code information at all and thus these users could not be included in the mapping exercise at all (the rolled-up sum of consumption for these users amounted to 6% of the total consumption). The impact is that some large industrial and commercial users are omitted in the mapping exercise. Furthermore, the K1A postal code is particularly problematic, as it applies to the Parliament Hill precinct but also other federal buildings (including Tunney's Pasture, Booth St., the National Research Council buildings on Sussex Drive and Montreal Road, and buildings in Gatineau) most of which are part of the federal DE systems; the K1A code has been avoided in this analysis. Thus, this analysis serves to examine DE systems in the context of broader multi-user networks as opposed to the high usage campuses and existing DE systems.

Figure 4 - Energy density map for the municipality of Ottawa, as undertaken using NG consumption data provided by Enbridge on a per postal code basis. These are totals for the year 2015.



The units of the map are GJ/km^2 per year, where the denominator is the area of the FSA, thus it provides the *average* values of energy use across the broad area. Realistically, DE system deployment will get built to serve only a portion of such a broad area, and later in this report, when future scenarios are assessed, estimations are made of the percentage of buildings (by type) that would likely connect to the DE system, per FSA. The advantage of this NG consumption approach is that it can be processed quickly over the entire municipality to provide the actual total energy available as an upper limit. Its disadvantage is that the privacy rules remove some of the bigger uses and it has a low spatial resolution.

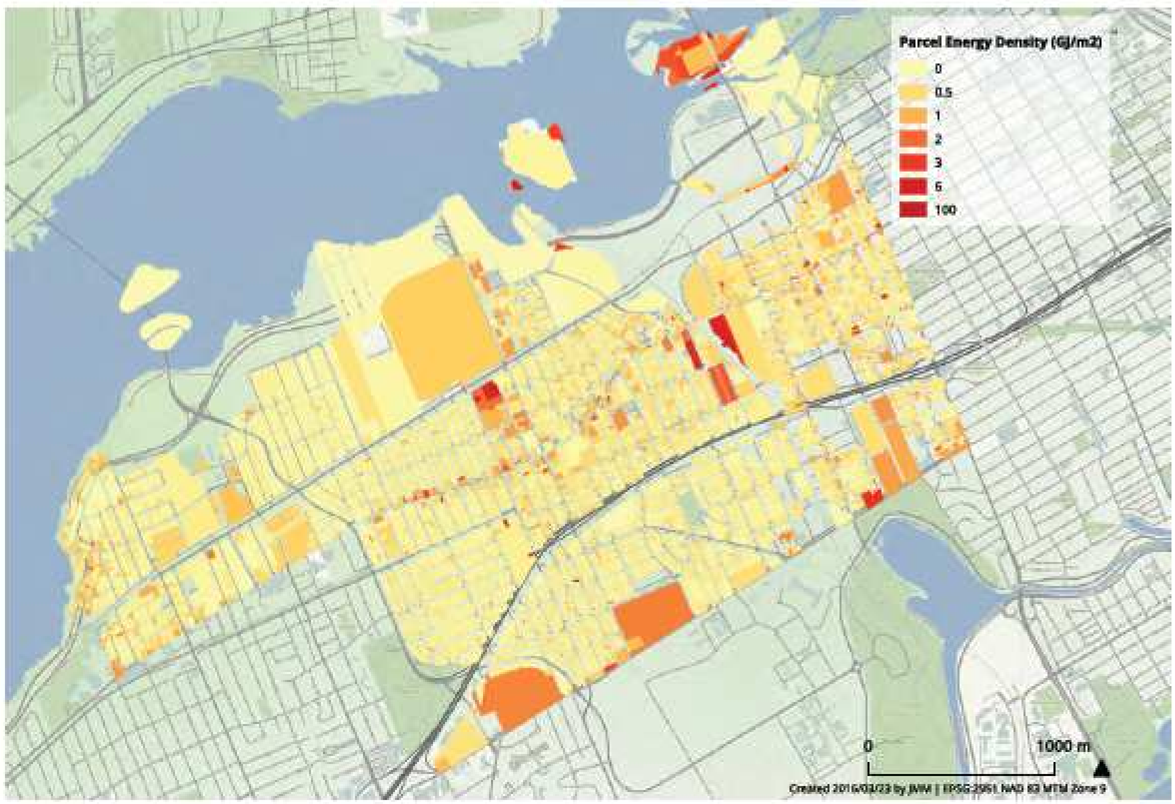
Mapping Using GIS and Building Archetypes

During the development and evaluation of energy mapping methods (Plan4DE and SMORES), Sustainable Solutions Group and Canmet Energy[7,19] decided to use a region in urban Ottawa as a case study; the work included the development of the energy intensity map shown in Figure 5. These methods are based on GIS data of building footprints combined with an estimation of energy intensity[5,7,18] using approximation energy use by building type. The units are annual GJ/m^2, where the dominator is the parcel area. The map can clearly help to visualize smaller target areas for DE systems.

Accuracy of Heat Maps

It is important to note that all modeling efforts are inaccurate compared to the reality, but the degree of accuracy can vary, as is briefly discussed in Appendix A. These maps and data are intended for use only during the very early stage analysis of “pre-pre-feasibility”. Obtaining actual descriptions of buildings and their energy demand data would be required to move through feasibility and economic analysis of candidate DE systems. Once the DE system feasibility studies are underway, the economics of a DE system are often evaluated with a different metric, that being the energy load served per length of pipe required in units of MWh/m or GJ/m.

Figure 5 – Energy use map from Plan4DE modeling of an urban area west of downtown Ottawa[7] which substantially overlaps with the K1Y postal code. Colour coding is of energy intensity of each parcel area.



Ottawa's Downtown EcoDistrict

The Ottawa Centre EcoDistrict undertook a brief survey in 2014[20] of buildings in the downtown core region extending from Wellington to Gloucester (5 blocks north-to-south) and Elgin to Bay (7 blocks east-to-west). Analysis included estimates of square footage of buildings. They found that up to 450,000 m^2 of potential floor space passed several criteria of relevance for potential connection to a DE system: interest expressed by owner, compatible heating systems, non-recent installation of new heating equipment, and minimum floor space of 1,000 m^2. This represented 47% of the estimated total area in that region. The study was an early examination towards the possibility for expansion of the Federal DE system into downtown.

SECTION 2 – GROWTH PROJECTIONS FOR DISTRICT ENERGY IN OTTAWA

Methodology of Pathway Projections

The future impact of district energy networks is defined by the available building energy needs and the energy supply technologies. Uptake is also greatly affected by constraints, including economical, regulatory and logistical, as will be examined herein. This section considers all these factors and develops projections of possible uptake scenarios, as well as some near-term opportunities for positively influencing uptake.

Constraints

Economics

Three key factors affect the economic viability of DE systems:

- the civic costs for construction, which vary by factors in the range of 2 to 4 times between new green field and downtown areas[5], and will have dependencies on landscape, ground/soil conditions and many other details;
- the energy intensity of the system, which can be expressed in area units (using either land area in units of GJ/km^2 or building square footage in MWh/m^2, or in linear units (of MWh/m, which is the amount of energy served per length of pipe);
- the cost of alternate fuel sources (if alternate fuel is considered) relative to the cost of NG; and
- the cost of NG, with lower prices favouring BAU choices.

In current conditions, many DE systems are economically viable against BAU. As a first brief point of reference, a phase 2 feasibility study[21] completed by FVB in February 2017 for a DE system in the City of Burlington was found to have an internal rate of return of 8 to 10% for systems that included NG CHP generation (unleveraged with a 4% discount rate assumed, and no outside funding incentives). Without CHP to provide electricity value, the IRR was 4%. It should be noted that the economic analysis included leveraging other infrastructure work also planned for the area (the retrofit and installation of deep utilities in the streets). Certainly, it is more economically attractive when the DE piping installation is integrated with the retrofit of a major municipal service, or a greenfield development.

As a second point of reference, considering systems in Canada that were operating in 2014[4] (and that used a hot temperature water supply), the median linear heat density was 4 MWh/m and the minimum was 0.4 MWh/m. Assuming a majority of the systems would be economically advantageous in today's market, this suggests a *very* rough economic feasibility in the range of 3-4 MWh/m.

This is in rough agreement with the 2012 study by CanMET[5] which found that systems with a linear heat density of 3 MWh/m and area heat intensities of the order of 113 kWh/m^2 were potentially viable – i.e. the levelized cost of the DE system (including capital costs) was similar to the BAU cost of energy. This study was conveniently done on an area of West Wellington and Hintonburg in Ottawa - this location was not based on particular motivations for this location for a DE system, but simply as a useful mixed-use test study. Figure 6, as adapted from the paper, provides a graphical overview of the scenarios in which a DE system is likely to be viable, depending on linear energy density and cost to construct. The orange curve in the figure represents the base-case analysis, and the five circled points on that curve are for the following regions (from left to right in the figure): a low-rise residential, a combination of region types, the Wellington Ave. linear commercial strip, a block of dense townhomes, and a dense commercial and condominium building at Holland Cross.

The analysis may not include all costs and financials of a full undertaking, such as all retrofit costs to buildings, replacement of high quality ground surface finishes, secondary costs of construction, or the impacts of partial uptake by the building owners, and is built on rough estimates of energy demand and optimal system design. Furthermore, the analysis had the assumption of continued use of NG. The use of other fuels, including biomass, are presently expected to be more expensive[22], which push the curves upward. Conversely, sources of waste heat may be less expensive, shifting curves downward into improved economic viability. A DE system with low-carbon supplies, if economically viable compared with BAU, is a low-cost method of carbon abatement (where viable is used in a general sense to mean lower, equal or even slightly higher cost, and which may also include long term – 20 to 40 year - horizons).

When evaluating the economics of potential projects, it may be important to consider the wider set of advantageous services and long-term investment advantages that are provided by a DE system[23], as have already been discussed.

Project Financing

A further economic constraint is the high upfront cost and need to create an energy service provider that is different than the building owner. There are generally three ownership models that have been used by DE systems worldwide and in North America:[21]

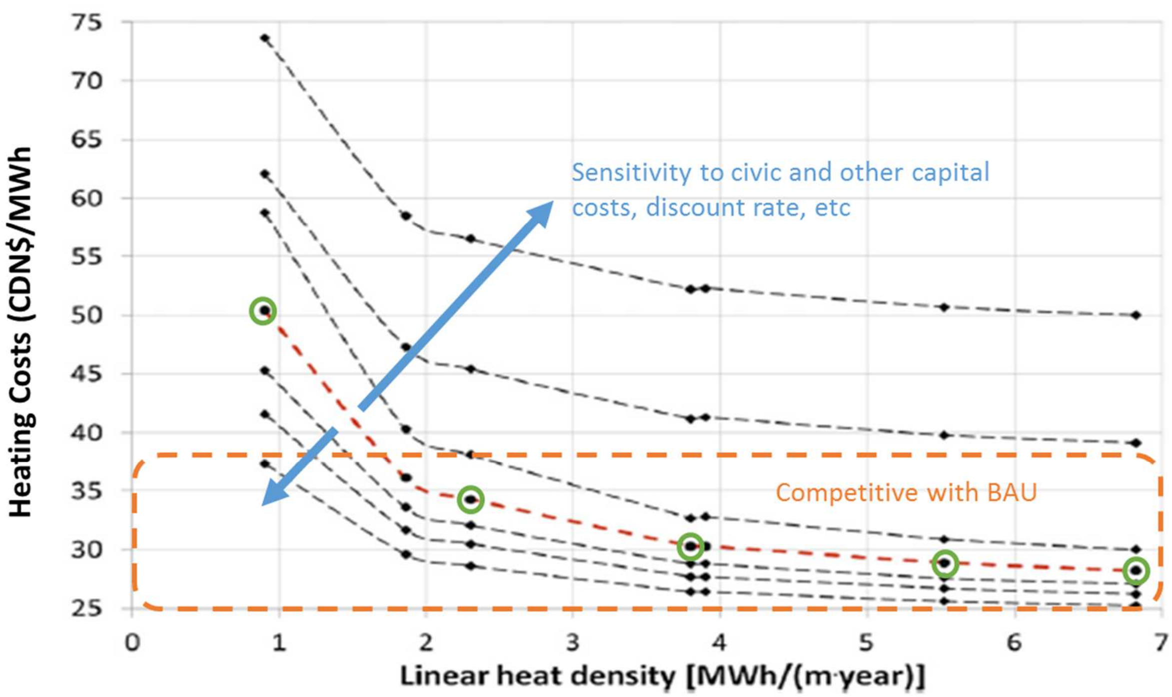
Public Sector – the City maintains the ownership. The City is well-positioned to influence expansion, long-term operation, and traditionally has been better positioned to carry long-term, lower interest type projects. Examples include Markham, Vancouver, Hamilton, etc.

