APPENDIX D

Phase B: Sustainability Report

Renewable Energy Generation Strategy – Corporate

The Town of Oakville

September 2021

blackstone
energy services

Contents

Executive Summary

The Town of Oakville ("The Town") has engaged Blackstone Energy Services ("Blackstone") to develop a Renewable Energy (RE) Generation Strategy for their corporate buildings. This strategy is to assist The Town with actionable direction that will help to achieve their 2050 target to have GHG levels at 80% below that of 2014[1]. Along with dedication to on-going energy conservation and demand management initiatives, renewable energy, the use of low carbon, high performance solutions, and collaboration with the community this target can be possible. Throughout this strategy Blackstone will ensure that The Town is able to meet their goals to:

- ✓ Assist to reduce the corporate carbon footprint to 80% below 2014[1] amounts by 2050
- ✓ Establish strategies to provide increase renewable energy generation
- ✓ Describe approaches for integrating renewable energy generation into new construction and major renovations/deep energy retrofits
- ✓ Outline the guidelines for business cases including sizing and annual generation estimates and life cycle cost parameters
- ✓ Describe possible future scenarios with increased renewable energy systems application within the Corporation

Blackstone has completed a background review of renewable energy technologies appropriate for municipal settings, a review of surrounding peers, and the existing installations. Blackstone, in collaboration with the staff in Facilities and Construction Management (FCM) group at The Town has:

- Reviewed renewable energy technology applications in a municipal corporate setting
- Analyzed functionality, scale and specifications that result in successful implementations
- Developed project cost estimates for the renewable technologies
- Identified barriers and risks for implementation

The knowledge gained from this analysis was leveraged to identify and validate potential for applications and inform a renewable energy evaluation matrix. The matrix analyzes each renewable energy technology against the variables listed below:

- Technical suitability
- Performance assessment methodology
- Energy generation/saving potential
- GHG offset potential
- Paybacks/return on investments
- Procurement implication
- Existing vs. new building application
- Maintenance and operations impact

[1] It is recommended the baseline year be reset to 2015 from 2014 to avoid the impact on GHG emissions from closing the coal fired electricity generation on the Ontario grid.

Strategic Plan for Renewable Energy and Clean Technology

The Town has shown consistent attention to the environment over the years. They accepted the fact that the human induced greenhouse gases are causing significant climate degradation and passed a climate emergency statement in 2018. The Town has prepared several energy and carbon reduction measures through conservation and demand management plans since 2005 with the most recent one published for a plan from 2020.

The Town has targeted a 20% reduction of corporate energy and GHG levels by 2030 and 80% lower levels by 2050 as compared to 2014[1]. At that pace The Town could reach a net-zero carbon footprint by 2050 if they tackle their GHG footprint consistently over the next 30 years. Achieving this target, as daunting as it may seem, is possible with a coordinated effort among the corporation and community. This strategic planning report was requested to describe technology and policy scenarios that will manifest in a low to net-zero carbon Town by 2050. Even with the level of action and measures taken over the years, a coordinated and collaborative approach is the preferred way to tackle big issues such as a community-wide environment issues program. There are both community and corporate teams preparing and attempting to implement GHG mitigation programs.

The strategies presented in this report address the need for a coordinated plan with shared and shareable results. The benefits of a strategy and collaboration across The Town will be reliable and sustainable energy and GHG reductions that are realistic, timely, cost effective, long lasting and something The Town can be proud of.

The Why, What, How & When of a RE Strategy:

- The Town has embarked on a path to achieve or be close to carbon neutrality by 2050
- A Climate Emergency was approved by Council in 2018
- A strategy will gather and present reasonable standards, policies, measures, and timelines that can be applied across the Corporate portfolio and be coordinated within the Community as well
- Define technologies that can be integrated into the Corporate framework and how to take advantage of the strengths acknowledging that they will evolve over time
- Prepare business case foundations for the solutions that will show the benefits and costs for RE technologies as they are available now with projected benefits to 2050
- The strategy will suggest trigger events to right size and right time RE implementation

Renewable Energy Technologies Considered:

- Solar energy including photovoltaics (electricity) and thermal energy (heated air and water)
- Heat pumps including ground source, air source and waste energy
- Decentralized and district energy systems (energy nodes)
- Bio energy (wood pellets)
- Hydrogen (stationary boilers and transportation)
- Wind energy (urban scale and large off-site)
- Batteries (resiliency and demand shedding)

Renewable Energy Strategic Plan Summary:

Each of these categories is described more fully in this report. The ranking of the measures being proposed for The Town's RE strategy is summarized below.

1. Continue to encourage, develop, formalize, and monitor renewable energy system integration into The Town developments, renovations, standards, and policies.
2. Promote the use of passive renewable energy solutions, such as daylighting, wind shading, wind assist ventilation, solar towers.
3. Describe trigger events to initiate renewable energy projects, i.e., building renovations, incentive programs, new buildings, anticipated legislation, and funding opportunities.
4. Solar photovoltaics – It is the most recognized, understood, and practical of the RE technologies available. It can be applied across the corporate portfolio as rooftop systems of the order of 2 MW of generation making about 2.5 million kWh/year Cost metrics are favorable with ~12-year paybacks, and it will generate for >30 years. Prepare for opportunities for large scale virtual metering projects to offset from off-site generation.
5. Solar hot water – Recognized, understood and practical. This solar technology reduces the carbon from natural gas heating and best applied in large settings such as at pools and community centres with annual hot water loads. Due to low commodity cost of natural gas, the paybacks tend to be longer (~25 years) however when the cost of a carbon tax is included the paybacks will be reduced by about 25% (~16-18 yrs). These systems will produce energy for >30 years. These can be integrated into district energy systems (supplementary source) and combined with geoexchange systems (boost winter energy supply).
6. Heat pump technologies – Important enabling system for low carbon plans. They use the ground, water, air, and wastewater as an energy source, are well understood and readily available in a range of sizes. Key technology for conversion from natural gas to electricity-based heating. Opportunities exist for new and renovation projects.
7. District or distributed energy systems – Uses distributed energy nodes to supply heat, cooling and electricity to communities or facility campuses such as athletic complexes and community centres tied to local loads. Increases resiliency. Opportunity to integrate other RE such as PV and solar hot water into heat pump and geoexchange networks. Opportunity to collaborate with Community DES and neighbourhood intensification plans. Common and well proven in the EU.
8. Other technologies such as bioenergy, wind, batteries, hydrogen have been reviewed and indicated where feasible. We recommend that these and any evolving technologies be monitored and reviewed annually for opportunities as they appear.
9. Start early with subject experts to understand and assess renewable energy solutions opportunities. Engage the SME and collaborate with The Town Facilities and Construction Management (FCM) department.
10. Consider an annual renewable systems portfolio and resource evaluation report, coordinated through the FCM department, and reported to Council.

Introduction

The intention of this report is to help The Town reduce current and future energy and carbon loads for their corporate facilities. What are the options to decarbonize the thermal and electrical supplies for the facilities and optimize systems that are used? What technologies are most suitable now and in the near term? Are there pending developments that will help The Town reach their targets? Currently, most of The Town's energy comes from conventional sources – natural gas and electricity from central grids, with a small percentage from solar power and heat pumps. Using enabling technologies such as renewable energy systems, The Town plans to direct more energy supply from low carbon electrical sources. Low carbon energy solutions include active and passive systems.

For this report, and resulting strategy, the focus is on active technologies. Passive systems such as daylighting, induced ventilation, landscaping, site planning are necessary components for successful long-term energy planning and best addressed in building and community design standards. These are discussed in the policy section of the Phase A report of the full project.

Blackstone evaluated ten (10) renewable energy (RE) technologies options during this study. These represent the currently available and most common technologies in use at a municipal scale and will likely be applicable at some scale within The Town for the next 10 to 30 years. New technologies will evolve from these systems typically with higher efficiencies for the same footprint, lower capital costs, lower operating and maintenance costs, longer life cycles, end-of-life recycling, and integration possibilities.

The 10 technologies evaluated were:

- ✓ Solar - Photovoltaic
- ✓ District Energy Systems
- ✓ Geo-Exchange Heat Pump Systems
- ✓ Air Source Heat Pumps
- ✓ Hydrogen & Fuel Cells
- ✓ Bio-Energy
- ✓ Solar Thermal - Hot Water
- ✓ Solar Thermal - Air
- ✓ Energy Storage
- ✓ Wind Turbines

These technologies were used to create a RE Rubric as well as a workshop hosted by Blackstone with The Town staff to get a sense of the awareness and acceptance of RES's. The rubric consists of two matrices – the Technology Assessment Matrix and the Applicability Matrix and shown below.

The Technology Assessment Matrix evaluates and ranks the renewable technology options individually and the Applicability Matrix evaluates and ranks the renewable technology options based on their relevance and feasibility to The Town's corporate building archetypes and to the larger Oakville community.

A summary of the technologies analyzed in this study and their ranks for the technology assessment and applicability are provided below. The detailed matrices and the methodology for the rubric can be found in Appendix A at the end of this report.

Table 1: Technology Assessment Ranking

RE Technologies	Technology Assessment Rank
Solar Photovoltaic	1
Solar Thermal Water	2
Air Source Heat Pumps	3
Solar Thermal Air	4
District Energy Systems	5
District Energy Heat Pump Based System	6
Geo-Exchange Heat Pump Systems	7
Wind Energy	8
Bio-Energy	9
Energy Storage	10
Hydrogen & Fuel Cells	11

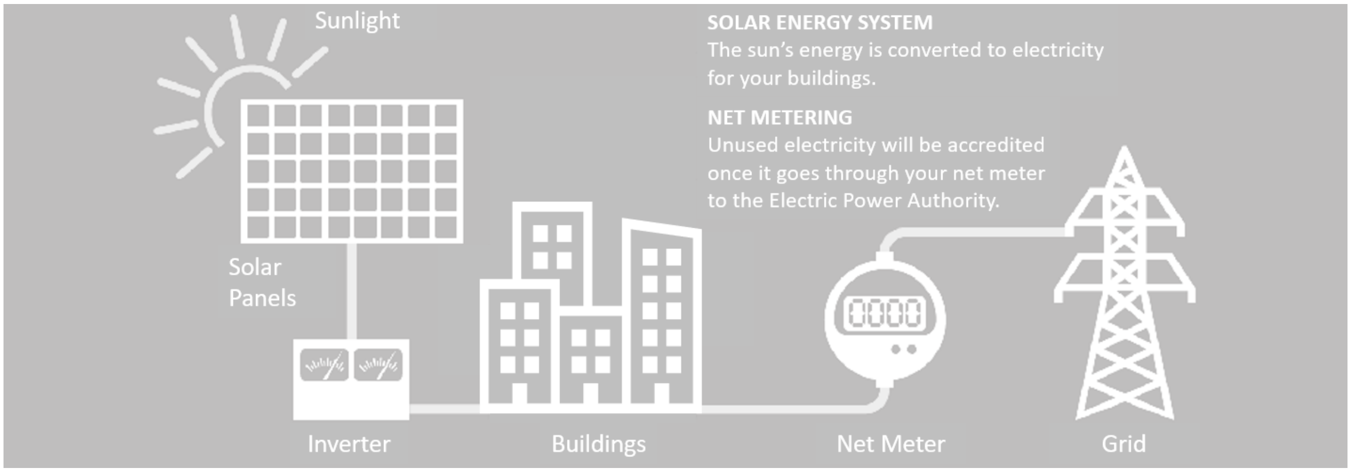
Table 2: Technology Applicability Ranking

RE Technologies	Technology Applicability Rank
Solar Photovoltaic	1
District Energy Systems	3
District Energy Heat Pump Based System	3
Air Source Heat Pumps	3
Solar Thermal Water	5
Geo-Exchange Heat Pump Systems	6
Solar Thermal Air	7
Energy Storage	8
Wind Energy	9
Bio-Energy	10
Hydrogen & Fuel Cells	11

1 Solar Photovoltaic

1.1 Product Background

Solar photovoltaic (PV) is the conversion of sunshine to electricity and is a mature technology. The solar modules generate power as direct current (DC). Grid connection is made via an inverter that converts the DC to alternating current (AC) that can be used in the buildings. A typical solar PV system is illustrated in the figure below.



Source: https://mozaw.com/grid-tied-solar-pv-system-installation/

Figure 1: Solar PV System

Installations are considered building application PV and building integration PV. BAPV include roof-mounted, with either direct structural connection to the building, or ballasted using concrete blocks or pavers and wall mounting though at reduced energy production as compared to roof mount but can provide window shading as awnings bringing added benefits. BIPV include PV that are a part of the envelope such as PV windows and exterior wall sections. BIPV may not seem financially viable in a classical payback model, but they are worthy of consideration given they integrate long life wall cladding with generation potential on available and underused production wall area and help buildings approach net zero energy performance. These applications are described in more detail later in this section.