Private Sector – a private developer takes the lead in the design and operation of the facility. As they seek an appropriate return on investment, the preference is either for high demand new developments of suitable size or the purchase of an existing DE system. Examples include Enwave (Toronto), Creative Energy (Vancouver), Veresen (London, Charlottetown).

Public Private Partnerships – a hybrid of the above ownership models. Examples include the Sudbury District Energy and District Energy Windsor.

To date, the main investors for DE facilities appear to be utilities, local government, senior government, and institutions. The shares for each of these investors are fairly similar (23 to 30% of facilities). The Drake Landing Solar Community created a not-for-profit organization as the owner and the operator of the solar district energy system, which involved a partnership between the municipal government, a utility company (ATCO Gas), the land developer and the home builder. Southeast False Creek is a designated neighbourhood with some unique bylaws and a special purpose utility developed by the municipality.

Figure 6 - High level economic viability study for a DE system in an urban environment. Adapted from Dalla Rosa[5].



Policy & Funding

A 2014 assessment of DE systems in Ontario has stated "While success stories in Markham, Guelph and Regent Park indicate that DE is no longer in a niche, the lack of public support – which includes citizens and government – is a limiting factor in its diffusion. This is not to say that it is being suppressed, but rather that it occupies a policy and regulatory void with respect to both community planning and energy planning."[3]

The implementation of a DE system with the other servicing for a neighbourhood can add one more degree of complexity into the planning process. The added time and risks have been barriers for development. Municipalities are starting to adopt policies that help support uptake[2,13,24] - the full range of policies is outside the scope of this analysis, but could be further investigated and discussed in the context of Ottawa opportunities. Furthermore, the planned release of the Ontario Long Term Energy Plan in Q3 of 2017, which is now expected to include thermal energy planning and also potentially integrate with initiatives from the Ontario Climate Change Action Plan, may provide a new set of supporting programs and funds for the development of DE systems.

In general, a key constraining policy is municipal approval for thermal energy pipes to cross a parcel boundary, pass under a road, or be placed under a park, as well as similar policies constraining crossings under rail lines.

In a 2014 survey of systems in Canada, the majority of systems have an estimated market value of less than $10 million, almost one-quarter are estimated at over $50 million[4]. DE systems have higher upfront costs than BAU, and possibly longer payback periods, thus various supportive financing policies that enable access to longer term and/or lower interest rate loans will be very advantageous to uptake. This can include municipal programs and the growing green investment market.

Several new policy and funding supports may develop in Ontario in 2017 and 2018: The Ontario Long Term Energy Plan is due to be released in the second half of 2017, as are opportunities through the Climate Change Action Plan and Green Investment Fund.

Carbon avoidance policies and financial incentives may also play key roles in moving the DE system into a more attractive business case for investors.

Local Development Capacity

Ottawa has a number of competent engineering firms with expertise in DE systems, as well as a solid number of institutional entities with long-term operating DE systems. Use of DE systems in the commercial and urban planning context is relatively new. Hydro Ottawa Limited is developing new business models in its partnership developments in the Zibi project.

Local Renewable Energy Supply Capacity

Biomass has the potential to be a major fuel source for achieving low-carbon DE systems. Presently, the costs of biomass heating may be more expensive than NG, but less expensive than other supply fuels[25]. Several government agencies are actively examining the opportunities to expand the forestry industry to supplying wood chips for heating sources, which could bring economic development advantages[26]. The Federal ESAP program is developing research specifically for biomass as a heat supply to their Ottawa DE system. There is substantial availability of biomass feedstock in Ontario, estimated at being able to sustainably provide 2 million tonnes of wood pellets per year[26], and wood pellets have an energy density for heating in the order of 17 GJ per tonne[25]. Thus, there is the approximate resource availability to provide 34,000 TJ, which is more than half of Ottawa's 2015 NG usage. The GHG emissions of wood pellets are reported to be 80% lower than NG (emissions are mostly related to transportation and processing). A detailed analysis of biomass as a supply option was outside of the scope of the present report, but is recommended for future work.

There are likely a certain number of waste heat supplies that may be available in select locations in Ottawa – a detailed study of these opportunities is also recommended.

The use of geothermal energy (also known as ground-source heat pumps) has been proven in practice for small to medium DE systems, and will only be constrained by site specific details and economics relative to other choices. The Pathway Study on Heat Pumps in Ottawa also identified that recent cold-climate air-source heat pumps may find opportunities for attractive economics as a partial supply, in particular with low-grade waste heat supplies and use of electricity in off-peak and other low market prices times available to large users.

Intermittent renewables (solar photovoltaics, solar thermal, wind) are likely to only constitute some portion of the mix unless high levels of storage are included. There is an extensive opportunity to place solar PV systems on rooftops, as detailed in The Pathway Study on Solar Power in Ottawa, and the development of grid competitive prices suggests that they may form a useful portion of a low carbon supply portfolio.

Uptake Projections

A first stage of this preliminary study, is to obtain an estimate of total energy that could potentially be connected to a district energy system. The assumptions developed here will become the aggressive scenario for uptake, where variables are denoted in **bold purple** font.

This analysis is undertaken using the postal code information. As a first step, a threshold for a minimum energy density in an FSA is set to 100,000 GJ/km^2. This threshold level eliminates the areas which are predominantly low-rise residential homes. Generally, FSAs with energy intensities greater than 100,000 GJ/km^2 were found to include commercial, apartment and residential sectors, with the split in NG consumption between the three sectors showing a median of 47, 17, and 36%, respectively. FSAs with lower energy intensities were dominated by residential and are expected to be less viable locations for DE systems. The list of priority postal code areas that are above the threshold are listed in Table 1.

Table 1 - NG consumption in the top postal code areas of Ottawa.

Postal Code FSA	Natural Gas Consumption (m^3)			Area (km^2)	Energy Density (GJ/km^2)
	Comm.	Apart.	Res.		
K2P	13,588,000	10,542,000	3,764,000	1.63	637,000
K1P	15,597,000	-	-	0.99	585,000
K1N	22,019,000	12,462,000	10,345,000	4.90	340,000
K1R	15,072,000	4,747,000	9,118,000	3.47	311,000
K1H	30,103,000	1,269,000	11,612,000	7.17	223,000
K1L	6,177,000	3,641,000	7,578,000	3.57	181,000
K1S	11,927,000	2,820,000	20,919,000	9.28	143,000
K1Y	13,402,000	1,212,000	12,883,000	7.26	141,000
K2V	2,883,000	-	1,512,000	1.30	126,000
K2A	5,798,000	3,292,000	10,502,000	6.27	116,000
K2M	1,922,000	-	19,263,000	7.30	108,000
K1Z	7,874,000	4,644,000	10,000,000	7.96	105,000
K2B	6,790,000	12,809,000	10,542,000	11.08	101,000

It is worth repeating the note that the K1A postal code and certain very high energy users are not included in the above table, thus existing DE systems at federal government and other campuses are for the most part not included in these numbers; this is as it should be for the purpose of examining the growth of DE systems to service more buildings across Ottawa; the analysis is inclusive of *growth* of federal DE systems to serve a broader set of customers.

It is assumed that the DE systems will be able to service up to **80%** of commercial and apartment customers in each targeted FSA, but only **20%** of low-rise residential homes (likely only those that are close to the denser areas).

DE systems are then assumed to be implemented over time, starting with areas with the higher energy intensities (for example starting with FSA K2P and K1P) then moving to areas with lower energy intensities (for example the areas represented by FSA K2B would be the last area to see district energy implementation). In terms of progress with time, a simple approximation is made that the DE systems in each FSA are developed at an even pace over a ten-year period.

It is also considered that new development in the city may connect to DE systems. Using information from City resources[27], new building growth in the commercial, apartment and residential sectors are assumed to be 0.5, 0.6 and 0.3% per year, respectively (these rates remain the same for all scenario projections). These are averages for the city, and for the present analysis not assigned to specific regions. It can be assumed that a majority of the growth is outside the FSAs of Table 1, and in less dense development practices, thus lower uptake rates will be used here. It is assumed that **20%** of new commercial and apartment buildings will be connected to district energy systems, while only **15%** of new residential will connect.

Finally, it is considered that the DE systems can either be served by NG, or by low-carbon supply. A simple assumption of a steady conversion rate over time of the entire set of DE systems is employed, up to a maximum non-carbon supply of **70% of the entire portfolio of DE systems**. From this, the quantity of NG displaced (no longer used) can be calculated, as well as the associated GHG reductions in kilotonnes of carbon dioxide equivalent ($ktCO_2eq$). Achieving this target will need the support for low carbon energy technologies from multiple levels of government and DE system designers that consider several energy supply opportunities.

Scenarios

The possible development paths for new or expanded DE systems in Ottawa are challenging to quantify; three general scenarios have been developed that project to 2050, in relation to the calculation methodology described above and the assumed uptake values (all noted in purple font):

- The “conservative” is the most pessimistic, assuming that policies that constrain multiple-parcel networks remain, funding and loan mechanisms do not develop and/or do not remain in place long enough relative to development cycles. Furthermore, the cost of NG remains very low (due to market prices and low carbon prices), which undercuts the opportunity for low carbon networks. This scenario uses inputs for uptake that are one fifth (⅕) of the values described above.

- In a moderate uptake scenario, policy adaptations are applied to a select number of new developments, and some incentives help to make low carbon supplies as viable as NG. This scenario uses inputs for uptake that are one half (½) of the assumed uptake values described above.
- In an aggressive uptake scenario, concerted effort is undertaken to integrate DE systems into development and planning of the City, and the full extent of the potential uptake described above is developed. Furthermore, carbon pricing and efforts to maximize a range of low carbon supplies results in 70% of the energy being supplied by zero carbon energy supply.

A summary of these assumptions is contained in Table 2.

Table 2 – Summary of the uptake assumptions for thermal load service provided by DE systems for three scenarios.

	Comm.	Apart.	Resi.	
Conservative Inputs				
% of existing buildings that are connected at max build-out	16	16	3	
% of new buildings that get connected	4	4	3	
% of DE service on low carbon supply at max build-out				14
Moderate Inputs				
% of existing buildings that are connected at max build-out	40	40	8	
% of new buildings that get connected	10	10	8	
% of DE service on low carbon supply at max build-out				40
Aggressive Inputs				
% of existing buildings that are connected at max build-out	80	80	15	
% of new buildings that get connected	20	20	15	
% of DE service on low carbon supply at max build-out				70

Projected outcomes for new energy generation, on five-year intervals between 2020 and 2050, for each of these three scenarios, are detailed in Table 3 and shown graphically in Figures 7 and 8. Figure 7 illustrates the total thermal energy service that would be provided by DE systems. Figure 8 illustrates the amount of NG that would no longer be required. The *cumulative* (cum.) aspect of the values is the total generation capacity that will be installed and in operation by the representative timeframe, and where capacity is an annual energy generation value in TJ/yr. In this analysis, a capacity of zero for non-campus DE systems in 2015.

Figure 9 provides an estimate of the greenhouse gas (GHG) emissions reductions that may be obtained assuming the emission levels for displaced NG are fully avoided by replacement with zero carbon sources.

Table 3 - Projected impact of future large-scale solar development for three different uptake scenarios.

	2015	2020	2025	2030	2035	2040	2045	2050
Conservative Scenario								
DE connected service (cum. TJ/yr)	0	17	240	690	1,100	1,300	1,400	1,500
NG Displaced (cum. TJ/yr)		4	60	180	300	390	460	500
GHG reduction (cum. kt CO_2eq/yr)		0	0	10	20	20	20	30
Moderate Scenario								
DE connected service (cum. TJ/yr)	0	42	590	1,700	2,600	3,100	3,400	3,500
NG Displaced (cum. TJ/yr)		10	170	580	1,000	1,400	1,800	2,000
GHG reduction (cum. kt CO_2eq/yr)		0	10	30	50	70	90	100
Aggressive Scenario								
DE connected service (cum. TJ/yr)	0	84	1,200	3,400	5,300	6,400	7,100	7,300
NG Displaced (cum. TJ/yr)		20	410	1,500	2,800	4,100	5,200	6,100
GHG reduction (cum. kt CO_2eq/yr)		1	20	80	140	200	260	310

Figure 7 - Projections of DE systems development, in TJ/yr of connected thermal energy service under conservative, moderate, and aggressive deployment scenarios.

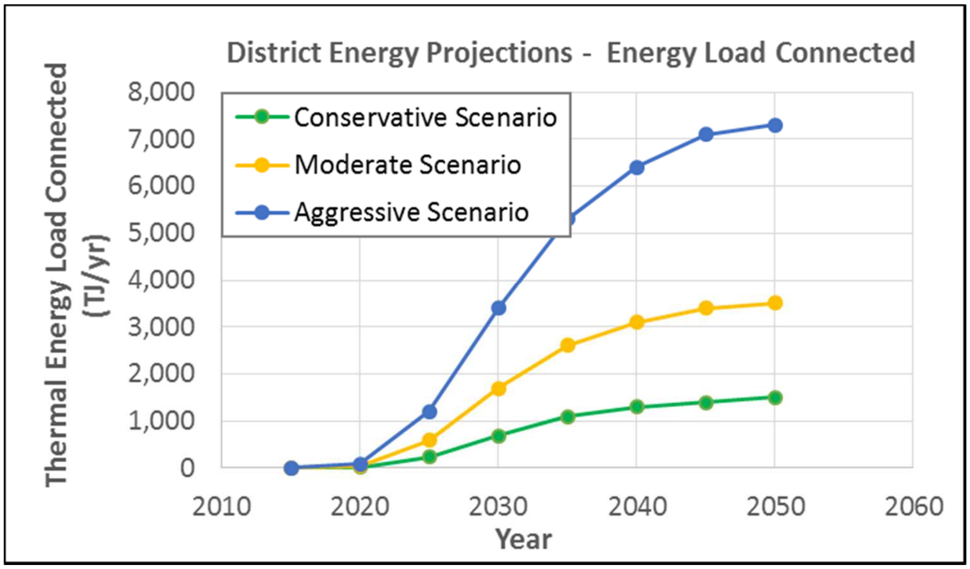


Figure 8 - Projections of the quantity of NG that would no longer be used in relation to the improved efficiency of DE systems and the partial conversion to low carbon energy supplies under conservative, moderate, and aggressive deployment scenarios.

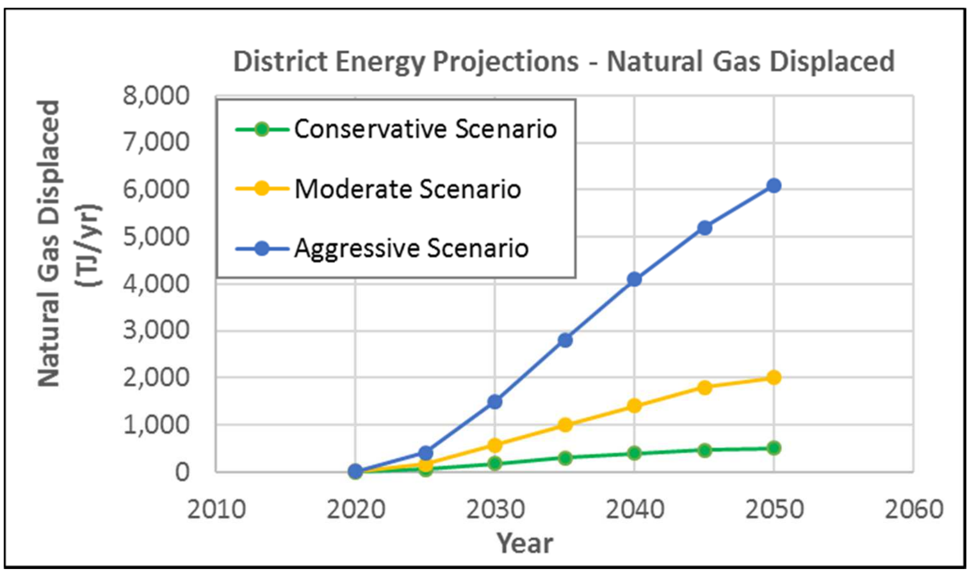
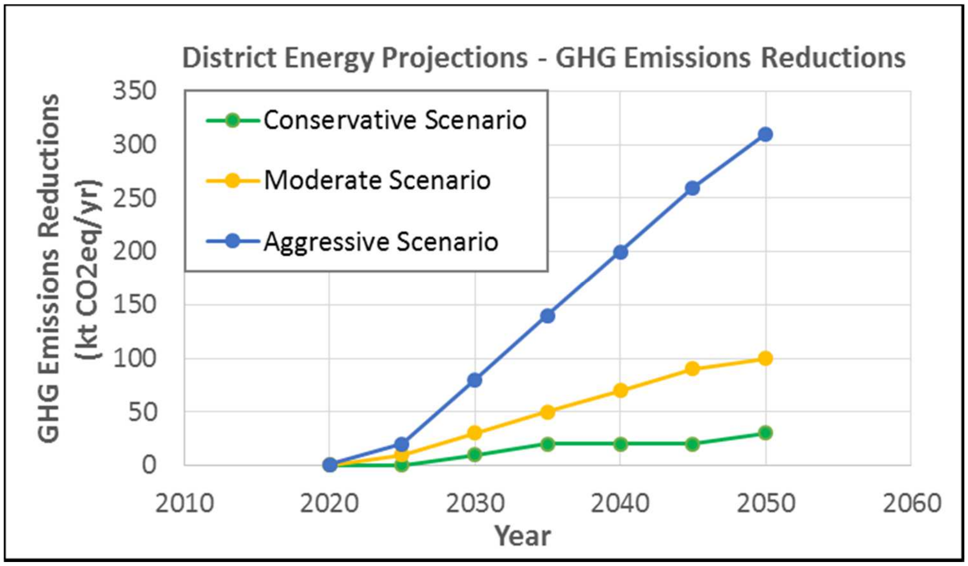


Figure 9 - Projections of GHG reductions that would be associated with the reduction of NG use in relation to DE system development under conservative, moderate, and aggressive deployment scenarios.



Opportunities to Advance DE systems

The City can have a substantive influence and role in the development of DE systems. This can be through multiple approaches, the full possibility of which is outside the scope of this Report[28], but can include:

- Community energy planning that considers the opportunities for alternative energy supplies and lower GHG footprints.
- Feasibility studies in neighbourhoods that have the potential for high density development.
- Collaboration of stakeholders to develop community capacity and a network of experts.
- Initiating a request for interest or request for qualification to assess the interest and ability of various parties to develop new DE systems and to provide services (including new owner/operator roles).
- Laying pipe in target locations for DE systems during municipal road re-work or deep utility infrastructure renewal.
- Addressing the capital financial requirements through multi-level government funding opportunities.

- Considering mechanisms to support the capital financial requirements, where investment is secured by the asset served not the asset owner directly, such as through these possible avenues:
    - green infrastructure and green bank programs offered by governments and by commercial investment sectors; and
    - private/public partnerships.
- Allowing thermal pipes under roads and other municipal right-of-ways to allow commercial DE systems to connect to other buildings.
- Developing localized by-laws in target neighbourhoods that require buildings to connect to the DE system. This could also include provisions for making future DE growth viable, by ensuring new buildings will be compatible with DE systems ("DE ready") via:
    - a hook-up capability; and
    - internal heating systems that can work with low temperature DE supplies.
- There may be opportunities to support or advance small-scale DE systems relating to a small number of commercial buildings (as was done at Beaver Barracks[1]).

The development of a DE system is a large infrastructure investment, and the stages must necessarily start with more extensive studies of feasibility for target regions, with tasks that would include:

- A scan of waste heat sources in particular looking at the waste heat from major sewer lines, such as the one that runs east near the Wateridge development in Rockcliffe.
- A more robust analysis of current and planned building energy use density should be undertaken, with leading opportunities further developed into phase 1 and 2 feasibility studies.
- Examination of biomass supply capacity and approximate costs in and around Ottawa (present and future) should be undertaken.
- Early feasibility studies of a select number of candidate locations, from which the most attractive are further examined.

Catalyst Projects

- Expansion of the Federal Government's DE systems to other sectors, which might include municipal buildings, commercial areas, and dense residential areas.
- Large new developments should potentially consider DE systems. The Lebreton Flats, Gladstone Village, and Wateridge developments may be excellent candidates due to numerous factors including: substantive re-development, a high density of condos, mixed use neighbourhoods, and site specific opportunities such as:
    - Waste heat from the planned hockey arena at Lebreton

- Significant intensification: Gladstone area – advantages include long-term property management by Ottawa Community Housing, interconnection to other DE systems (new Civic Hospital, Lebreton Flats), and other major load centres (Plant Recreation Centre, Little Italy's ongoing densification)
- Proximity to large institutions as other users: Wateridge Village (former Rockcliffe Base) – main sewer line waste heat, connections to Montfort Hospital and National Research Council Montreal Road campus.

- Smaller scale interconnection of multiple buildings to a common energy supply in higher density new developments around the City.

APPENDIX 1 - ACCURACY OF HEAT MAPS

It is important to note that all modeling efforts are inaccurate compared to the reality, but the degree of accuracy can vary. The downside of the NG consumption by postal code data[5] is that postal codes are not 100% tied to an exact geographic region, such that a percentage of properties may be outside the code's designated boundary. Also, only monthly or annual values are provided by the utility. An advantage is that it is the actual energy usage, and does not rely on approximations. The GIS + building archetype approach may be better for a high-resolution analysis of neighbourhoods or per building intensities, but the method may still carry substantial uncertainty due to the use of average or archetype descriptions of building demand. A report of energy modeling methods to the IEA found that the two models differed by 50%, while a collection of six different modeling methods showed a standard deviation of 32%[19]. It is also worth noting that neither approach included in this report addresses future growth and infill development, which can substantially change energy intensity. Though it sounds simple, a map of urban density (square footage per ground area) may be a quick approach to get maps that help to envision where DE candidate neighbourhoods could be considered.