Most modules installed over the past 30 years are made from crystallised silicon. Incremental improvements have pushed efficiencies to about 20% realizing more output capacity for the same size module thereby increasing a systems performance for the same array area. Common types of solar panels are categorized in the table below.

Table 3: Common Types of Solar Panels

Solar Panel Type	Efficiency	Advantages	Disadvantages
Monocrystalline	~20%	• High efficiency/performance • Optimized for commercial use • High life-time value	• Comparatively Expensive
Polycrystalline	~15%	• Low cost, most common	• Lower efficiency/performance • Sensitive to high temperatures
Thin-film	~7% to 10%	• Portable and flexible • Lightweight • Aesthetics	• Lowest efficiency/performance • Low life-time value

All components are standardised and subject to testing and certification practices by IEC/CSA/ULC with well understood performance metrics that are improving each design iteration. Design, engineering, installation practices and warranties have been refined with years of successful application for roof, ground and building integrated arrays making the performance well understood. Top tier suppliers carry limited performance warranties that specify that actual power output will be no less than 98% of the labeled power output in the first year. From years 2 to 30, the annual power decline will be no more than 0.45% and no less than 85% of the labeled power output. The supplier will either repair or replace the module with a version with the same power output as the original.

Installations in The Town will typically be roof-mounted, with either direct structural connection to the building, or ballasted using concrete blocks or pavers (BAPV). Ground mounted systems are possible and should be considered where large tracts of land are available such as brown fields or parking lots (canopies over parked cars).

1.2 Market Overview

Photovoltaics (PV) product design and installation is a recognized and mature market. The installation of PV is increasing globally (+22% in 2019) and expected to grow at an average of +15% to 2030. The Town has experience with PV applications now. The technology is at the point where non-technology costs (evaluation, engineering, wiring, labour) are as material to project economics as the modules. PV levelized cost of energy (LCOE) is at or below the price of grid electricity within the life cycle of the systems (i.e., the cost of a kWh from PV is at or below that for a purchased kWh from the grid). There are many PV component manufacturers producing at a significant scale with local representation for all required services. Product life cycles are increasing and covered by reliable warranties. The local distribution company (Oakville Hydro) is familiar with the application, inspection, and approvals process. The Town should be comfortable promoting the use of solar electricity on existing and new buildings and available land (i.e., brown fields, car ports) as a part of their low GHG future. Pending Federal incentive programs will favour renewable energy system applications which Oakville should be prepared to take advantage of. Having PV in the low carbon technology mix and plans within Oakville is recommended at ~35% of electrical loads by 2030. See Report D for more on the contribution scenarios for PV to the corporate grid.

1.3 Application to Building Portfolio/Grid Connectivity

Connection Impact Assessment

Every PV project requires a connection impact assessment (CIA) from the local distribution company (LDC) – Oakville Hydro. The CIA establishes if the proposed connection to the grid is safe, sufficient grid capacity, defines any infrastructure upgrades, and will not affect grid stability. Utilities set their own rules and standards for this process setting both application costs for the CIA process and upgrades required for connection. The LDC will typically preform a pre-CIA at the request of the developer which gives a high level “go/no-go” perspective and should be initiated early in the development.

The pre-CIA will indicate if the proposed system capacity is too large for the connection point which will guide the project maximum generation size. There may be a cost for the pre-CIA, depending on the address and available information.

Typically, the utility prefers systems that do not feed back into the grid but rather are used totally within the facility. Applications such as large ground or parking lot canopy projects are specifically meant to feed into the grid and should be discussed early to make sure all parties are aware of the design and connection needs.

All on-site generation systems require signage indicating there is a second source of energy on the premises for the safety of emergency crews. In keeping with that, safety disconnects are critical and must be easily accessed.

Installation Criteria

Solar PV is ideally installed at an angle of approximately 15-30° from the horizontal and facing within 45° of south to maximise PV annual energy generation. All solar is negatively affected by shading. A “shadow study” is recommended prior to final design and tender to verify annual shading effects from rooftop units, combustion flues, elevator sheds, other buildings, etc. The latest string and micro-inverter technologies make shading issues less of a concern, are safer and would be the preferred inverter solution. Existing rooftop equipment will require maintenance clearance - walk-around space is required at equipment and roof edges. In addition, row-to-row spacing requires module spacing to limit modules from shading another. Care must be taken to avoid window washing anchors. The final area available for solar will be less than that of the edge-to-edge roof area.

Building integrated and building applied PV systems (BIPV and BAPV respectively) where the PV systems are mounted either as a part of the structural wall (BIPV) or onto the exterior wall (BAPV) are the current facility installation methods. Examples of BIPV are when the exterior wall is made up of the PV panels like conventional glass curtain walls. These can also be skylights, awnings, roof systems (such as over train stations). These require the direction of an architect and structural engineer from the beginning design stages. They can be integrated into the “look” of the building readily. They are an expensive system when the existing wall must be removed.

Figure 2: Example of BIPV systems – the PV is the wall

BAPV is basically a PV array mounted onto a racking that is hung onto the outside wall. Though less expensive than the BIPV, they require a strong existing wall system. A structural engineer is required with a reputable solar system installer.

Figure 3: Example of BAPV – the PV is mounted onto the wall

Electrical connections need to be confirmed to ensure there is capacity at the grid connection and room for the required metering and equipment. Sometimes an interface transformer is required. The pre- and post project CIA will guide these needs and is coordinated through the local distribution company (Oakville Hydro). They must be contacted early in the decision process to make sure the capacity is available. All solar installations will require a structural assessment by a professional engineer to determine that the building (either roof or wall) is able to handle the additional weight. This step needs to be completed early in the development to make sure any further effort is worth the time and cost. Consider PV applications whenever the roof is being replaced.

Layout Limitations

Roofs with lots of equipment, existing pathways, or narrow roof areas will likely be low priority and ranked as such. The most cost-effective installation methodology for a flat roof is ballasting, where the racking is weighed down with concrete blocks or pavers. This is a very common way to place an array and well understood. The smaller the sections of array (i.e., < 50 sq. m.), require greater ballast mass to hold it down in the wind. A structural engineer will be able to assess and define the layout for any racking arrangement.

Vertically installed solar is an option where large areas of wall space are available and accessible (mentioned above – BIPV and BAPV). While some maintenance/inspection is required periodically, this should not eliminate wall mounted systems from consideration. Performance will be lower than a sloped/horizontal system, though it can be offset with larger areas. There are innovative ways to install vertical/horizontal PV arrays that provide shade over windows (i.e., awnings) providing a dual function – energy generation and high sun shading in the summer months.

For tall buildings, it can be difficult to run wires from a roof to the electrical room. Consideration must be made for a visible power disconnect at or near the street level which may require long wiring runs. For ground mounts such as parking lot canopies, it may be difficult to get access to a connection point inside a building. The design team will be able to evaluate these concerns early in the development and prior to committing to a system installation. In all cases a structural engineer will be required to stamp the designs for any PV array. In some cases, the installer can arrange to have the designs stamped by a professional engineer. An EPC (engineer, procure, construct) contract can provide all the services required for a full PV array installation from design through to commissioning.

Portfolio Sustainability

PV installations for buildings typically connect as “net-metered” – in effect “slowing down” the main electrical meter. Depending on the system size, these rarely feed back into the grid and for some LDC’s is the preferred sizing criteria. The main limitation would be the availability of appropriate roof, wall, or ground surface area and connection capacity. Life cycle economics should govern financial suitability. PV modules come with 25 to 30-year production warranties so long-term life cycle costing should be applied. The Town is reviewing policies and standards that will promote renewable and alternate energy system applications including “solar ready” designs. These measures will increase the opportunities for solar PV on more of The Town’s portfolio.

Ground Mount Systems

The Town has policies in place that define setbacks and suitability in any given area for generation systems, including solar arrays which will need to be reviewed for a ground mount (i.e., grey field, brown field, parking lots). An opportunity for large array applications on the ground are solar-covered parking structures (canopies). Ground mount systems tend to be less expensive on a $/kW installed basis compared to roof mounts given the large scales and number of developers who engineer, procure and contract ground mount. A typical carport solar system is shown in the figure below.

Currently, costs for car ports are in the region of ~30% higher than building installed systems ($/kW installed) though there are more vendors joining this growth which should lower the costs as applications increase. The visibility and marketing potential of canopy PV is an important consideration. There is also the potential combination with electric vehicle charging stations with parking lot PV which is expected to grow significantly and become a part of a distributed energy system concept in the near future.

Source: https://www.constructioncanada.net/designing-for-solar-pv/2/

Figure 4: Carport Solar System Example

Virtual Power Plants

As Ontario shutters the nuclear power stations at Pickering through to 2025, and as a tax on carbon comes into effect, hydrocarbon emissions from natural gas power stations will carry increased costs to and beyond 2030. While maximizing on-site renewable power will be essential to offset the increased electrical loads due to electrification, Ontario will also need to expand large solar and wind farms to meet Provincial demand needs. PV will be an important element of The Town's path to a low carbon future.

A common method to develop and source this renewable power (predominantly solar and wind) is through power purchase agreements (PPA), contracted between consumers and independent power producers. These PPAs are deemed "virtual" (VPPA) because the power plant is not located on the consumer's site; rather the power plants are large and "virtually" deliver power to multiple consumers, contracted through a VPPA.

The method described above allows for the free market to determine who wants to buy power from the renewable power plant: those motivated to buy the renewable power will do so at an agreed upon price per kWh over a set time (typically 12 – 15 years); those unmotivated will not. As renewables have variable production, the concept of net metering (whereby excess renewable power generation can be "banked" with the local distribution company) for on-site and VPPAs is being considered for Ontario. This is referred to as Virtual Net Metering and is the concept of how power would be delivered/billed to disparate consumers of power generated from large, renewable power plants.

Assuming Ontario allows this methodology, to meet its GHG emissions goals, The Town of Oakville, its residents, and businesses will need to enter into VPPAs with independent power producers. As a piece of good news, the cost of large renewable power generation continues to drop, and this translates to low commodity prices for consumers. For instance, a 100 MW solar or wind project in Ontario would likely have a resulting commodity price of about 7 cents per kWh, a significant drop from the 13-14 cents per kWh currently being charged to Class B consumers in Ontario. Note also that these are usually restricted to MW-scale plants.

Blackstone has recognized this future and is developing large-scale renewable power projects to help meet its clients' needs in the 2024-2025-time frame. We recommend The Town investigate this concept further and consider the opportunity to partner with a VPPA provider to offset the increased electrification to meet their GHG reduction targets for 2030 and beyond.

See Section 1.10 – Strategic Direction, for examples of PV sizing to meet a range of GHG levels.

1.4 Application as Retrofit vs. New Construction/Major Renovation

Solar energy works well for both new construction and retrofit/renovations. A south-facing pitched roof of 20-45° is considered ideal though most large areas within The Town tend to be flat rooftops. The common racking system is a ballasted array which tend to be at 0°to 15°from horizontal which reduces the ideal performance by ~10% which is not much considering the reduced cost of a ballasted system versus a 45°rack mount. The array should face within 45° of south for the best annual performance. Systems facing due east (90°) and west (270°) are not uncommon – roofs with this solar access should not be avoided but also not priority sites. For a flat roof, ensure the arrays are clear of mechanical equipment and other shading. In all cases, structural and connection capacity must be taken into consideration. An existing roof may not have the structural capacity or may have recently been re-roofed. The roofing company should be contacted for guidance to ensure any warranties are maintained. Roofs that are due for reroofing should consider a PV system. An advantage of a ballasted system is that the panels can be moved for reroofing later. Comments in the Policies section within this report propose that all new buildings and renovation include, at a minimum, "solar ready" design features (e.g., plumbing, and electrical chases, room for meter cases and connections in the electrical room, structural capacity).

All PV systems will require electrical safety authority and LDC approvals before, during and after a system is installed.

1.5 Economics

Solar installation prices have been declining steadily since 2010. The following chart shows the estimated price for solar panel installations in Ontario.