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Pathway Study on Wind Power in Ottawa

Presented to:

The City of Ottawa
110 Laurier Ave W
Ottawa, ON K1P 1J1

In relation to
The City of Ottawa Energy Evolution Program

By:

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October 17, 2017

ABOUT THIS REPORT

City of Ottawa Energy Evolution Program

On July 8, 2015, Ottawa City Council approved the development of a Renewable Energy Strategy as part of the 2015-2018 City Strategic Plan. This initiative has been developed into a program entitled Energy Evolution – Ottawa's Renewable Energy Strategy. A main goal of Energy Evolution is to develop a baseline analysis of energy supply and demand within the City of Ottawa and assess options, in collaboration with community partners, for all such partners to advance energy conservation, energy efficiency and renewable energy generation within their respective areas of control and influence. The Energy Evolution program has interacted closely with community stakeholders from local utilities, the federal government and other government institutions, the development sector, academia, the non-profit sector, and the private sector at large. Leidos Canada was engaged by the City to support analysis in the energy supply domain, including research reports and facilitation of discussion with stakeholders.

The Purpose of this Report

This and other "Pathway Study" documents are focused technical notes describing how the specific energy technology may develop in Ottawa. The document considered the overall technical potential for implementation, and then further considered the constraints (economic, regulatory, etc.) that are likely to reduce uptake. It suggests opportunities to influence uptake rates and catalyst projects that may be attractive to consider further. Results of the Pathway Studies are intended to be used along with the Baseline Study of energy data towards an overall assessment of future energy strategies within the City of Ottawa Energy Evolution program.

A draft form of this Pathway Study was circulated to key stakeholders and experts in the topic during the summer of 2017. Meetings were also undertaken during this period, where these representatives contributed their insights and ideas towards the development of leading project opportunities in relation to the topic of the Pathway.

Other documents in this series are:

- Baseline Study on Energy Use in Ottawa in 2015
- Pathway Study on Waterpower in Ottawa
- Pathway Study on Solar Power in Ottawa
- Pathway Study on Biogas Power and Energy in Ottawa
- Pathway Study on District Energy Systems in Ottawa
- Pathway Study on Heat Pump Technology in Ottawa

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Key Units

MW — Megawatts is 1,000,000 watts, and is a measure of power, used here in the context of the power rating or the capacity of a generation facility. A typical wind turbine has an electrical power production of approximately 2 MW (at a predefined wind strength), which is equivalent to the power required to operate approximately 1,800 microwaves simultaneously.

TJ — Terajoules is a measure of energy, base unit of joules, and used here in the context of total energy delivered over one year. As a simplistic example, a wind turbine producing on average 1.5 MW of power for 100 hours will deliver 150 MWh of energy, which can be converted in to units of joules as 0.54 TJ.

kt CO_2eq — kilotonnes of carbon dioxide (CO_2) and other equivalent greenhouse gases, which is the common unit for quantifying the greenhouse gas emissions related to a process.

Pathway Study on Wind Power in Ottawa

EXECUTIVE SUMMARY

This pathway examined the opportunities and constraints associated with the development of wind turbine power plants that are grid-connected electricity generators. Wind Power generation has developed over the past eight years to become a meaningful percentage of the energy supply of Ontario, accounting for 6% of the annual electrical energy. Wind generation facilities (wind farms) are developed preferentially where the winds are strong, and the region of Ottawa possess a relatively low wind resource, making it less economically attractive than other locations. There are three wind generation facilities to the south and east of Ottawa (total capacity of 162 MW) where wind resources are comparable to that of Ottawa, and two of which will be selling power at less than $0.11/kWh. Progress in technology efficiency improvements and cost reductions continue to improve the competitiveness of wind generation on the electricity market. Development of a small number of multi-turbine wind farms within Ottawa are projected between now and 2050 under an aggressive scenario. Development is mostly hinged on economics and policies within the electricity market to procure or allow for third party procurement of distributed electricity. The development of a single or pair of turbines connected to distribution power lines and in more industrial regions can also be contemplated, including for technology demonstration and self-consumption. Overall, wind generation is projected to be a small contribution to energy needs of the city.

Wind Power Summary Table

Energy Type:	Local renewable electricity
Pathway Potential - cumulative to 2050, under an aggressive scenario (conservative and moderate scenario projections are contained in Section 2 of the report)	
Electricity Generation	200 MW (1,900 TJ)
% of Electricity Supply(1)	6%
GHG Reductions(2)	26 kt CO_2eq
% of GHG Emissions(3)	0.5%
Other Impacts:	Economic development through locally developed projects and development of expertise.

(1) As a % of Ottawa's 2015 electricity usage (32,200 TJ), as per the Baseline Study.
(2) Assumes the 2015 Ontario grid's average emissions levels.
(3) As a % of Ottawa's 2015 total emissions (5,200 kt CO_2eq), as per the Baseline Study.

SECTION 1 – PRESENT ASSESSMENT OF WIND POWER IN OTTAWA

Pathway Description

This pathway relates to the development of wind turbine power plants that are grid-connected electricity generators, a form of renewable energy (RE).

Pathway Boundaries

The pathway is focused on large-capacity wind generation for which the dominant type of equipment is large, horizontal-axis 3-blade turbines. Small-scale turbines of many designs exist, but are not in common use and do not have a proven return on investment[1]. They may have some applications in off-grid and other niche uses, but such opportunities are not expected to develop into substantial magnitudes of energy generation in the next 20 to 30 years, and therefore are not included in this pathway.

This Pathway only quantifies wind projects within the municipal boundaries of the City of Ottawa but, for context, it has been relevant to discuss the wind opportunity in Eastern Ontario.

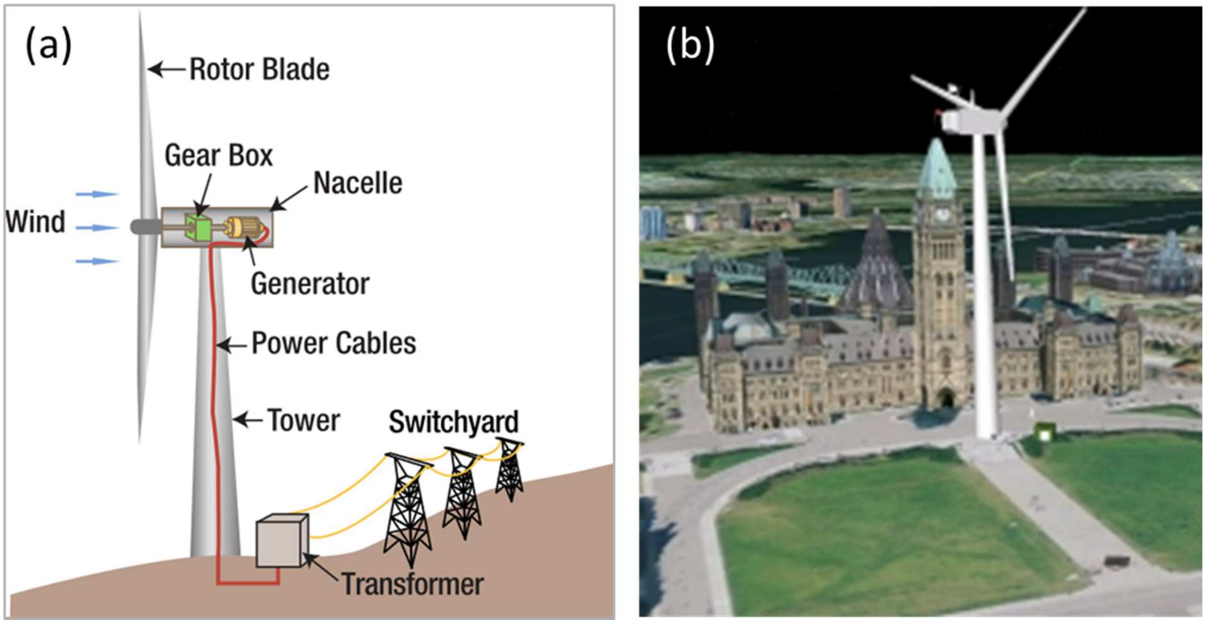
Background

Large or utility-scale wind projects, or wind farms, have been deployed across Ontario over the past ten years as a response to the favourable tariff rates offered in the Renewable Energy Standard Offer Program (RESOP) and the Feed-in Tariff (FIT) programs. A wind project typically consists of several turbines grouped together on open land, each spaced apart by somewhat regular distances, with the possibility for land in between the turbine tower being used for agriculture or other purposes. A picture from the South Branch Wind Farm is provided in Figure 1. The term "wind farm" is commonly used to mean harvesting of the wind, with or without co-located agriculture. Projects with one or two turbines do exist also.

Figure 1 – Image from the South Branch Wind Farm in Brinston, Ontario, care of EDP Renewables[2].

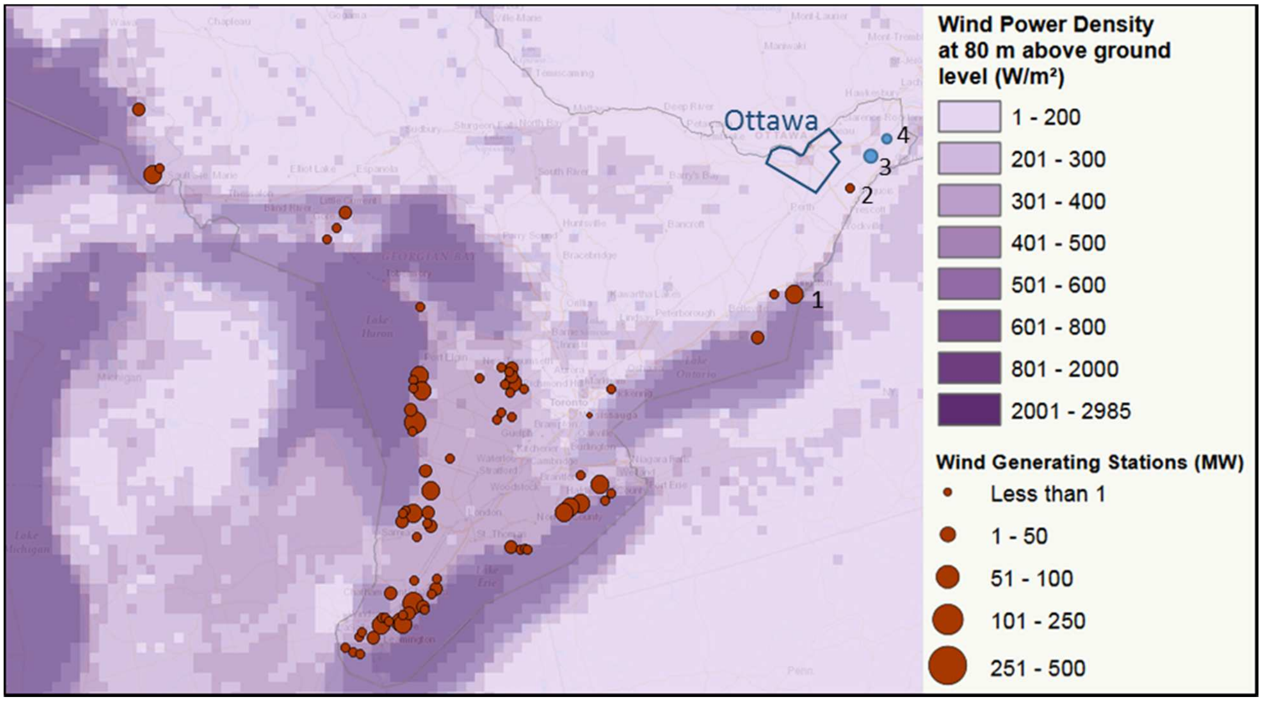
The large majority of turbines have been “horizontal axis” with nameplate power ratings typically in the range of 1.6 to 2.5 MW, with newer projects moving towards 2.5 to 3.5 MW turbines. Ontario is one of the largest wind markets in Canada, with 3,983 MW installed, which represents 11% of the supply capacity[3]. As illustrated in Figure 2(a), the blades are connected through a gearbox to a generator located within the “nacelle” at the top of the tower from which the electricity generated is conditioned and made suitable for connection to high voltage grid lines. Because wind speeds increase with the height above the ground and because there are fixed costs associated with each deployed turbine, wind turbines tend to be very tall, with main tower heights in the range of 80 to 130 m, and blade lengths in the range of 40 to 60 m; a comparison to the Parliament of Canada’s Peace Tower (92 m tall) is provided as a point of reference in Figure 2(b).