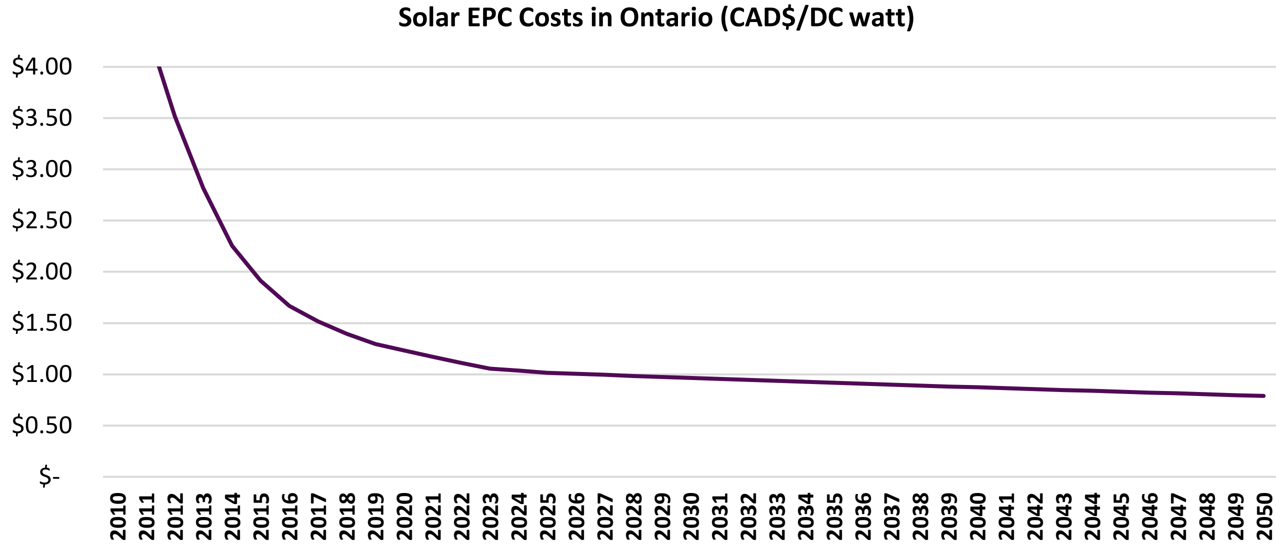


Figure 5: Summary and projected cost of PV systems, total installed, $/DC watt

All commercial-scale system of about 150kW$_{DC}$ and upwards in size would cost ~$1,400 per installed kW$_{DC}$ including soft costs, varying with system size, racking, roof type, and distance to the meter room (total cost ~$210,000). Each installed kW$_{DC}$ would develop approximately 1,100kWh/yr., this equates to at $0.14 per kWh about $23,000/yr., for the 150kW$_{DC}$ array at $0.14/kWh. Each kW$_{DC}$ of modules requires about 10m^2 of roof space so the 150kW system referenced here will need about 1,500m^2.
An advantage of net-metering is that the system displaces electricity at the rate for the time it is generating into the building, which tends to be during peak energy demand periods of the day. This is also the time when the grid tends to depend on natural gas fired peaker plants so the effect of the PV array is to reduce the need for high GHG electricity when it is most needed for air conditioning loads. (Note: this GHG marginal emissions factor is not currently taken into consideration by the utilities but should be tracked by The Town for future reference).

Annual maintenance costs are approximately 0.3% of the construction cost, consisting of a spring and fall inspection. PV module performance is affected by dirt – cleaning of an array should be planned at least annually to optimize generation and is a good time to inspect the system.

The costs and generation information for a typical 150 kW$_{DC}$ system, based on the specified assumptions, is summarized in the following table.

Table 4: Example of PV system costs and performance (2020 costs)

Metrics for a typical 150 kW Solar PV System	
System Size (kW_{DC})	150
Space Required (sq. m)	1,500
System Cost ($)	$210,000
Estimated payback	<10 years
Estimated Annual Generation (kWh/yr)	165,000
30 year levelized cost of elect ($/kWh)	$0.03
Maintenance Cost ($)/yr	$1,050
Annual GHG Offset (tCO_2e/yr)	7.74

A carport system will cost more due to the structure and wiring to the building or grid connection point. An estimate is that for the same size system in kW_{DC} as a ballasted roof system will be ~2-3 times and produce ~5-10% less energy annually. They are very visible and provide shade which is of value though not easy to assess.

The value of carbon is expected to increase during the life cycle of the PV array (>30 years). At Federal carbon levy rates for 2021, a 150kW array will avoid ~$310 in carbon costs; in 2030 it will be $1,316. As The Town increases their GHG reductions, these savings will accumulate across the renewable and alternate energy systems portfolio. The Town (through the FCM) should include carbon savings with attendant costs for all renewable projects and considered in all life cycle cost assessments for 25 years.

An advantage of solar PV is that it generates power during peak sun and typically when the grid uses gas fired peaker plants. This means PV will offset more GHG's at an hourly resolution than the annual GHG emissions factors currently being used for on-site generation. Though not accepted for carbon accounting, The Town should track "marginal emissions" for all PV (and renewable energy) both for promotion of the success story and in case these savings are allowed in the future.

PV systems have a productive life expectancy of 30+ years, with some electrical equipment replacement/repairs (inverters typically) expected during that lifecycle. Modules once installed are essentially maintenance free (other than cleaning) and rarely fail. Panel warranties guarantee the output to be at 80% of nameplate in year 25. Inverter warranties are typically 10 years under normal use. Replacement of the inverters should be carried every 12 years in the life cycle cost analyses.

BIPV and BAPV – Integrated and Applied PV

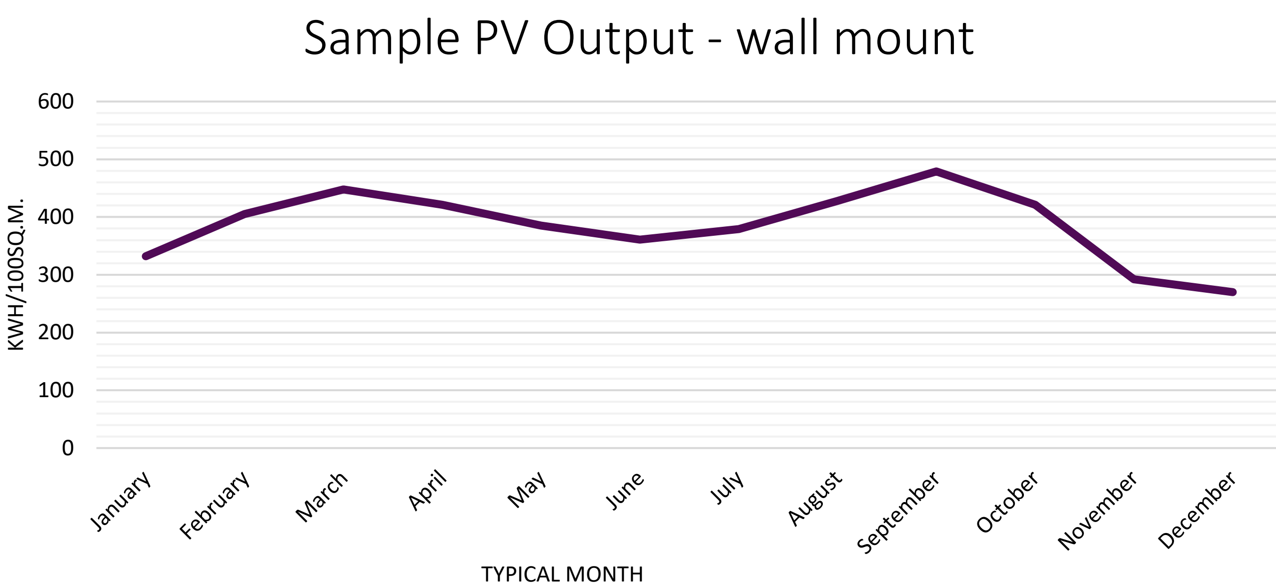


Figure 6: Estimated performance for a 5.7 kW wall mounted BIPV array

The graph above illustrates a sample of BIPV performance, vertical, 100 m^2, and 5.7 kW and 0% transmission (opaque from inside to outside), producing about 4,000 kWh/yr. At increased transmission (opacity), the output goes down as the light transmission goes up. At 15% transmission, the system would be 3.5 kW and produce about 2,800 kWh/yr.

Of the BIPV applications, a fully integrated PV envelope will be more expensive due to the structural elements required to complete the wall. Though a sample has been shown above for 100 m^2, most BIPV systems are at or above 1,000m^2 before the benefits of scale are available. An estimated cost for a full BIPV wall can be expected to be between $1 million and $1.5 million depending on the fastening system. As a result, the paybacks tend to be at ~20 years without the cost of carbon included.

A wall mounted BAPV (basically an array mounted on racking onto an existing wall) can be expected to cost about half of a BIPV but is more dependent on the structural integrity of the existing wall and will not produce as much electricity as a roof system due to its vertical aspect. The paybacks are therefore less than a fully BIPV, but more than a roof mounted, ballasted system.

As for any PV system, the connection must be evaluated before making the decision to go forward with an installation. This is done early in the design process in coordination with the local distribution company.

1.6 Energy Modelling

Commercial grade software, properly used, can calculate the expected energy generation to about 95% accuracy. Note also that year to year weather variations can result in production swings of about 5-10%. Helioscope, PVSYST, PV-Sol, and RETScreen are well known simulation tools. There are also very good shading study tools that help to fine tune the performance potential and should be included in a PV project development.

We recommend any modelling include a long-term performance timeline (i.e., 30 years) and include GHG avoidance metrics (both annual and marginal emissions). Models should include best estimates for electricity and GHG costs for the life cycle. We recommend the levelized cost of energy calculations be prepared that include estimated replacement/repair costs for inverters as well as annual cleaning.

Early evaluation of a site can be done by the FCM using relatively easy to use software such as RETScreen which can reveal if a site is worth more investigation. The services of a professional modelling team should be retained for more detailed site assessment (they typically also complete shadow studies and can offer structural services).

1.7 Procurement

Given the robust market for PV systems, The Town will have access to quality suppliers, consultants, and products. There is not expected to be any issue with sourcing multiple competitive quotes for this work through normal procurement processes. Retain the services of subject matter experts to assist with the development of request for proposals and to help with the evaluation of the responses. Tender scope should include site assessment, shadow studies, structural, electrical, performance, pre-CIA, CIA services.

Procurement polices in place now and those being recommended encourage life cycle cost analyses. For generation systems this is the preferred way to evaluate a project and leads to the levelized cost of energy (LCOE) comparisons. There are many jurisdictions adopting a cost/kW installed as the vendor selection tool. This can be achieved if the tender defines the minimum array size (kW_{DC}) to compare vendor submissions evenly.

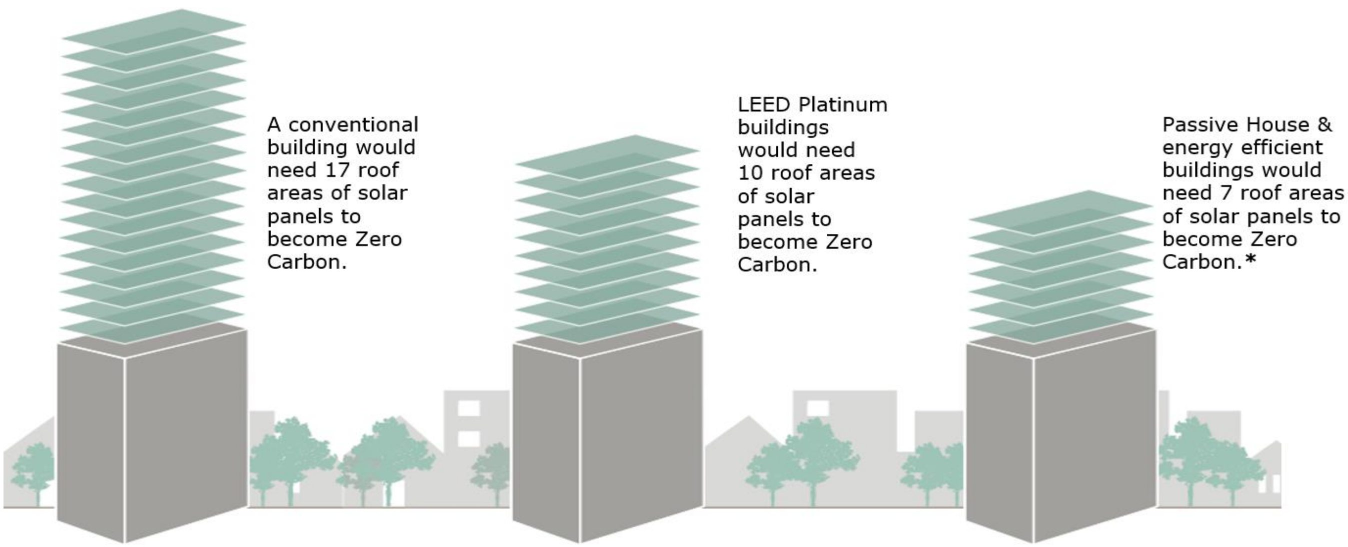
A good understanding the site will affect the overall capacity, layout, and technology choice. The report provided by each respondent will illustrate a suggested PV array layout from which the cost/watt and annual kWh can be shown. This information is included in the evaluation matrix along with a ranking for vendor PV application competency tests and experience. As technologies are improving constantly, it is recommended to specify product performance that is at the upper end of the efficiency range (i.e., maximize kWh/kW_{DC}). All assumptions, technologies and efficiencies should be listed for comparison amongst the vendors.