Figure 2 - (a) Diagram of the major components of a wind turbine, from Wikimedia Commons[4], and (b) graphical representation of a 100 m tower wind turbine next to the Parliament of Canada's Peace Tower[5].



The power that can be generated by a wind turbine is a non-linear function of the speed of the wind, where power output is proportional to the cube of the wind speed. Power output is also limited to certain minimum and maximum speeds at which the turbines operate well. This is a very different relationship than solar (where photovoltaic power production is linearly related to the power of the sun). The impact of the cubic relationship is that power production of a turbine varies dramatically with location, and locations with relatively small decreases in wind strength can be non-economic locations for wind development compared to neighbouring regions. In Ontario, the majority of the wind developments are next to the Great Lakes, as can be observed from Figure 3, care of the Map of Clean Energy Resources and Projects in Canada[6], put out by Natural Resources Canada.

Figure 3 - Map of wind resource strength (purple shading) and wind farm locations (brown dots)[4], with the addition of two new projects under development in 2016-2017 (blue dots). Details of numbered projects are provided in Table 1.



Wind Generation in Eastern Ontario

As can be observed in Figure 3, there are only a small number of wind farms in proximity to Ottawa, but none within the municipal boundaries. Details on the four nearby wind farms, as numbered in Figure 3, are provided in Table 1. One of the largest nearby farms is on Wolfe Island, in Lake Ontario near Kingston, which consists of 86 turbines with a total capacity of 198 MW. An installation of ten 3 MW turbines is located closer to Ottawa in Brinston, and two new farms (blue dots) are in the process of being developed in eastern Ontario under round 1 of the IESO Large Renewable Procurement process (LRP1)[7].

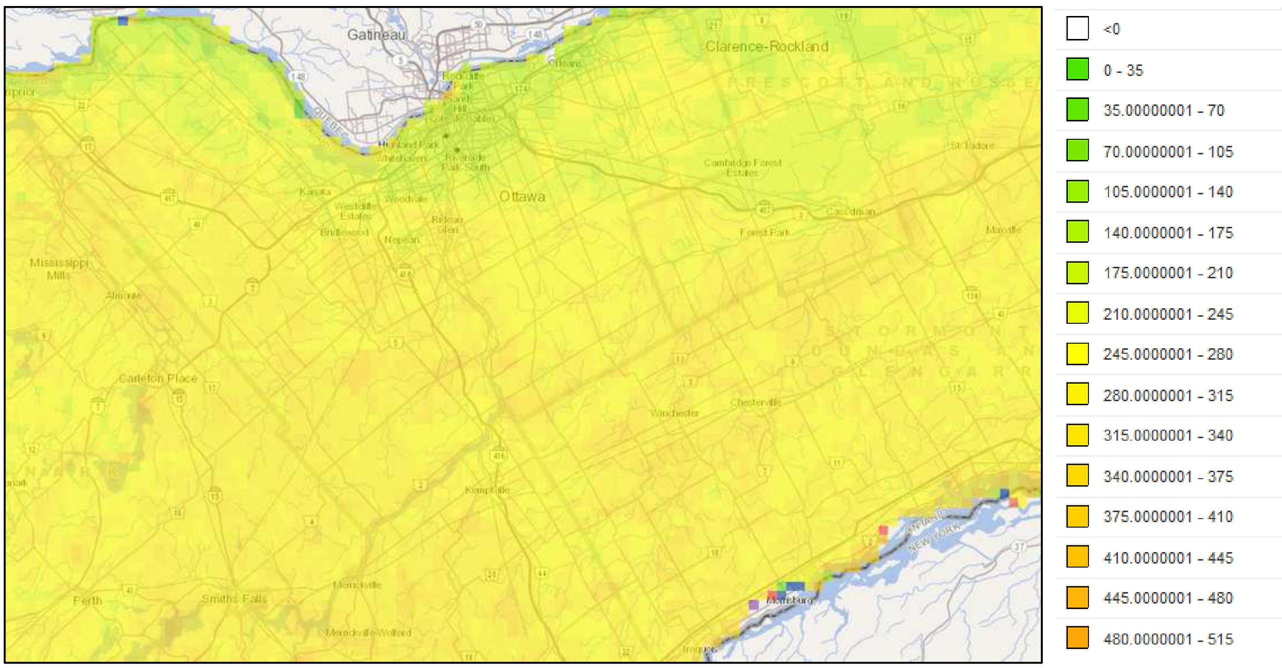
Table 1 - List of utility-scale wind farms found in Eastern Ontario in 2017. None are within the municipality of Ottawa.

	Location - Project	Capacity in 2016 (MW_{ac})	Estimated Annual Energy[(1)] (TJ/yr)	Developer (Owner if different)	Power Purchase
1	Wolfe Island	198	1,700[8]	TransAlta/ Canadian Hydro Developers	unknown
2	United Counties of Stormont, Dundas, and Glengarry, ON (Brinston) - South Branch Wind Farm	30	328[9]	EDP Renewables	unknown
3	North Stormont - Nation Rise Wind Farm	100	945	EDP Renewables	2016 LRP1
4	St. Bernadin - Eastern Winds	32	300	RES	2016 LRP1
(1) Energy production values derived from project websites where references are given, or are estimated using an approximate capacity factor of 0.30, which is the average from the two farms with production values.					

Wind Resource in Ottawa

The purple colour shading in Figure 3 shows wind power potential across southern Ontario, indicating that Eastern Ontario in general has a low wind resource. A higher resolution image of wind power in Eastern Ontario is given in Figure 4 – it provides a better illustration of local variations. Localized geographic features, such as ridgelines, can cause microclimatic variations and that further influences exact placements and viability of projects, and during development ground-based wind measurement stations are deployed to confirm the resource. In addition to the projects listed in Table 1, a handful of other wind projects have been proposed in the wide area encircling Ottawa - from Carleton Place in the west, near Kemptville in the south and St. Isidore to the east. These are in regions with the slightly orange shading in Figure 4, as characterised by a wind resource in the 315 to 375 W/m^2 range. Presently, these proposed projects are listed as not proceeding, with some specifically due to failure to obtain a power purchase agreement (PPA) contract with the province[10]. Thus a general conclusion that can be drawn is that the wind resource in this area *has* been sufficient to host viable projects, at least in the case where long term PPAs at elevated tariffs could be obtained.

Figure 4 - Wind power in W/m^3 for Eastern Ontario at the height of 100m above ground, from the Ontario Ministry of Natural Resources and Forestry Renewable Energy Atlas.



Project Siting

Wind farms must go through an environmental approvals process, which includes meeting requirements for setbacks from other properties and buildings, Ontario's rules have a standard setback of 550 m from a dwelling, with some additional conditions and caveats for noise conditions[11]; a full discussion of these topics is outside the scope of this report. There have frequently been concerns and protests by local residents in the vicinities of wind farms, but the present approvals process in Ontario has not given municipalities the authority to prevent projects from proceeding.

The size of the turbines and the setback requirements mean that turbines are usually sited in rural areas. The price of land may be an influencing factor as well, such that projects are more likely to be developed at reasonable distances from city centres.

The magnitude of power produced at a farm necessitates connection to high voltage lines, and farms are typically developed within 10 to 40 km from an existing line, depending on project size. Most frequently, projects are connected to the 115 kV or 230 kV lines.

Project Financing

Wind farms have high upfront capital costs, with low operations and maintenance costs and no “fuel” costs. To date, projects have been financed when there is a secure PPA for the electricity produced. The RESOP and FIT programs are two example PPAs issued by the IESO for procurement into the Ontario supply mix. PPAs for RE generators larger than 500 kW were shifted from the FIT process into a newly developed Large Renewable Procurement[12]. The first round of the LRP, (LRP1) was opened in 2014 and concluded in 2016, the weighted average bid price for wind projects was $0.0859/kWh, with a range of $0.0645 to $0.1055/kWh. Included in this mix are the two projects presently under development in Eastern Ontario, as were further detailed in Table 1. At these prices, the cost of wind is within parity of the net cost of electricity to consumers. A second round of the LRP process was initiated, but then cancelled in September 2016.

Energy Production Profile

Wind is an intermittent source of energy, with a production profile in Ontario that has a small number of very high production hours, and an overall large variation in hourly production. The production profile includes nighttime and wintertime generation, which are good counterpoints to solar’s daily and seasonal profiles. But Ontario has recently (over the past 2 to 4 years) had a challenge with surplus baseload generation at night, which is likely to continue in the near-term. The intermittency of wind can be accommodated by curtailment (wind generation is turned down when not needed), and by dispatchable fossil-fuel or hydropower generation. These are options for low to medium levels of penetration of wind on the grid, but more advanced solutions are required for increased penetration.

The IESO already requires that all renewable energy generators with a capacity rating of 5 MW or more install reporting and control systems such that the IESO can signal the plant to reduce or “curtail” its output during periods that the grid has an excess supply.

New Advances

The price of wind energy has decreased significantly over the past decade[13] due to a number of factors:

- highly engineered blades, drivetrains and generators that are optimized for improved efficiency;
- improved design and deployment methods that allow for taller towers, which can access stronger and more stable winds, making both low and high wind resource locations more profitable;
- project development and supply chains have become more competitive and more efficient;
- wind farm operations have been refined.

These advances have also allowed for sites with lower wind speed resources to be economically viable. Moving forward, price declines will continue, but due to technology maturation, the declines will be at a more moderate pace[14] than previously and than solar photovoltaic technologies. Plants with integration of other technologies and grid-friendly services can mitigate penetration issues – this includes integration of solar, storage, curtailment, using curtailed power for renewable natural gas (hydrogen) generation, etc. These opportunities are already deployed in practice in select locations, and can further advance with market and regulatory reform, lower equipment costs and smart planning.

There are a large number of smaller wind turbine designs, in the range of 50 W to 300 kW, including small horizontal axis designs that are similar to big turbines, as well as vertical axis (egg beater style) turbines, and other novel designs. These have been deployed in small numbers as research and development (R&D) and demonstration projects, and but they have not presently taken off for commercial generation. R&D continues in this domain, and future advances combined with opportunistic deployments for integration into urban environments, such as windy rooftops and corridors, may develop into attractive considerations in the future. They also are of use for small scale off-grid power. But, substantially larger R&D efforts exist for optimizing standard large scale turbines, due to the immediate commercial opportunities for large scale power generation.

SECTION 2 – GROWTH PROJECTIONS OF WIND POWER IN OTTAWA

Methodology of Pathway Projections

The future energy that can be produced by wind generation facilities is defined by both the technology and wind resources, as ascertained in the previous section, but then the uptake is also greatly affected by constraints, including market, economical, regulatory and logistical, as will be examined herein. The section concludes by considering all these factors and projecting possible uptake scenarios, as well as some near-term opportunities for positively influencing uptake.

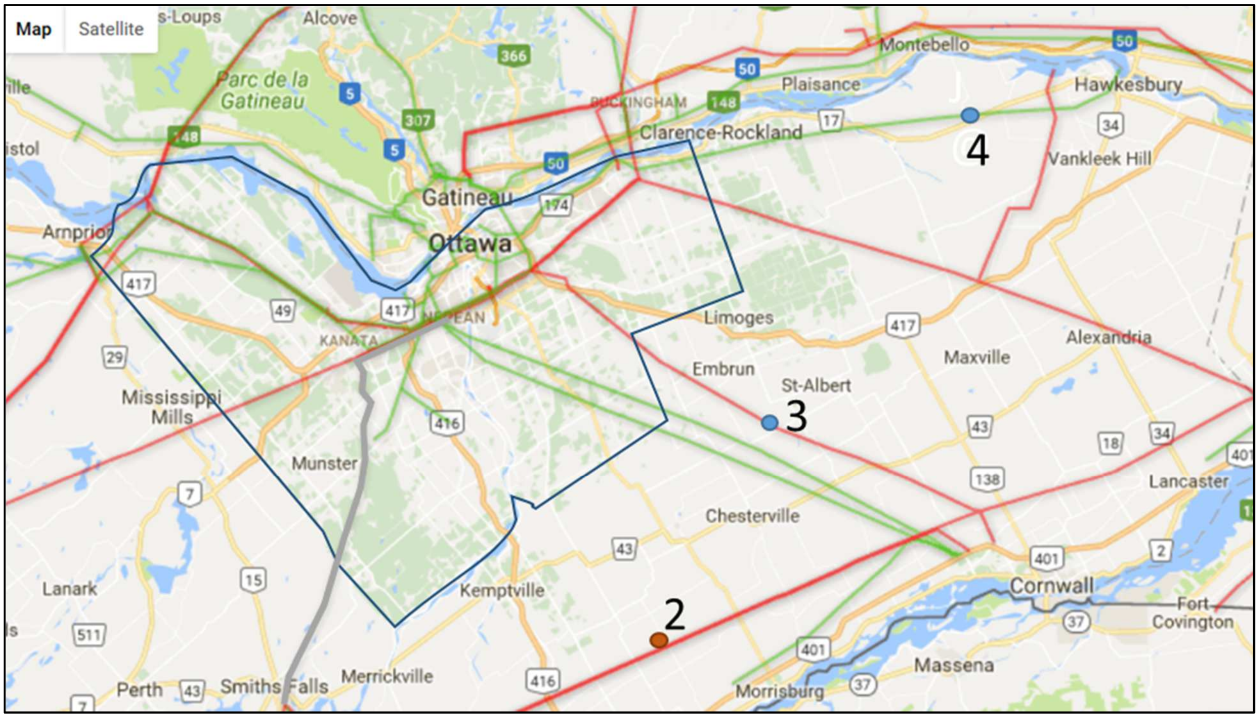
Constraints

Location Constraints

The absence of low cost rural land and proximity to a transmission line means that there are few locations within the City of Ottawa that will be attractive to the development of large scale wind farms. The larger the wind project, the larger the transmission line voltage and capacity will need to be. Projects with a small number of turbines may connect to the major distribution system lines. A map of the transmission lines serving Ottawa and Eastern Ontario are shown in Figure 5. Not shown on the map, new 230 kV lines are proposed for development in south Nepean and towards Manotick.

It should be noted that lower land costs and higher wind resources will likely enable more development of wind farms in regions bordering the municipality than within it.

Figure 5 - Transmission lines in Eastern Ontario, with 115kV lines noted in green and the 230 kV in red, and 500 kV line in gray, from the Canadian Electricity Association[15]. The three Eastern Ontario wind projects from Table 2 are also marked.



Grid Constraints

The capacity of electrical transmission lines to support connection of a new electricity generator is carefully assessed against total power flows and system reliability. It reassessed on a regular basis, depending on equipment upgrades and newly connected electricity generators; new generators reduce the capacity of the line they connect to and may prevent further projects. Capacity has been a limiting factor for some developments in Eastern Ontario.

These grid constraint rules are outside of the City's direct control and thus have not been researched in detail for this report. The present rules have the potential to be changed, with solutions that could include:

- detailed rule-sets that consider the hourly profiles of load and generation and may also be based on advanced grid stability studies;
- grid equipment upgrades; and
- grid operational methods that work in concert with smart plant controls, including storage, to deliver grid stability while allowing higher penetration of RE.

Furthermore, as overall levels of wind and other intermittent renewables are added to the provincial system, balancing energy and power of generation with load poses certain challenges that will need to be met with a range of solutions for grid modernization, which would include:

- a broad geographic spread for intermittent sources, which, when aggregated, provide a smoother net output than a concentration in one area. This may also include the aggregation of multiple technologies.
- plants that by economic design include reasonable levels of curtailment.
- advancements in the electricity markets and systems, such as more aggressive demand shifting (motivation: higher consumption during peak production periods and reducing it in periods of low production), integration of storage at the plant, and integration of storage on the grid.
- new levels of integrated planning of the interties with neighbouring grids, which may require adaptations to intertie capacities, technical balancing methods and market arrangements.

The technical merits and costs of implementing such solutions are complex and require consideration of how consumption profiles and generation resources in both local and neighbouring jurisdictions may vary in the long term. A range of studies have[16,17] and will continue to contribute to future strategies.

Market Constraints

The most common type of PPA for a wind farm in Ontario has been a contract with the IESO, but in the very near term, with IESO's cancelling of the LRP process, there are no known upcoming offerings of new PPAs for large plants. The IESO forecasts that there will be an oversupply of contracted generation (all types) in the province until 2021 or 2022[18]. This assessment is dependent on many factors and may change quickly depending on technical, political and policy reasons. Provincial PPAs are bound to be re-issued in the future, but likely at pricing competitive with market prices. Though generators can consider selling on to the spot market, the wind resource available in Eastern Ontario will likely not be competitive with Ontario spot market pricing for an extended period of time, until there is sufficient movement in the decreasing wind pricing and increasing electricity prices.

Alternative types of power sales mechanisms are expected to start to grow. There may be opportunities to access sales at prices in the retail range, or use a combination of sales into the provincial spot market along with other "added value" revenue streams. Many of these mechanisms are common to other renewable generation technologies, and are listed briefly here:

- virtual net-metering;
- community choice aggregation (similar to net-metering);
- direct sales to a major consumer, such as the Federal Government;
- difference contracting between two parties; and
- renewable energy credits and carbon emission avoidance credits as adders that help turn a marginally viable project into a viable one, such as the model employed by Bullfrog Power.

Uptake Projections

Scenarios

The current expectation is that there is only a low potential for wind generation within Ottawa, and that uptake will consist of a small number of discrete projects rather than a continuous growth. It is not feasible to predict the size of these projects, as large projects with many turbines may be more economic, but niche local opportunities may support the development of small projects. Leidos has developed three possible scenarios for future uptake between now and 2050.

- The “conservative” is the most pessimistic, assuming that there are no market mechanisms or innovations that provide well-priced PPAs for wind in marginal locations, leading to few development opportunities. A small project of 1 or 2 turbines may be developed for a total capacity of 10 MW.
- In a moderate uptake scenario, in the medium term, there are improved market mechanisms that can sell electricity at consumer-level prices, allowing for 1 to 2 wind farms to be developed relatively close to the municipal boundaries, with a total capacity of 100 MW.
- In an aggressive uptake scenario, there would also be a re-emergence of supply needed in the Ontario supply mix, such that PPAs for wind are offered. This would encourage the development of twice as much capacity as the moderate scenario, or 200 MW.

Projected outcomes for new energy generation, on five year intervals between 2020 and 2050, for each of these three scenarios, are detailed in Table 2 and shown graphically in Figure 6. The *cumulative* (cum.) aspect of the values is the total generation capacity that will be installed and in operation by the representative timeframe, and where capacity is an annual energy generation value in TJ/yr.

Figure 7 provides an estimate of the greenhouse gas (GHG) emissions reductions that may be obtained assuming wind production displaces electricity from the Ontario grid, and assuming the 2015 average emissions levels of the Ontario grid[19]. This is a rough estimate, since future emissions values and marginal offsets may be different. Since Ontario's electricity generation consists of mostly low carbon supplies, the GHG emission reduction value of wind power and all other renewable electricity generation technologies are low.

Table 2 - Projected impact of future wind development for three different uptake scenarios.

	2015	2020	2025	2030	2035	2040	2045	2050	Total New
Conservative Scenario									
MW new	0	0	0	0	10	0	0	0	10
TJ/yr new	0	0	0	0	90	0	0	0	90
TJ/yr cum.	0	0	0	0	90	90	90	90	
Moderate Scenario									
MW new	0	0	0	0	50	50	0	0	100
TJ/yr new	0	0	0	0	470	470	0	0	940
TJ/yr cum.	0	0	0	0	470	940	940	940	
Aggressive Scenario									
MW new	0			60		60	80	0	200
TJ/yr new	0	0	0	570	0	570	760	0	1,900
TJ/yr cum.	0	0	0	570	570	1,140	1,900	1,900	

Figure 6 - Projections of wind farm generation in TJ/yr under conservative, moderate, and aggressive deployment scenarios.

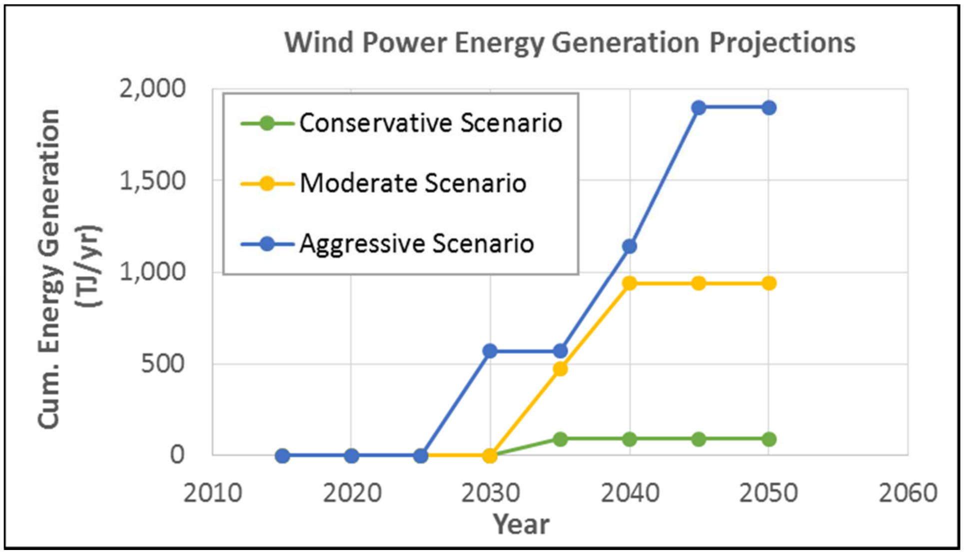
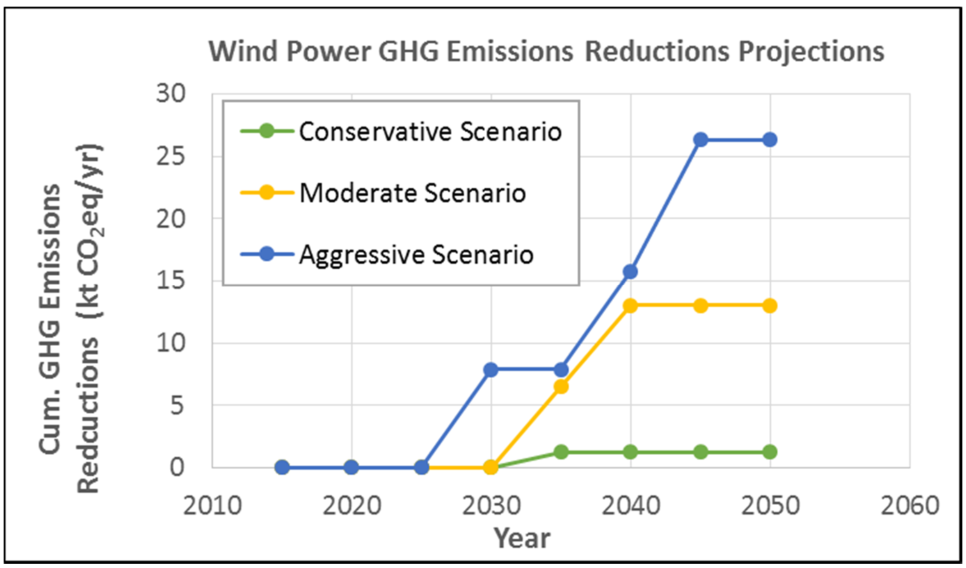