1.8 Barriers to Implementation

Space Requirement

Based on the technology review of solar PV, one of the key barriers for implementation will be the shade free space requirement. A typical solar PV system would require about 10 sq. m of space per kW installed (0.8-1 $kW_{DC}/10m^2$ roof area). When considering the use of PV technology, it should be noted that the more energy efficient the building is, fewer solar panels are required to make it zero carbon.

The figure below shows the correlation between energy efficient building design and future renewable energy requirements in terms of solar panels. The image also references the total amount of roof space that would be required to accommodate the solar panels required for Oakville's buildings to reach zero carbon.



Source: New Buildings Institute: Net Zero and Living Building Challenge Financial Study: A cost comparison report for buildings in the District of Columbia

Figure 7: Illustrating the impact of building efficiency on PV size to bring a building to net-zero carbon.

Other Considerations

Barriers will typically be related to structural, solar access, connection capacity, and costs, then by Town policy, accepting life cycle cost models and possibly public reticence to renewable energy (the "look"). Structural and connection capacity are critical and usually cost prohibitive to overcome if a site is not suitable due to these reasons. When this is the case, The Town should direct the efforts to more pragmatic sites using an evaluation/ranking matrix that compares LCOE, longevity, costs, and public value for each site.

Town policies and building design standards can be used to ensure renewable and alternate energy systems are considered as a normal component in developing a project, both new and retrofits. Sometimes (though rarely for PV of late) the public perception of alternate energy is against it as "unusual" or "too different" to be taken seriously. This attitude can derail an otherwise solid generation concept and is best dealt with through awareness and education of the benefits. New developments in the planned intensification growth areas should include solar energy as a default consideration when site preparation can be included from the beginning.

1.9 Current/ Future Implementation in Municipalities & Equivalent Organizations

Solar PV has been installed across numerous municipalities, including multiple projects within The Town itself. The City of Toronto, Guelph, Hamilton, and other near-by communities have robust build out programs across their building portfolios. Municipalities have considered financing models such as:

1. A roof lease model, whereby an annual lease payment to the building owner is made by a private developer who then owns, operates, and maintains the system for a set lease term, selling electricity directly to the grid.

2. Ownership model with costs paid directly to a solar contractor based on prevailing procurement policies. An annual maintenance agreement could then either be signed with the contractor, a specialist maintenance contractor, or the system may be maintained in-house staff.

3. Local infrastructure cost (LIC), green bonds and property tax-based financing are concepts that have been used in many jurisdictions and can be considered to finance the projects.

4. Canadian tax code (CRA 43.2) allows for certain depreciation schedules that benefit renewable technologies and could be offered to entities that can use the value of the depreciation to offset income taxes.

1.10 Strategic Direction

Solar energy is an accepted technology, lasts a long time and showcases the use of renewable energy very well. The direction would be to promote the installation of PV wherever feasible and aim for a minimum contribution to the corporate electrical loads from solar power by 2030 and beyond. This will be a balancing act between the low carbon electricity grid, though high cost, versus the low cost and high carbon of natural gas. The tables on the page below illustrate the scenarios for offsetting only the electrical loads for the corporation and the potential if The Town were to go to full electrification and use PV to offset the net carbon that results.

PV system applications be investigated at all new construction and major renovations, in particular when roofs are being upgraded. Net metered systems are recommended and should be driven by minimum energy performance milestones. Be prepared to enter into a virtual power plant application as they emerge, and pilot project opportunities appear.

The following tables describe the scale of PV required to achieve a range of electricity contributions to the Town's grid purchases (2019) for a selection of properties. An electrification path combined with offsets from PV as natural gas heating is reduced. The table below outlines the sampled facilities in the four archetypes.

Table 5: List of buildings used to estimate PV array options – representative of complete Corporate portfolio

Cultural & Recreation	Operations & Administration	Arenas	Other
Oakville Trafalgar Community Centre	Transit Facility	Maple Grove Arena	Salt & Sand Structure
Trafalgar Park Community Centre	Town Hall	Kinoak Arena	Public Parking Garage
Queen Elizabeth Park Culture and Community Centre	Central Operations Depot	Sixteen Mile Sports Complex	Parks Outdoor Washrooms
Glen Abbey Community Centre	Fire Station 3 (new)	Joshua's Creek Arena	Parking Meters
River Oaks Community Centre	North Operations Depot	-	Parks Lighting
Sir John Colborne Recreation Centre for Seniors	-	-	Splash Pads
Central Library	-	-	Street Lights
Oakville Centre for the Performing Arts	-	-	Traffic Lighting
Centennial Pool	-	-	-
Iroquois Ridge Community Centre	-	-	-

Table 6: Illustrating the contribution from PV for electrical portion loads only

Building Type	Electricity Only (2019)		PV req'd for 10% GHG reduction (kW)	PV req'd for 20% GHG reduction (kW)	PV req'd for 40% GHG reduction (kW)	PV req'd for 80% GHG reduction (kW)
	tonnes	kWh				
Culture & Recreation Facilities	413	10,327,889	898	1,796	3,592	7,185
Operations/Administrative	379	9,464,000	823	1,646	3,292	6,584
Arenas	291	7,268,539	632	1,264	2,528	5,056
Other	216	5,397,088	469	939	1,877	3,754
Total	**1,082**	**32,457,516**	**2,822**	**5,645**	**11,290**	**22,579**

Here we see the PV sizes to meet a range of GHG reductions for the corporate electrical loads only, based on 2019 electricity. The estimated area required for the PV array sizes will be about 10 times the kW value in square meters, i.e., 898kW will require ~8,980m^2 of roof/ground space.

The following table shows the estimated PV sizes required if all thermal loads were met with electricity then offset using a range of contribution per centages by PV arrays. This is a high-level exercise to show the approximate scale of the PV systems to offset the increased electricity for the sample buildings shown above. This does not cover the complete Corporate portfolio.

Table 7: Full Electrification Scenario and the Impact of PV to offset

Building Types	Natural Gas (2019)		Electrification of all Natural Gas – sample sites				Est. PV kW to offset % of GHG/yr – sample archetypes			
	Quantity	GHG	Electricity (2019 base)	Electricity (HP+Elec boiler)	Total Electrification	Electrification GHG	10%	20%	50%	80%
	m3	Tonnes	kWh	ekWh	ekWh	Tonnes	kW	kW	kW	kW
Culture & Recreation (10 sites)	1,495,746	2,827	10,327,889	8,333,444	18,661,333	746	1,696	3,393	8,482	13,572
Operations/ Admin. (5 sites)	1,057,469	1,999	9,464,000	5,891,614	15,355,614	614	1,396	2,792	6,980	11,168
Arenas (4 sites)	504,674	954	7,268,539	2,811,755	10,080,293	403	916	1,833	4,582	7,331
Other	9,008	17	5,397,088	50,187	5,447,276	218	-	-	-	-
Total	**3,066,897**	**5,796**	**32,457,516**	**17,087,000**	**49,544,516**	**1,982**	**4,009**	**8,018**	**20,044**	**32,071**

This assumes that natural gas loads are met using a combination of heat pumps (75% of total load) and electric boilers (25% of total and for peaking) of the annual heating loads. The base electricity will stay and represents ~50% of the equivalent energy profile, with natural gas, as ekWh., ~50%. The effect of the heat pumps is to provide a large portion of the heating (~75%) at an annual COP of ~3.5. This is a full electrification scenario. For example, at the Culture & Recreation sites, to replace the heating by natural gas with electricity would be ~16,308,148 kWh and add ~746 tonnes CO_2, however, avoiding a net ~2,081 tonnes CO_2 (2,827 – 746). An array of ~1,696 kW would offset 10% of this new CO_2 level. The impact of PV for each archetype, within the sample, with increasing amounts of PV from 10% to 80% is shown.

The tables above assume the electrical loads in The Town for these sites stay about the same as in 2019. The PV array sizes range from between 4,009 kW (10%) to 32,071 kW (80%). Recall that the area required is estimated at ~10 times the kW required in square meters (i.e., 3,370 kW needs ~33,700 m^2 of ground/roof area). For reference, the PV system at Glen Abbey is ~226 kW_{DC} and covers ~1,800 m^2; the system at 16 Mile is 549 kW_{DC} and covers ~5,000m^2.

The Culture & Recreation Facilities and Operations/Administration buildings offer the most opportunity for GHG reductions through electrification. The "Other" row includes streetlights, parking, splash pads, etc., with no to very low natural gas use and why the GHG reduction is negative. This group is not included in the calculations that follow.

The following table illustrates estimated cost performance for the Culture & Recreation sites, estimated costs (2020), using an electrical escalation of 2%, a PV panel degradation of 0.55%/yr. and actual GHG costs/tonne to 2030, again at the range of PV system contributions.

Table 8: Estimated PV array performance to 2030

Culture & Recreation	PV system size kWdc	Est Cost	Est Energy Generated kWh/yr.	Est Value $ 2021	Elect CUSUM $ value 10 yrs.	Tonnes/ yr.	GHG CUSUM value 10 yrs.	Total value $ 10 yrs.
10% from PV	1,483	$2,817,700	1,683,205	$252,481	$2,752,896	72	$72,258	$2,825,154
20% from PV	2,965	$5,633,500	3,365,275	$504,791	$5,336,060	145	$144,467	$5,480,527
50% from PV	7,413	$14,084,700	8,413,755	$1,262,063	$12,107,596	362	$361,192	$12,468,788
80% from PV	11,860	$22,534,000	13,461,100	$2,019,165	$21,344,239	579	$577,868	$21,922,107

The recommended strategic direction includes:

1. Anticipate and estimate electrification of natural gas heating of The Town's corporate energy loads.
2. Estimate impact of electrification and consider offsetting the increase with PV.
3. Trigger PV opportunity reviews when roof upgrades and HVAC replacements are being planned.
4. Set PV contribution levels based on the assumption that electrification will occur over the next 20 years.
5. Target 80% of full electrification levels by 2050.
6. Encourage Town policy to meet these goals; include PV into revised building performance standards.
7. Investigate opportunities to participate in virtual power plant projects.
8. The table below suggests a PV installation schedule. * "Other" section energy is based on the electrical loads for that sector as natural gas loads are minimal. This illustrates the total electrical loads that could be offset by the PV in stages based on 2019 energy profiles.

Table 9: Proposed PV Installation Schedule to address GHG contributed from natural gas and electricity

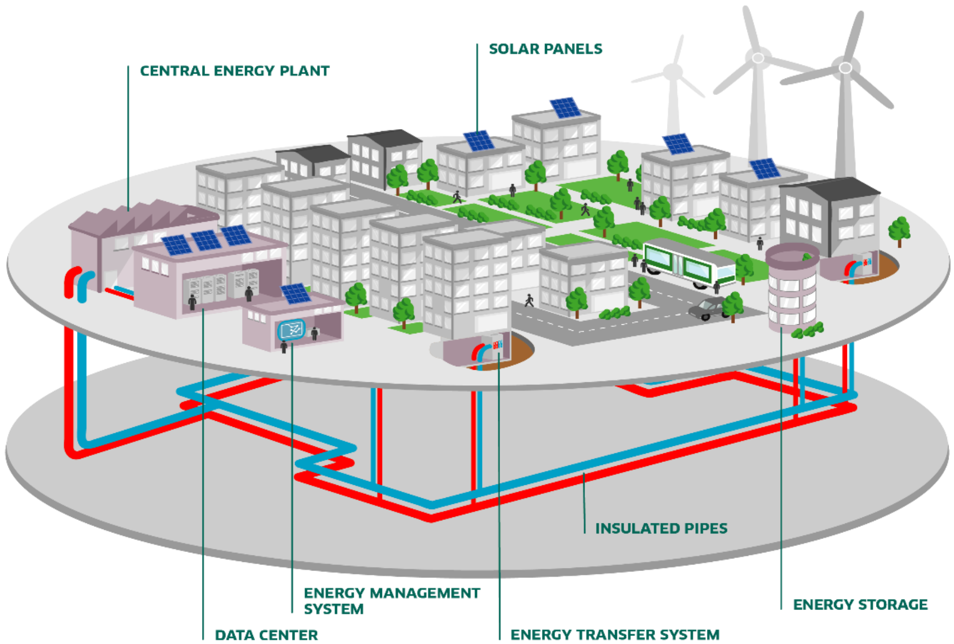
Building Types	2025	2030	2040	2050
	kW installed	kW installed	kW installed	kW installed
Culture & Recreation (10 sites)	1,696	3,393	8,482	13,572
Operations/Administrative (5 sites)	1,396	2,792	6,980	11,168
Arenas (4 sites)	916	1,833	4,582	7,331
Other	472	945	2,362	3,780
Total	**4,481**	**8,963**	**22,406**	**35,851**
Total estimated kWh/yr. contribution	**5,400,000**	**10,760,000**	**26,700,000**	**43,000,000**

The proposed system sizing shown above represent between 10% (2025) and 30% (2030) contribution to the corporate loads. It is possible the level of PV output at scales shown for 2050 could offset close to if not all of the corporate electricity loads. These systems can be installed on available roof areas (horizontal racking) or a combination of roof and parking lot/ground areas. Arrays proposed from ~2025 on would require large land-based and significant building integrated arrays.