Figure 7 – Projections of greenhouse gas emissions reductions that may be realized, assuming the wind generation displaces Ontario grid electricity.



Opportunities to Advance Wind Power

- The City likely has very little direct authority to enable wind farm development, while the power available to the municipality in approving or rejecting support for wind projects is unclear and may be changed by the province.
- Best public support is obtained when project development involves local ownership. Should favourable economic conditions materialize, development partnerships between private developers and Energy Ottawa, Ottawa Renewable Energy Co-op, and/or other community partners could be pursued.

Catalyst Projects

- Potential locations for small wind farms consisting of 1 or 2 turbines, connecting to high voltage *distribution* lines (e.g. 24 kV) may exist at or near facilities situated in the Greenbelt, such as near the National Research Council's wind tunnel facilities, or the CANMET research complex on Haanel Drive[20]. These locations are well distanced from residential areas, and an alignment with the agencies' main businesses could be attractive.
- More innovative small-scale turbines, perhaps as developed by local companies, could be more easily integrated in the urban context; these would have small net capacities but could still be inspiring to have combined with other renewable and smart energy solutions.

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20 Through personal communication with Mr. Graham Finlay, he reports having had conversations with CANMET.

Pathway Study of

Electrification of Transport – Light Vehicles

for

Energy Evolution: Ottawa's Community Energy Transition Strategy

Phase 1

By Mike Fletcher, Project Manager

Building Engineering and Energy Management Branch
Recreation, Cultural and Facility Services Department
City of Ottawa

October 17, 2017

ELECTRIFICATION OF TRANSPORT – LIGHT VEHICLES

OTTAWA ENERGY EVOLUTION: PATHWAY STUDY

This and other “Pathway Study” documents are focused technical notes describing how a specific energy technology may develop in Ottawa. The document includes consideration of the overall potential and the constraints that are likely to reduce uptake, as well as influences that the community may have to encourage technology uptake. Results of multiple Pathway Studies are intended to be used along with the Baseline Study of energy data towards an overall assessment of future energy strategies within the Ottawa Energy Evolution program. More general information on the Energy Evolution program can be found elsewhere.

Pathway Description

This pathway describes the current and potential contribution of electrification of cars and light trucks both in fleets and those that are privately owned to realize the goals of Energy Evolution. Cars, motorcycles, e-bikes, SUVs, small vans and pick-up trucks are included in this pathway analysis. Any other moving vehicles and equipment are discussed in the large vehicles and equipment pathway.

The Baseline Study produced by Leidos Consulting identifies the road transportation sector as the second largest energy consumer in the community at 31,200 Terajoules (TJ), out of a total of 114,200 TJ. As most transportation fuels are carbon intensive, reducing the use of transportation fuels will decrease greenhouse gas (GHG) emissions even more than the energy numbers would suggest. Using the U.S.’s Energy Information Administration’s data about transportation, approximately 61% of all transportation fuels are those used by cars or light trucks.[i]

Transport electrification should firstly be thought of as a conservation initiative. Electric vehicle efficiency energy to wheels has been calculated in the 70 percent range, whereas gasoline vehicle efficiency is in the mid-teens. [ii] The upshot of this increased efficiency is that electric vehicles are over three times more efficient than comparable gas powered models. If such an energy efficiency improvement were applied to the entire transportation fleet, energy consumption for transportation would fall to 14,757 TJ. Additional benefits of electrification will be discussed further in this pathway.

Pathway Boundaries

This pathway will only consider vehicles registered (or owned in the case of e-bikes) within the geographic boundaries of the City of Ottawa. Modal shift (e.g., from single occupancy vehicles to other forms of transportation such as biking or public transit) and changes in average trip length are not considered in this pathway. The pathway will consider both partially electrified vehicles (such as plug in hybrid electric vehicles - PHEV) and fully electric vehicles (EV). Hybrid vehicles that do not consume external electricity and fuel cell vehicles are excluded. Heavier vehicles such as trucks, busses and specialized equipment will be considered in another pathway. All types of EV charging are considered herein.

Introduction

EVs are defined as any vehicle that is partially or entirely propelled by electricity and plugs in to recharge. In terms of charging infrastructure, there are three types of EV charging stations:

- Level 1 charging stations, which use a 120 volt (V) standard wall plug and can supply up to 1.2 kilowatt (kW) of power
- Level 2 charging stations, which use a 240 V special plug and can supply up to 9 kW of power
- DC Fast Chargers, which use a 480 V special plug and can supply at least 50 kW of power

As of 2016, there were over 9,000 EVs registered in Ontario[iii], 7% of which are estimated to be in Ottawa. Although there is no breakdown between PHEV and EVs, Electric Circuit reports that the split between PHEVs and EVs in Quebec is roughly 55:45.[iv] It's likely that the split is roughly the same in Ottawa. At the time of writing there are 12 companies offering 24 different models of EVs in Canada. [v]Most models are cars, SUV's and Crossovers but plans for pickup trucks[vi] are in the works and minivans[vii] have just arrived on the market. The range of EVs continues to increase with cars in the $40,000 price range ($26,000 after the provincial incentive) now available that can travel 400 km on a single charge. Trends suggest that the up-front cost of ownership and range will continue to improve.

The Ministry of Environment and Climate Change released Ontario's Climate Change Action Plan in 2016. As part of this Plan, the Ministry has set a target that 5% of passenger vehicle sales are to be EVs by 2020, and the Province currently offers incentives of up to $14,000 off the purchase of an EV. Additionally, as of January 1, 2018, certain new building types will be required to provide EV charging infrastructure under the Ontario Building Code.

Possible Constraints

Increased electrical demand from the adoption of electric vehicles raises questions about the adequacy of the local distribution system. On a system level, replacing the electricity used to extract crude petroleum and refine it into gasoline would provide 5-10% of the electricity required for electrified transport also just extracting and refining petroleum uses the same amount of energy as electrified transportation[viii] would consume in total. Provincially, the 2017 Long Term Energy Plan will consider the addition of 2.4 million EV's by 2035 in its most aggressive scenario. The plan estimates that this will increase electrical demand by only 8 TWh annually.[ix] Based on annual electricity production of 160 TWh on both the transmission and distribution grids in Ontario, this is only a 5% increase in total electrical energy consumption.

Although the overall assessment indicates that a high degree of EV penetration is possible, supply issues at the feeder line level can still present challenges. The EMAP report produced several years ago precisely detailed the differences in the distribution system in different parts of the city and the demographics of prospective EV buyers[x]. Overall, the report concluded that a 25% penetration of EV's into the car and light truck fleet could be managed by the distribution grid before challenges start to present themselves.

Even with adequate electrical supply, however, the cost of a service upgrade to an otherwise ideal site can be cost prohibitive. Also, for safety reasons, Hydro Ottawa allows no more than one electrical feed into each property parcel (i.e. each property PIN number). This can lead to challenges if a site's feed is too small for desired EV charging or if the location for the feed to a site is poorly located to serve the desired location for EV charging.

Besides electricity infrastructure challenges, several factors related to vehicles themselves have slowed vehicle adoption. Availability challenges with some models has caused delays in uptake. The most recent delays have been those in supply for the Tesla Model 3[xi] but it is notable that this has been driven by high sales demand.

Developing this Pathway

The way in which EV drivers charge their cars has been extensively studied. Between 2011 and 2014, the US Department of Energy and ChargePoint America conducted the largest survey undertaken to date of how Americans charge their EV's.[xii] The report noted that most charging takes place at home with workplaces as a strong second. An important aspect of the report considered EV adoptions and had a great deal to say about the location of publically available charging infrastructure in terms of helping to determine optimal sites in which to locate chargers.

The presence of publicly available charging infrastructure is important for the adoption of EVs. High speed charging infrastructure (see table 1 below for a local summary) is important for the reduction of range anxiety that causes EV owners or prospective owners to believe that longer trips are not possible. Also, it is almost essential for EV owners who live in residences where they are not able to charge to have access to public charging.

Although initially a wide distribution of high speed chargers is required to deal with range anxiety, eventually certain charging sites stand out as being quite popular. This has already happened in Quebec, for example, where DC fast chargers half way between Montreal and Quebec City sometimes have busy periods and a desire to have multiple DC Fast Chargers at single sites emerged as a key request in Electric Circuit's 2016 customer survey.[xiii]

Table 1: Installed or Planned DC Fast Chargers in Ottawa as of August 2017

Location	Fee for Use	In Service Date	Notes
141 Clarence St.	$17 per hour	February 2017	Electric Circuit Network. Inside a paid parking garage. Parking fees apply to charging station users.
2685 Iris Rd.	Free, but set up with a card reader	March 2017	Two fast chargers at this location. Location is a department store. Fee for use may come into place
101 Centrepointe Dr.	$17 per hour	April 2017	Electric Circuit Network
145 Roland Michener Dr.	$17 per hour	April 2017	Electric Circuit Network. Two Fast Chargers at this Location
687 Somerset St. W.	$17 per hour	June 2017	Electric Circuit Network
3355 Fallowfield Rd.	$17 per hour	June 2017	Electric Circuit Network

Location	Fee for Use	In Service Date	Notes
4561 Bank St.	TBD	TBD, in 2017 if approved	Site is being considered by the City and Electric Circuit
TBD	Free	2017-18	Tesla Supercharging. Site not determined (Could possibly be in Gatineau). Tesla chargers can only charge Tesla vehicles

Another industry trend concerns the power rating of DC Fast Chargers. With the exception of Tesla, DC Fast Chargers are generally rated at 50kW. These chargers can typically give EVs 100km of range with 20 minutes of charging. The industry however is recognizing the consumer benefit of faster charging and recently a prototype 150kW charger[xiv] has been installed in California. Public chargers at up to 400kW are now being designed.[xv]

Level 2 (L2) charging is helpful in encouraging EV adoption especially if it is well situated. An L2 charger located at a site where EVs are parked for long periods, such as a City of Ottawa Park and Ride lot or other long term parking, can be useful in filling an EVs battery over a longer period. Additionally, such charging is often preferred by EV or PHEV drivers as it allows top-up charging which can enable an EV driver to complete a trip or allow a PHEV to complete a trip without engaging operation of the gas power train.