2 District Energy Systems

2.1 Product Background

There are many projects that could be deemed as district energy. For this report we define it as multiple buildings connected through a network of pipes for heating and/or cooling, with energy provided by a centrally located generation plant. These are common in Ontario on universities, college campuses, and hospitals. A typical district energy system is demonstrated in the following figure.



Source: https://www.engieservices.ca/district-heating-and-cooling

Figure 8: Schematic of DES concept

By centralising generation equipment, individual buildings only have heat exchangers and localised pumping systems to distribute heating/cooling water. This has the following impacts:

- Showcases the community commitment to GHG reduction and energy efficiency
- Ability to specify high efficiency, modular and centrally located equipment
- Greater control of operations, energy use and price stability
- Reduced mechanical equipment within buildings
- Centralized, consistent maintenance and operation by dedicated staff
- Production and transmission within the community keeping utility value local
- Ability to partner for ownership and operation of the plant and distribution
- Energy price stability and bargaining power amongst energy users
- Ability to integrate renewable energy, e.g. solar thermal, geo-exchange, and other alternate sources
- Increased energy supply resiliency

2.2 Market Overview

Central plants and district energy systems (DES) are common in Canada and have been so for a long time. Equipment is no different from other heating/cooling applications, while controls systems are also commonplace. Technologies that can contribute to a DES are becoming more common such as wastewater energy capture with heat exchangers and heat pumps. There are an increasing number of energy-as-a-service companies entering the DES marketplace. These can provide the financing, engineering, design, and operations The Town can partner with, connecting to the DES development with a long-term energy supply and carbon credit contract. The Town brings certainty to the load profiles with well understood growth plans and the energy service provider has the engineering and staffing to maintain the DES with a vested interest in efficiency. This is now a conventional and mature market. There are design firms and consultants that can evaluate and prepare feasibility studies and plans for community scale DES making competitive bidding possible.

2.3 Application to Building Portfolio/Grid Connectivity

Scale

DES is best considered for new developments where thermal off-takers (facilities that will contract to take the thermal energy from the DES) can be designed into the plan for the DES from an early stage. Retrofitting an existing community for the switch to DES, unless a major street level upgrade is planned and a central plant possible, is typically too disruptive and costly to consider. Money is better spent replacing old heating/cooling systems and upgrading the envelopes and other conservation measures for existing building stock with a view to high performance designs.

Any new Town developments where a DES is considered should discuss the connection of Town facilities early in the design stages. The Master Plan includes six intensification areas that could include district energy systems combined with renewable and alternate energy technologies. These will be more efficient than decentralized systems and offer the Town corporation sites opportunities for increased system efficiencies, lower carbon energy sources and smaller mechanical rooms. Combined with upgraded building energy standards, developing with a DES plan will ensure the net increase in energy and GHG levels are reduced across the Town.

When available, the Town should approach a DES from a life cycle cost perspective. Comparing a DES with multiple conventional systems over a full life cycle should be used and include the costs/benefits of reduced GHG emissions. When a DES is being considered within the Town, FCM should facilitate a feasibility study to fully understand all the opportunities a DES could bring to the corporation including a partnership ownership/operation model with long term energy and carbon credit contracts.

Currently, The Town is reviewing DES models for community level projects. The Corporation, coordinated through the FCM, should be engaged with these assessments as many of their properties will be included inside the new and/or refurbished communities. Any DES developments where Corporate facilities can join should be considered where possible either at early design, large renovation, or the opportunity to participate. Most DES arrangements look for thermal off-takers to help make them feasible – the Town would provide a DES developer with certainty and a long-term contract that are desired.

Low Energy Building Design

Low energy buildings designs should be pursued, consistent with long term conservation planning, and discussed further in the policies section of this report. This is in keeping with The Town's long-term goals and reduces the carbon footprints of new and renovated facilities. With low energy designs the DES would be sized accordingly and improve the life cycle cost metrics. It is important for the success of the application of a DES concept that realistic loads and profiles are taken into consideration as well as the potential for growth in the community.

Developing and enforcing low energy/high performance designs should apply to both new and existing buildings. The Town should target energy performance KPI's that are staged in line with current low energy design standards such as the Toronto Green Standard at a minimum. In fact, it is recommended the Town adopt higher performance standards for new and renovations. The FCM is tracking energy performance now and should continue to do so and actively search for energy conservation measures. Efforts to reduce the thermal loads should be pursued when ever possible, thereby making them more applicable for future DES connections which favour lower temperature sources for heating.

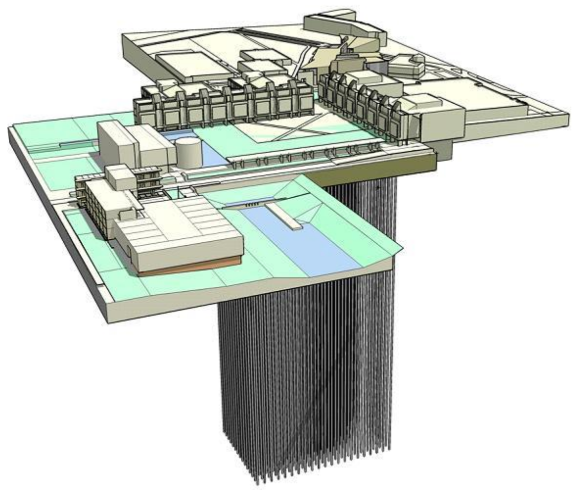
District Energy Plant Type & Heat Pumps

While gas boilers and electric chillers have been the default technologies employed, heat pumps with a geo-exchange storage system are a technically viable and low carbon option. Consideration for peak heating during extreme low outdoor temperatures (which occur ~2% of the winter heating hours each winter), and the fact that weather patterns are shifting to less heating days is prudent for any DES developments.

DES plants are typically designed to supply lower supply temperatures than common in conventional heating systems as they increasingly incorporate heat pump technologies for heating. Therefore, it is even more important to ensure high performance building designs are enforced in new building designs and efforts made to reduce thermal loads in existing buildings to allow for low carbon, low temperature designs (i.e., 40 – 60 °C) to satisfy the heating loads most of the year.. A complete DES review, feasibility and design process will determine the best combination of low temperature services and peak heating supply systems and still maintain an efficient and low carbon facility (e.g., see the discussion above in the PV section around a combination of heat pumps and electric boilers).

These are complicated designs and require design expertise offered by consulting firms familiar with DES concepts.

Please see the geo-exchange heat pump section for more detail. The following schematic shows the geo-exchange system that is at the core of the UOIT central plant in Oshawa to show the scale of a heat pump system.



Source: https://shared.uoit.ca/shared/faculty/feas/images/pictures/BHTES-model.jpg

Figure 9: sample of deep borehole configuration for a large ground source heat pump DES

2.4 Economics

A long-term life cycle cost analysis is required for a DES development. The costs for a DES are dependent on the application, size, location, fuel mix, off-takers, maintenance, and operations therefore difficult to predict without a better understanding of the buildings and loads. Consideration for the use of individual energy systems against the benefits of a DES for energy and GHG factors should be used. A DES allows some certainty around utility rates and maintenance over long contract terms. Because of the long-term nature of a DES operation, alternate energy systems that would otherwise have long paybacks can be considered as they will be a part of a long-term utility contract. This allows the benefits of solar thermal and waste energy capture to be considered and help keep utility costs low. A DES will have a lower GHG footprint than multiple heating/cooling plants which reduces the exposure to carbon costs later.

As indicated above, The Town should consider a third-party ownership model for the DES which will use a long-term financial model for analysis and a business case. A central plant is a reliable energy supply, stable and predictable cost, and low carbon that is shared among the clients which could include the Town's facilities. There are several factors and variables to consider (energy cost projections, GHG costs, growth, product costs, installation, maintenance, etc.) and that will be assessed by a feasibility study. The FCM is well positioned to steer such a study and ensure the facilities are well represented.

2.5 Carbon Offset Potential

There is more opportunity for precise control of the total energy delivered with a DES and therefore better control of energy use and emissions. In addition, the cost and operational efficiencies for integrating a large geo-exchange or renewable energy system would be significant for a large central plant system. There is the potential for improved long-term efficiency and lower carbon operation if given that centralised maintenance and operation is more consistent than for distributed heating/cooling plants. The case for micro-grid energy systems can be utilized where possible. These are well suited for locations where annual thermal loads are present which can be shared through the year. Using a DES in the planned intensification growth areas would offer the opportunity to plan for reduced GHG levels compared to conventional heating systems.

Geothermal Systems Combined with Solar

One area for consideration is the use of solar thermal energy in combination with a DES when a geo-exchange system is included. This combination further reduces the energy and carbon footprint of a geo-exchange system and the DES network in general. This concept is used in Europe and successful in Alberta at Drake Landing Community Solar (see description later in this report including a link to the site).

In discussion above (Photovoltaics) combining PV with a heat pump based thermal distribution can offset a large portion of the net GHGs.

2.6 Energy Generation Potential

Employing heat pumps combined with solar thermal (or photovoltaics) have energy generation potential. Please see the two separate sections for these technologies within this section. A DES by itself is not a renewable energy system but one that reduces the carbon load compared to a distinct energy plant in each building.

2.7 Energy Modelling

It is critical to understand both the peak and annual energy consumption profiles for each building connected to the district energy system to size the central plant and to balance loads. This is completed for new construction and renovation projects using an hourly energy model of loads and utility profile analyses with an understanding of the building occupancy loads. Though the long-term simulation of a district energy system is relatively complex (hourly with multiple variables), the process has been developed and implemented by several consultants familiar with the application.

The modelling for new developments will require assumptions around future building loads and growth that will be defined by The Town in collaboration with the consultants. It is prudent to assess a DES under low, medium, and high growth scenarios. Heat pumps and solar thermal will be addressed elsewhere in this section.

Engineering consultant’s expert in the development and assessment of these types of systems and the integration of various energy resources should be retained early in the development stages.

2.8 Procurement

The Town has procurement polices that will address the requirements for selecting the consultants and general contracting partners. The Town, through the FCM, should be made aware of any DES feasibility studies and developments. Procurement policies within The Town include life cycle cost analysis protocols and should be enforced for any new energy system development.

Should The Town consider third party ownership/operation, procurement policies and the terms of the contract need to be defined for such arrangements, reviewed, and made appropriate for that ownership model that typically run for many years. This type of ownership/operating model can have long term cost benefits for The Town and should be reviewed when a large DES is considered. There are firms that will take on the ownership and operation of these assets. The FCM should be involved with any discussions around DES opportunities from an early stage.

The FCM should connect with any community group efforts for DES developments and participate in the evaluation of the possibilities and ensure procurement policies that affect the corporation are taken into consideration.

2.9 Barriers to Implementation

The major barrier is scale and location. Without the necessary building density, district energy is rarely a viable economic option, given higher first costs and operational management requirements. The Town’s planned six intensification developments should include DES evaluation when they are being designed. Currently, there is a community effort to assess a DES solution which should be considered when the corporation is considering a DES plan.

Though the Town is not planning to become a large electricity generator, they should be aware that The Master Plan defines setbacks for large generation projects and will need to be met or varied by Council for any DES plant. Any electrical generation will need to be discussed with Oakville Hydro if it is to be integrated with their grid.

2.10 Current/ Future Implementation in Municipalities & Equivalent Organizations

Town of Markham – Markham Energy District

The Town of Markham has owned an operated a district heating and cooling system on a new development site since the early 2000's. It serves both Town of Markham and private assets, including a YMCA and a hospital. Markham District Energy is wholly owned by the Town of Markham.

City of North Vancouver – Lonsdale Energy

Like Markham, this is a wholly owned subsidiary of the City. They operate multiple smaller plants serving over 7 million square feet of City, residential and private commercial developments. They state that they are committed to a move to non-carbon fuels 'when it is economical to do so'. One of the plants already has supplemental heat supplied by solar thermal.

EnerFORGE – Oshawa Power Inc.

This private company owns multiple district energy assets including the large GSHP-based plant at UOIT, Regent Park's central plants and a combined heat and power plant at Durham College.

2.11 Strategic Direction

The Town is planning to develop intensification neighbourhoods which could be candidates for a DES model. This is being studied now under a separate program within The Town. The corporation and FCM should maintain a connection with this effort to be aware of opportunities to design new buildings or renovations that can connect to a community DES. The community uses many corporate facilities now so it is very likely there will be a need for buildings within the developments that will come under the FCM.

Other DES opportunities within the FCM should be pursued when available, such as for large athletic facilities with multiple thermal off takers nearby. In all cases, renewable energy systems should be considered in the DES designs.

1. Connect with and participate with any community level DES developments
2. Ensure building performance standards (new and renovation) anticipate DES possibilities including designs that can use low temperature heating water and consideration for connection to a DES grid.
3. Encourage a life cycle cost analysis, including the cost of carbon, for evaluating a DES connection or campus for multiple Corporate buildings.
4. Ensure RE such as PV and solar thermal energy is considered during DES evaluation and design and target a RE contribution fraction in keeping with that suggested for PV to offset GHG from the DES, i.e., 10% for sites developed by 2025; 30% for facilities developed by 2030; 50% by 2040 and 80%+ by 2050.

3 Geo-Exchange Heat Pump Systems

3.1 Product Background

This refers to an electrically driven heat pump system that employs an underground energy storage system via an array of (typically) vertical boreholes. It does not use the ground as a source of "free" heat rather uses the ground to store heat exchanged trans-seasonally – the heat rejected from the buildings during summer cooling recharges the ground for wither heating. This is a critical design criterion for the success of any ground source heat pump system. The ground temperature is stable below about 20ft giving typical 650+ft deep borehole array access to a large bank of stored energy. Proper application of the technology requires balancing the energy flows between summer and winter to meet the loads for optimum performance. Heat pumps and geo-exchange at a range of scales are well understood and suitable for individual building and district energy designs.

Central to a geo-exchange system is a heat pump, which consists of an electrically-driven compressor which can upgrade low-grade heat in the ground (e.g. 60°F) to a usable higher grade heat (120°-140°F), which is suitable for heating, or reject the heat to the ground in the summer for cooling. The heat pump "switches" back and forth between heating and cooling according to the seasonal demands. Heat is transferred to and from the ground with a heat transfer fluid, typically food grade propylene glycol.

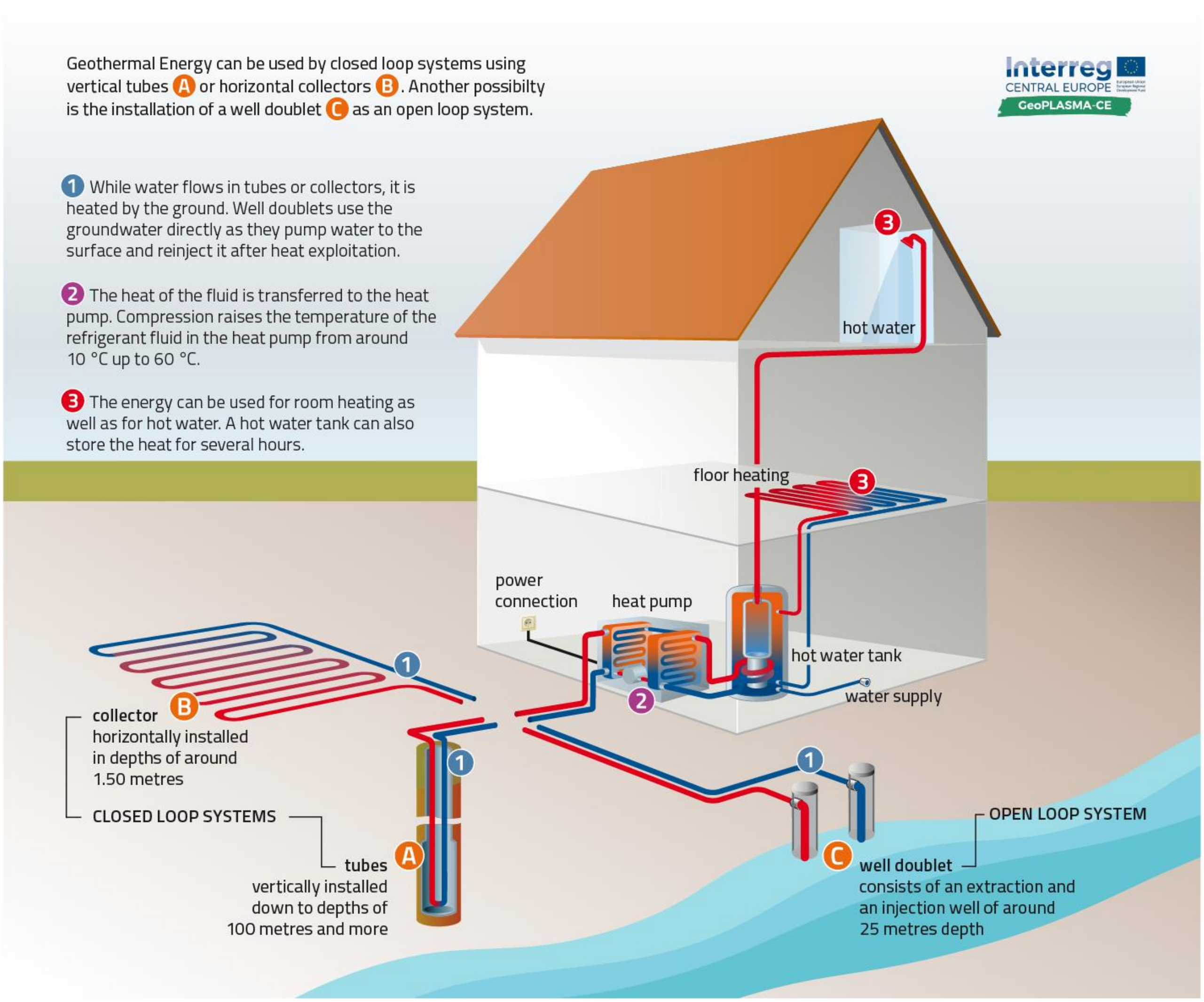
Trans-Seasonal Storage

In the summertime, waste heat that is normally ejected by a conventional air conditioner condenser or cooling tower is pumped underground through a series of piped boreholes (typically 650ft deep), warming the surrounding ground which has an ability to store this heat over time. During the heating season, this low-grade heat is extracted from the ground an upgraded by the compressor, making it appropriate for building loads. By removing this stored heat during the winter, the ground cools which then becomes available for cooling during the summer and the cycle repeats as the ground is re-warmed. A geo-exchange system is best thought of as a trans-seasonal energy storage system. Keys to its proper function are:

- A balanced load, whereby summer heat rejection is close to winter heat requirements. That way the ground's temperature is balanced, and heat pumps can operate throughout the year without short-changing any season.
- A good understanding of the ground's structure and thermal conductivity for the full depth of the boreholes. This dictates the number, depth, and performance of required boreholes.
- Accurate building energy simulations prior to design and construction to understand the annual (hourly) heating and cooling requirements. This drives overall system size and whether supplemental heating/cooling is required.
- Supplemental heating from solar thermal panels or other alternate energy sources can be designed into the system and either used directly or stored to reduce heat pump electrical consumption and increase overall system efficiencies at reduced GHG levels.

Considerations

The most implemented geo-exchange systems are closed loop systems. Closed loop geo-exchange systems use a mix of antifreeze and water which cycles through pipes buried in the ground to transfer heat – to the ground in the summer and from the ground in the winter. In special cases (and when permitted), groundwater can be used as a natural refrigerant to transfer thermodynamic energy as water is an excellent thermal conductor, and groundwater is naturally insulated and much closer in temperature to the surrounding ground. These are classified as open loop systems. The following figure depicts the differences between typical closed loop and open loop geothermal systems. The image shows a residence – the scale of collector and well size increases for commercial building loads.



Source: GeoPLASMA-CE – https://portal.geoplasma-ce.eu/

Figure 10: Typical water-based heat pump layout.

For a well or an aquifer to be used as an open loop, three criteria must be considered: well capacity, water chemistry, and pumping power costs – which are explored below.

Well Capacity

Many sites do not have enough water in the earth to satisfy the water flow rates of a geo-exchange heat pump. The amount of water required for the operation of a geothermal heat pump on an open loop is 1.5 gallons per minute, per ton of capacity. The temperature of the water may increase the flow requirements. During heating mode, if the water temperature is lower than 41°F, the flow must be increased until the leaving water temperature stays above the freeze protection settings. In warmer climates, during cooling mode, the water flow rates may need to be increased so the geothermal heat pumps efficiency will be acceptable.

The annual amount of water used by a 3-ton geothermal heat pump is about one million gallons a year. This is a very large amount of water, but since geothermal heat pumps don't change the water quality, only water temperature, all of the water used by a geothermal heat pump can be safely returned back to the earth without contaminating the ground/aquifers or wasting any water.

Water Chemistry

There are many factors that will determine if your water chemistry is satisfactory. Poor water chemistry can either scale or damage your piping and heat exchanger components. The mineral profile, pH, and temperature of the water must all be within the correct ranges for the well water to be compatible with a geothermal heat pump's water heat exchanger and system components.

Some types and amounts of dissolved minerals will scale heat exchangers over time. Scaled heat exchangers can be cleaned, but it is a significant maintenance consideration and can lower operating efficiencies.

Well Water Pumping Costs

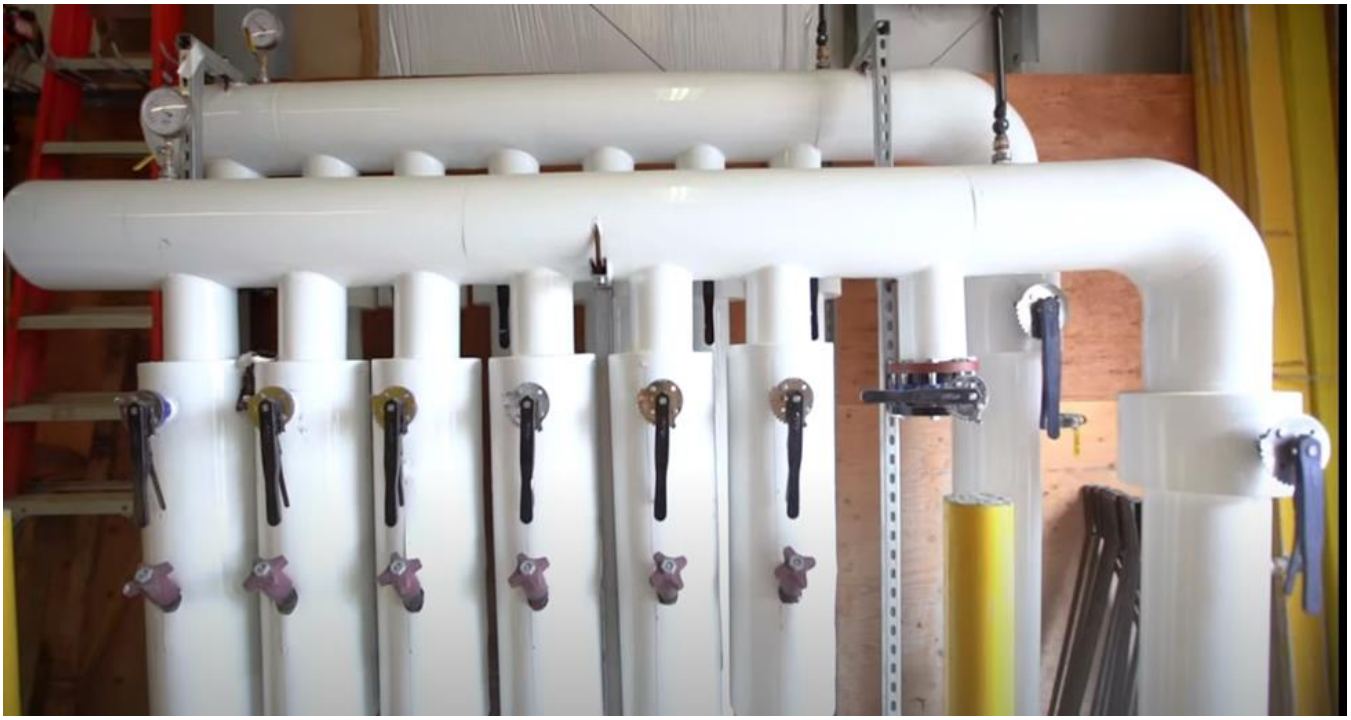
The costs of the well pump will also affect whether a well should be used for an open loop. The main costs of pumping well water the size of motors to overcome the total dynamic head of the well and the type of motor used in the pumping configuration. The cost of operation of the well pumping should be considered in the business case to determine the ongoing operating costs for the application.

An open loop geo-exchange heat pump is a very good option for building owner/operators to consider where lower upfront capital costs are desired and where there is sufficient ground water quality and capacity available. An open loop ground-source system can potentially create a capital cost reduction in the range of 30-70% when compared to the cost of a closed loop and often delivers the most energy efficient performance available. This solution is recommended where applicable.