Level 1 (L1) charging can take the form of either 120 volt outlets or chargers served by a 120-volt electrical service at up to 20 amps. They have a niche role as a perk in employee parking and long term parking [xvi] areas. Additionally, L1 charging can be used for scooters and e-bikes.

Besides improving the supply of adequate charging infrastructure, there are several other ways to encourage EV adoption. EV's can find roles in fleet applications with lower life cycle costs than fuel powered vehicles. Indeed in Canada an entire Taxi company is EV only[xvii]. Fleetcarma, a Canadian company, has developed a software program and device to analyze which vehicles in a fleet have a usage pattern that would be ideally served by a conversion to an EV[xviii]. Another action related to mass deployment has been group purchases. These group purchases lower unit prices and encourage interest. A recent group purchase in Montreal solicited interest from 2,800 people. [xix]

Uptake Projections

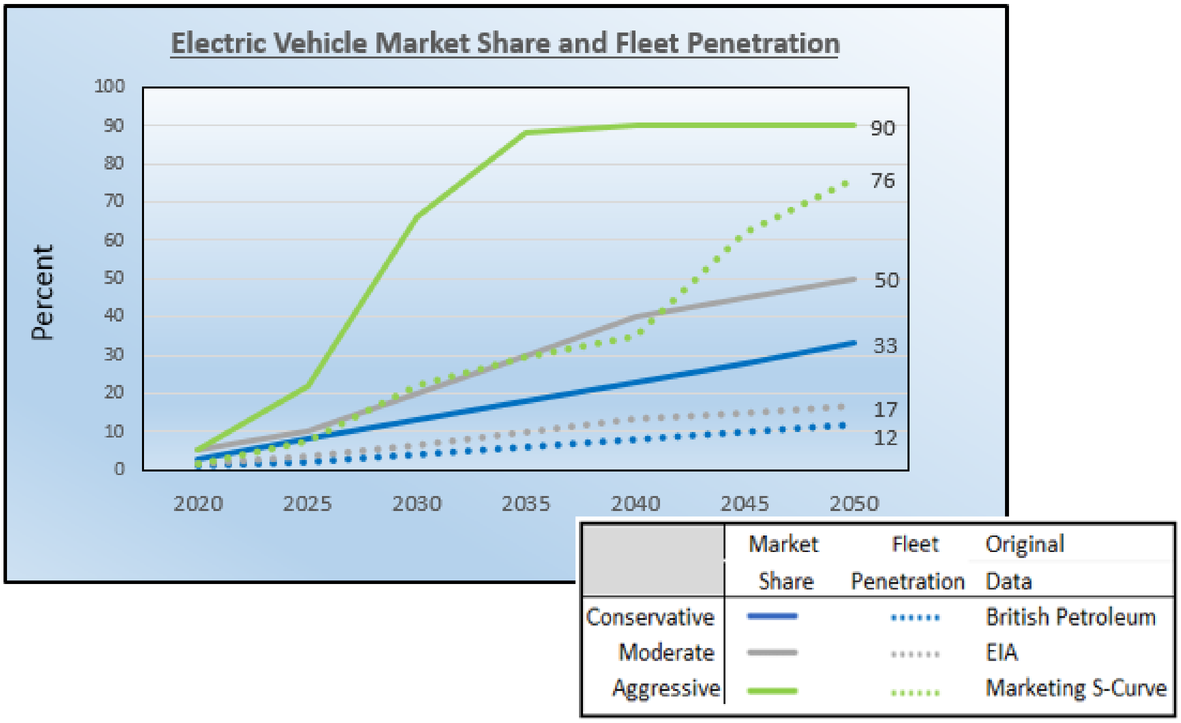
As EVs are a new consumer technology, estimates of possible consumer uptake abound. The scenarios herein are taken from organizations who have produced their own estimates and are described as follows:

1. The Conservative Scenario is based on the 2017 Edition of the BP Energy outlook.[xx] The 2035 projection was linearly interpolated and extrapolated to cover the study period.
2. The Moderate Scenario is based on a 2016 report by the International Energy Agency (IEA)[xxi]
3. The Aggressive Scenario focused less on the technological aspects of EVs but looked more at consumer adoption curves for new products and services such as personal computers and smart phones for example. This was done by On Climate Change Policy[xxii]

Some modeling was done to translate annual market share into fleet size and to estimate how much gasoline is burned by PHEV's

The first work of this analysis is to determine and compare EV market penetration under the three scenarios. The differences in the amount of market share and fleet penetration differ markedly. It should be noted that On Climate Change Policy assumes that 90% is the maximum penetration of EV share for this market.

Graph 1: Market Penetration of EVs for Cars and Light Trucks

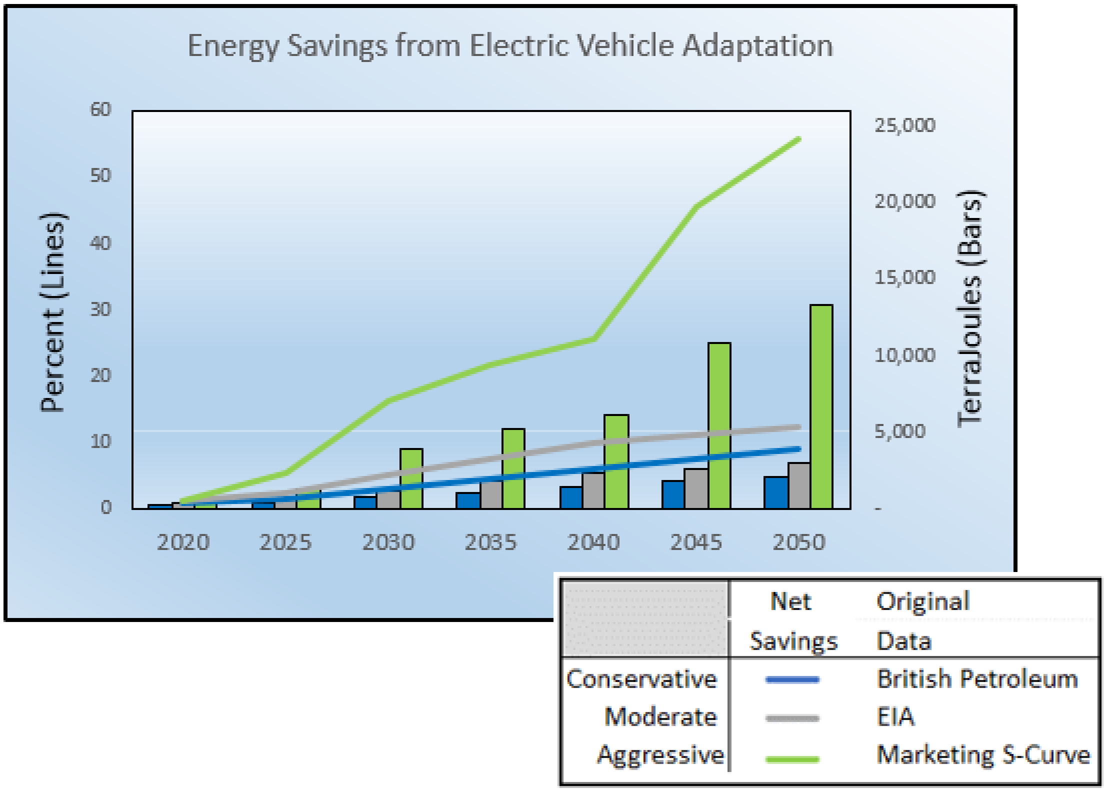


Using the fleet penetration data and the efficiency data, it was possible to estimate the reduction in energy that EVs are able to offer over the study period. EV's move energy consumption from petroleum to electricity but as noted earlier, their enhanced efficiency means that much less energy is required to power the fleet. In addition to this large net energy reduction, most of our options for renewable energy exist in the form of electricity.

Table 2: Energy Savings from EV Fleet Penetration

Year	Gasoline Displacement / Electricity Increase and Savings (Annual TJ or %)											
	Conservative Scenario				Moderate Scenario				Aggressive Scenario			
	↓ Gasoline	↑ Electric	Savings	Percent	↓ Gasoline	↑ Electric	Savings	Percent	↓ Gasoline	↑ Electric	Savings	Percent
2020	229	54	175	1	381	90	291	1	381	90	291	1
2025	458	108	350	1	763	180	583	2	1,678	396	1,282	5
2030	915	216	699	3	1,526	360	1,166	5	5,035	1,189	3,846	16
2035	1,373	324	1,049	4	2,289	540	1,748	7	6,713	1,585	5,128	22
2040	1,831	432	1,399	6	3,052	720	2,331	10	8,010	1,891	6,119	26
2045	2,289	540	1,748	7	3,433	811	2,622	11	14,190	3,350	10,839	45
2050	2,746	648	2,098	9	3,814	901	2,914	12	17,394	4,107	13,287	56

Graph 2: Net Energy Savings from EV Adoption



Ways to Encourage Electrification of Cars and Light Trucks

- Encourage workplace charging. This has been shown to increase the likelihood of people to purchase PHEV or EV's six fold[xxiii]
- Ensure that there is adequate capacity DC Fast Chargers. Monitor their use and be ready to add chargers when line-ups occur
- Make higher speed DC Fast Chargers available when they arrive on the market to continue reducing charging times even further
- Consider a group purchase of Fleetcarma services for a group of fleets across several organizations. This could in turn lead to a group EV purchase
- Continue to support and promote PHEV and EV fairs and educational sessions
- Enforce parking rules at EV charging stations so that they are available to EVs that need to charge
- Ensure that new facilities or facility retrofits and expansion or redevelopment of the distribution grid are compatible with requirements for EV charging
- Develop and maintain or link to a map of publically available EV charging infrastructure in Ottawa
- Continue and expand access to high occupancy lanes for PHEV's and EV's
- Commercial and retail establishments could consider PHEV and EV charging as a 'lost leader' to get customers to their establishments

- Encourage electrical utilities to reduce or eliminate demand charges for electrical accounts that exclusively feed EV charging. This will be particularly important if DC Fast Chargers with a capacity of greater than 200 kW become available
- Consider possible locations for high amounts of DC Fast charging which are driver friendly and have adequate electrical supply. Use the designation of these sites in distribution grid and possibly sub-transmission grid planning
- Incentivise car sales representatives to sell PHEV's and EV's
- For fleets, encourage the use of telemetric services that can determine which fleet vehicles are good candidates for conversion to EV's
- Prioritize installation of charging stations in areas of the electrical distribution grid with ample supply. This can serve to move load away from parts of the grid with tight supply which will be helpful should PHEV and EV deployment continue to develop.
- Implement a low cost commercial grade electrical sub-metering solution for electric vehicle charging
- Encourage actions which aim to put a price on carbon pollution to shift the value proposition away from fuel vehicles and towards EV's
- Set a long term goal to eliminate non-electric vehicles from parts or all of the City, perhaps the downtown by 2040 for example.
- Encourage the province to develop a zero emission vehicle (ZEV) standard as has been done in other jurisdictions such as Quebec
- Encourage the use of EV's in car sharing and taxi companies

Catalyst Projects

- A project to charge vehicles where they wait such as taxi stands.
- Conduct an EV group purchase for interested parties

Glossary

DC Fast Charger. Chargers that provide power at 50kW or greater. The chargers rectify AC power to DC prior to feeding it to the vehicle

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