Efficiency >100%

The key benefit of using heat pumps is their ability to generate more heating/cooling energy than the electricity used to drive its compressors. Through the vapour compression cycle, a geo-exchange heat pump can generate on average approximately 3.5 units of heating energy for each unit of electricity consumed (known as the coefficient of performance or COP). A heat pump’s ability to compete on cost with natural gas is therefore purely driven by the comparison of the COP vs. the cost premium of electricity per delivered unit of heat.

Blackstone implemented a 250-ton Geothermal Heat Pump System and 500kW Solar Array at Conestoga College. These measures resulted in a reduction of Scope 1 GHG emissions by 90%. Additionally, the solar project generates 800MWh of energy annually. These solutions offset 315 tCO_2e respectively annually.



Picture 1: Blackstone Project – Conestoga College – 250-ton geothermal ground-source heat pump system

Current/Future Geoexchange Applications

Geoexchange applications are being used in more municipalities and communities across Ontario. The Town currently has two such systems; one at the Transit Facility and another at the Oakville Trafalgar Community Centre (each ~180 tons). All will go through the same criteria considered by The Town of Oakville to decide how to take advantage of this low carbon and energy efficient technology. Below is a list of samples where geoexchange has been used as a primary source of heating and cooling.

1. University of Toronto, St. George Campus: This downtown campus is installing multiple geoexchange systems to help them reach their 2030 GHG targets. The Landmark geoexchange system will be installed beneath a new ~300 spot underground parking garage to supply buildings around the Circle with ~350 boreholes, 650 ft deep. A second field is at The Huron Sussex neighbourhood with ~200 boreholes on ~5,400 m^2 of land, under a playing field. This will supply heating and cooling to existing buildings on the north west quad of the campus. These systems will replace high pressure steam energy and is combined with high performance energy conservation programs to make the buildings suitable for lower temperature heating for most of the year, with electric boilers as peakers.

2. University of Toronto, Scarborough Campus: Set in the east end of Toronto, the system supplies thermal energy to a Pan-Am aquatic centre using 100 boreholes under a parking lot (300 tons cooling) and another at the new Science Building, 100 boreholes under the quad, and a third one, 67 holes, 200 tons cooling under the foundation of the building. All of these are 650 ft deep.
3. Conestoga College: This system can supply both heating and cooling simultaneously. It consists of 130 boreholes that are located under parking areas, about 40,950 ft^2 of space required.

3.2 Market Overview

Large scale geo-exchange systems are common with more than 100,000 systems in Canada. They are well understood from design through to operation and maintenance. They can be designed for a large range of application sizes including single, central systems and multiple units that can be staged.

Most major HVAC/refrigeration companies sell heat pumps. All heat pumps are covered in detail by various codes and standards. High performance specifications (many are listed with Energy Star) should be used for all designs.

The borehole drilling and connection is completed by specialist contractors of which there are a number in Ontario. Borehole drilling technology has improved and now can bore “directionally” making some locations a candidate whereas before they could not be accessed (e.g., some are now being installed under parking garages).

Cadillac Fairview Pacific Centre
Geothermal In-place urban retrofit (400 ft deep)

Figure 11: Example image of borehole rig for use in underground parking areas

Permitting is similar to HVAC applications except for the borehole component that includes concerns such as water use and storm drain loading which must be dealt with separately.

3.3 Application to Building Portfolio/Grid Connectivity

The impact of the existing building's mechanical design requires careful review. Recall that heat pumps deliver 140°F water which is typically lower than original design conditions. That said, a low temperature source will satisfy a large portion of the heating loads for most buildings through the year so that in some cases, an electric (low carbon) boiler can be used as a "peaker". An audit and energy modelling of the building will determine if a low temperature source can be efficiently used for heating and to what degree without adding too much peaker.

Careful attention to the balance of energy transferred each season is important for the success of a heat pump application. If the cooling season does not "recharge" the ground with sufficient heat, the ground may not be able to support a full heating season, leading to an increased use of supplemental heat. The same for the cooling season – if heat is not removed in balance with the winter, the heat pumps will have to "work harder" and the COP will suffer.

Heat Pump & Mechanical Systems Implications

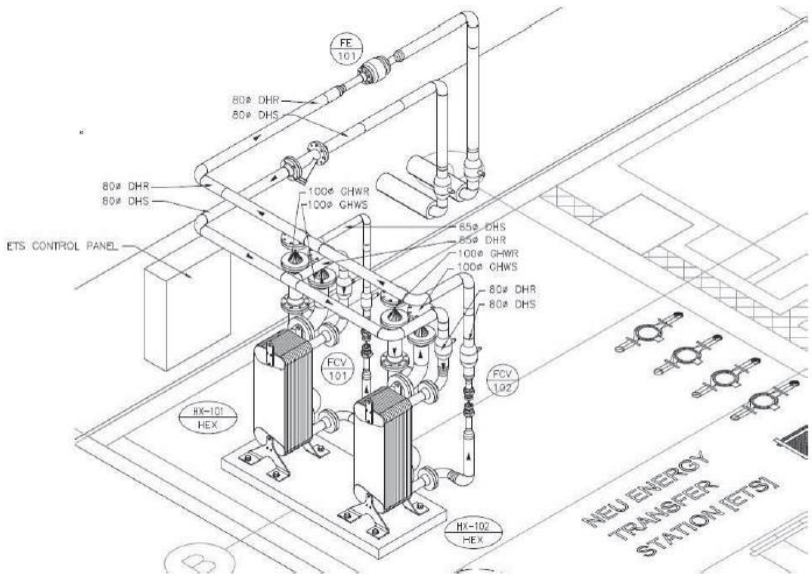
The key component within a geo-exchange system is the electric heat pump. They are available in both water to water and air to air types, meaning they can usually replace either a furnace-type HVAC system or a boiler/chiller hydronic system without much alteration.

Traditionally, the issue with heat pumps is the maximum temperature of heating fluid that can be delivered. A typical building running on a boiler loop using radiators and/or fan coils is designed to run on 180°F supply water temperature, to meet design winter heat loads. Heat pumps are currently able to reach temperatures in the region of 120°-130°F, which is not hot enough to provide adequate heat to most existing buildings. Any additional heating required to make existing terminal equipment work with lower grade heat would require the peaker (high efficiency boiler, electric heater). As indicated, a model of the building will determine the fraction of the year the heat pump will satisfy the loads and how much peaker is needed.

Electricity is about four times as costly for an equivalent kWh (ekWh) as for natural gas – about $0.12/kWh for electricity versus $0.03/ekWh at 80% efficiency, for natural gas. However, a heat pump will generate 3-4 times as much heat value for each kWh delivered so for an equally efficient building, a heat pump would be comparable to natural gas in annual energy costs. Electricity is far greener with almost six times less GHG than natural gas per ekWh delivered. This benefit is in keeping with The Town's goal to a lower GHG footprint for their assets. Using a heat pump to reduce the GHG presence is recommended as a measure to consider when a renovation is being completed and room for boreholes is available.

Note that the COP varies based on ground temperature, heat pump operating point, sizing to loads, refrigerant used etc. It is important not to focus only on the peak published COP, but the lower seasonal COP value and ensure the design teams are presenting solutions that meet the actual loads.

Recent product developments are toward high temperature grade-capable heat pumps, which will expand the range of retrofit opportunities. The Town should encourage the review and consideration of these higher temperature systems as they evolve and come to the market, which is expected to be more prevalent within 5-8 years. As this means replacing existing boilers and chillers, a retrofit will likely be complex, invasive, and technically involved project. A full life cycle cost analysis is recommended to determine the viability of converting to a geo-exchange and heat pumps in any given building or collection of buildings.



Typical energy transfer station for a geoexchange connection

Source: “City of Vancouver - Neighbourhood Connectivity Standards, 2014”

Figure 12: Example schematic of a heat exchanger transfer station for use with heat pump systems.

Borehole Installation

Even if the heat pumps are easy to install, significant site impact will be incurred with the drilling of boreholes and then routing piping into the building’s mechanical room. Parking lots are a good place for this application and should be considered if the thermal loads exist nearby. The Town already has experience of borehole installation work and understands the scheduling and site preparation needs. Currently there are not many contractors that provide drilling for borehole arrays. This should be taken into consideration when planning for a borehole field. Of note is that, currently, borehole depth is restricted to 650ft. There is a chance this will be extended to 850ft which will reduce the number of boreholes for energy capture. The technology has expanded the potential sites with the capability of directional boring making it more possible to install boreholes where only vertical drilling was possible. Drilling requires a source of water which then needs to be routed to drain systems without over-loading them or introducing sediment.

3.4 Application as Retrofit vs. New Construction/Major Renovation

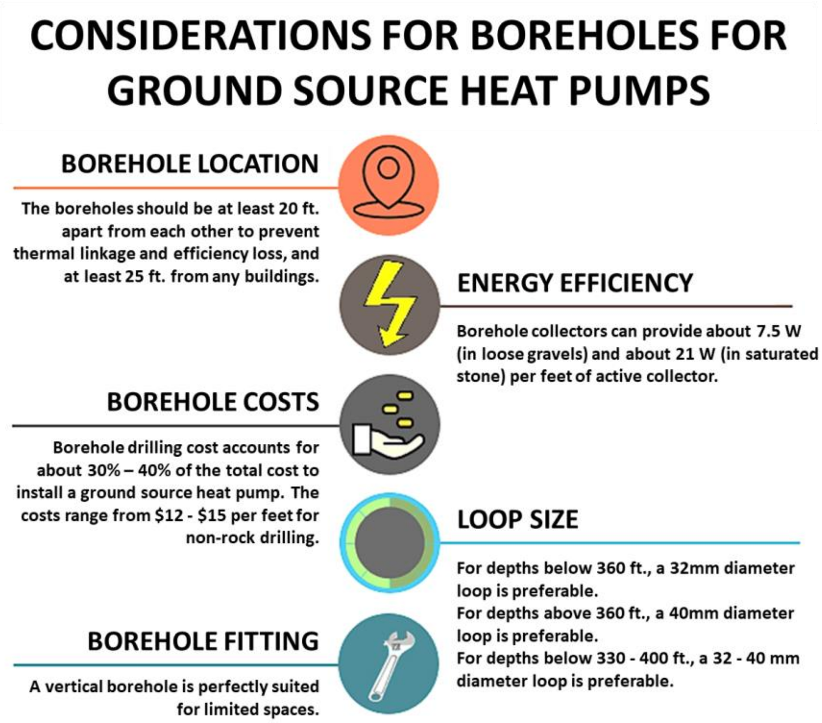
This is best applied to new construction, major renovations, significant end of life HVAC replacement, or a major lifecycle facility renovation. Available land is usually a major prerequisite though directional boring should be considered where possible. Heat pumps and geo-exchange versions will be a major solution for achieving low carbon design in the foreseeable future.

The low carbon benefits of heat pumps will make them an increasingly common solution for achieving GHG targets and recommended for use in new and renovation projects.

3.5 Economics

The costs for a geo-exchange system include engineering and other soft costs, drilling the boreholes, borehole liners, headers, and distribution, trenching to the mechanical connection points, mechanical room equipment to transfer the ground energy, heat pump equipment (central plant, distributed heat pumps), supplementary heating/cooling equipment if required and building distribution and terminal devices. A renovation will be more on a first cost ($/kWh delivered) given the need for internal design and system changes.

The costs for a typical geo-exchange field are between 30-40% of the total project cost and is fairly linear with the size of the array. Depending on the ground conditions, the ground source heat pump boreholes are drilled at about 20 feet apart from each other and about 25 feet from the nearest building. The depth is conditional on the property's characteristics (size, insulation, heating capacity) that require heating, the average being about 800 feet. The borehole requirements for any ground source system is provided in the figure below.



Source: greenmatch.co.uk (image adapted)

Figure 13: General considerations for ground source heat pump applications

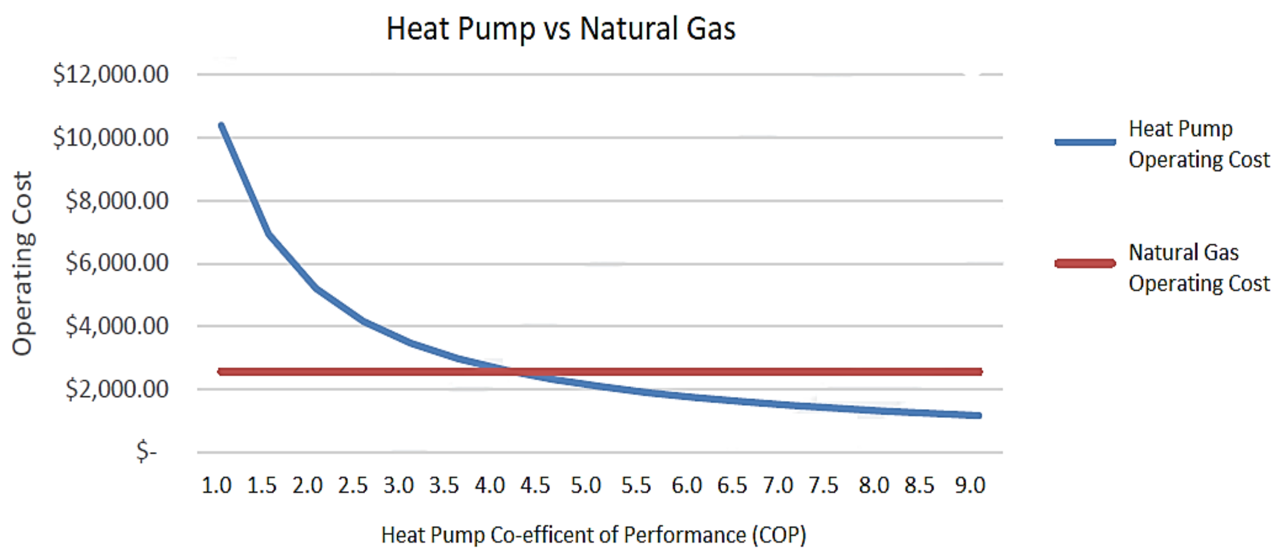
The costs and space information for a typical 250 tonne ground source heat pump, based on the specified assumptions, is summarized in the following table.

Table 10: Example of performance and costs for 250 Ton heat pump system

Metrics for a typical 250-ton Heat Pump	
Heat Pump Capacity (tons)	250
No. Of Boreholes Required	63
Borehole Depth (ft.)	800
Space between boreholes (ft.)	20
Total Land Area (sq. ft.)	40000
Drilling Cost ($/ft.)	$15
Estimated Total Drilling Cost ($)	$750,000
Equipment & Engineering Cost ($/ton)	$7,750
Estimated Total Equipment & Engineering Cost ($)	$1,937,500
Total Project Cost ($)	**$2,687,500**

The operational economics centre on the relatively high cost of electricity when compared to natural gas per unit delivered heat, though given the benefit of the COP, the actual (annual) differences are not great with cooling included. A full life cycle comparison, including the carbon costs, is recommended.

However, improvements to heat pump technology and an increased cost of carbon will make heat pumps a cost-competitive alternative to natural gas equipment. The technology cost curve mapped against technology efficiency is illustrated in the figure below.



Source: Graham Cootes (P.Eng.), HTS Toronto. Email: graham.coote@hts.com

Figure 14: Illustrating benefits for costing of heat pumps as performance (COP) improves

It is expected that the natural gas operating cost will be higher than the cost illustrated above when the carbon charges as part of the federal carbon backstop are taken into consideration.

3.6 Carbon Offset Potential

There is a significant carbon saving in the move away from natural gas. The following figure shows the carbon emissions (gCO_2e) associated with various fuels for equivalent energy output (ekWh). That is, an elimination of about 75% of the carbon footprint based on Ontario's current electricity carbon footprint.

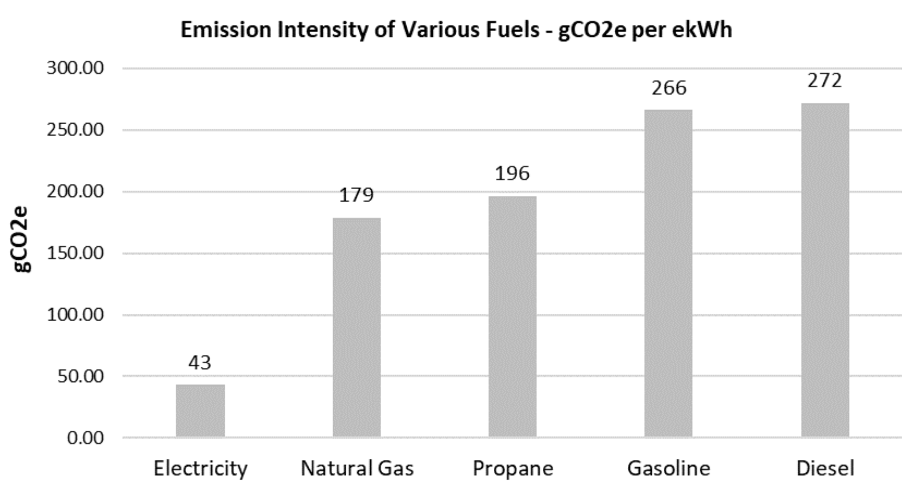


Figure 15: Emissions Intensity of Various Fuels

3.7 Energy Generation Potential

Geo-exchange heat pumps do not generate energy. For the area around Oakville, the ground temperature is constant below 5-6m at about 11-12°C all year. The ground loop will store heat (cooling mode) or release heat (winter mode), while the COP of the heat pump can bring that energy back with an energy cost of only 25% of the heat generated. It is therefore a significant reduction in the overall energy footprint. Combined with enhanced building performance standards geo-exchange and heat pumps will bring about large energy and GHG reductions. An important consideration for the success of these systems is to ensure the energy captured during the summer cooling mode recharges the ground for use during the heating season. If this is not the case, the system will under-perform in the winter and require the back-up heat to come on often. As this is usually an electric coil, this can increase the annual energy costs far above what was estimated.

3.8 Energy Modelling

A geo-exchange system's predictability relies on several factors which include:

- The building energy model: The model must be hourly and reflect the capacity of heat pump energy performance with the ground conditions and building heating loads.
- Building energy balance: To ensure the heat pump balance with ground temperatures can sustain the heating/cooling cycles each year. The summer reject heat is used to recharge the ground for winter heating. This is an important consideration when designing and operating these systems.
- Measurement of the ground's thermal conductivity and presence of groundwater: This requires pre-construction testing. Groundwater movement can remove the stored heat, although the groundwater itself can be an excellent energy source (note that using ground water is not always allowed and must be verified before it is considered).
- Modeling the geo-exchange system itself is complex and depends on detailed ground loop and building load characteristics combined with a good understanding of the technologies and tools by the modelling team. Subject matter experts should be retained for any detailed evaluations and designs.

3.9 Procurement

Heat pumps are very similar to conventional HVAC contracting work and so does not present an issue. Drilling is not a concern, though as mentioned above, there are only a few drillers locally. Installation specialists for the ground loop itself are not that common, although this should not present a problem. It would be prudent to work with a specialist construction firm, given the interrelated nature of the key components and to ensure competent design and commissioning and limit potential issues post-commissioning. It is possible to tender the borehole work separately from the HVAC component. On the design side, it is recommended to ensure the engineering firm has a track record for the evaluation, design, and implementation of a geo-exchange system from the ground to the mechanical room including project management, administration, and commissioning.

3.10 Barriers to Implementation

Staging during construction of the borehole field is a pre-requisite for any retrofit application. If it is a large borehole field, it is possible to have multiple drilling rigs going at one time. The Town needs to be fully aware of upfront development costs because of the borehole testing, design, and modeling requirements. Ground conductivity and thermal performance may become a barrier to the successful application (i.e., moving water will draw heat away). In some cases, the ground could be unsuitable for drilling and removal due to contamination. Electrical capacity within an existing facility needs to be established early in the design. Not all existing terminal equipment (radiators, heating coils) may be suitably sized for a retrofit application and could add costs that render the project impractical.

3.11 Current/ Future Implementation in Municipalities & Equivalent Organizations

There are many different locations – private and public – employing this technology *(source: https://sustainabletechnologies.ca/map-of-geoexchange-systems-in-ontario/)*. As detailed elsewhere in this report, there are already systems under operation within the Town's facilities. Following are some specific additional examples:

- UOIT, Durham: This new campus construction (2005) was based around a low temperature heating loop powered by heat pumps and a large geo-exchange borehole system.
- University of Toronto: The St. George campus is introducing geo-exchange systems into the DES to reduce overall energy costs and GHG footprint. The U of T is planning significant ground source heat pump applications that will deliver into the existing low temperature network. Approximately 600+ boreholes is planned in 3 systems that will offset ~15,000 tonnes CO_2e/yr. by removing the need for gas fired steam.
- Pan Am Games Aquatic Facility, U of T, Scarborough: This large pool complex is operated using a geo-exchange heat pump system. Approximately 150 boreholes with a further 60 boreholes for a new chemistry facility.

3.12 Strategic Direction

Heat pumps will make up a large part of the electrification on the thermal loads for The Town. Ground source systems should be considered when there is sufficient ground to use such as under a new building, under a parking lot or nearby grounds that permit the installation of the borehole field. The supply temperatures from current heat pump technologies are less than conventional heating systems which means retrofitting into an existing building will likely require terminal device conversions, derating and possibly a booster heater. The facility needs to have cooling and heating loads that can be balanced annually to ensure the ground is properly charged. The FCM should prepare a trigger event schedule that uses end of life and HVAC renovations to bring heat pump solutions to the building into consideration. Consider geoexchange solutions for large campus-like opportunities and where thermal off-takers are available, such as around an athletic facility, large community centre, and operations centres. Geoexchange systems should be evaluated using a life cycle cost assessment against a conventional gas fired boiler/chiller system and include the carbon costs, utility escalation, maintenance, and operations.

4 Air Source Heat Pump Systems

4.1 Market Overview

In many respects an air source heat pump (ASHP) system is like a geo-exchange system: use of an electric heat pump to deliver heating and cooling from a source of thermal energy. In the case of an ASHP, the air is the thermal energy source or sink.

- ASHPs are often packaged with a variable refrigerant flow (VRF) energy delivery system as opposed to a traditional water based hydraulic system. This allows them to transfer heat from one area in a building to another.
- They are also available as air-to-water and air to air systems, meaning they can replace boiler/chiller and rooftop air handling or other air delivery systems, without the need for new terminal equipment. Like geoexchange systems, they deliver low temperature heating which must be taken into consideration for retrofit applications.
- ASHPs are also available in air to air, so they can replace rooftop air handling or furnace-type equipment.
- There is no trans-seasonal storage with these systems. The air itself is the source of energy. The refrigerants have a boiling point sufficiently low that they can still operate at below-20°C outside air temperatures with COPs at ~1.5.
- System heating output capacity will change (decrease) with lower outdoor temperatures. This means the system is potentially oversized to meet peak design day design loads, or as with low temperature supply heat pumps discussed above, additional heating may be required to meet those few coldest days. Careful economic analysis and modelling will determine the best combination of peak heating loads.

Source: https://galvezairconditioning.com/cherry-services/heating-services-commercial-install

Figure 16: Typical rooftop-mounted commercial air source heat pumps

- They do require thermal balancing between heating and cooling like a geoexchange system does.
- Effective strategy for retrofit planning
- They require large roof or ground areas for the large-scale equipment. Approximately 20 kW/m^2 area required.

4.2 Application to Building Portfolio/Grid Connectivity

An ASHP retrofit is possible in most buildings, particularly smaller ones currently running on furnace-type or rooftop mechanical equipment where straight swap-outs are possible. The use of the VRF attributes is well suited to buildings that have concurrent cooling and heating loads. For larger buildings, the terminal equipment needs to be able to work with the heat pump's lower temperature characteristics. ASHPs, although much quieter than comparable air conditioning equipment, need to be designed with noise criteria taken into consideration – like a conventional air conditioner – condenser location is an important consideration.

Hot Water Heaters

Air source heat pump hot water heaters are a separate product category and are used solely for generating hot water. They are a relatively new market entrant and work well in places where there is a consistent access to useable waste heat, for example in a mechanical room and where a flue cannot be installed. They are a direct replacement for a conventional gas-fired tank system in the 50-200 US Gal storage capacity range, although costs are much higher as compared to either gas or electricity-powered hot water heaters.

4.3 Application as Retrofit vs. New Construction/Major Renovation

ASHPs are a consideration for all types of construction, new and retrofit. A VRF loop is much smaller than conventional hot water plumbing or ducting making them particularly convenient in renovations where space is a premium. An ASHP requires roof or ground area at the site. For new construction they can be designed into the structure from the schematic design stages. They can also be sized according to higher performance thermal designs and take advantage of the lower temperature supply temperatures for heating. For retrofits they will be replacing existing equipment, typically on the roof. They may not be capable of satisfying the full heating loads efficiently which may require a booster heater for the few hours of design low temperatures each winter.

4.4 Economics

Today, using a heat pump can cost twice as much as traditional packaged rooftop units that consist of direct expansion (DX) cooling and natural gas burners. But heat pump technology is becoming increasingly cost-effective and, according to the National Energy Board, costs could drop 10% to 20% by 2025 to 2030, and 20% to 30% by 2040.

Heating

Depending on outdoor air temperature, a heat pump can achieve COP as high as 3.4 in heating mode, meaning the heat pump can produce 3.4kWh of heating energy for every kWh of electricity consumed. As outdoor air temperature drops below 0°C, the efficiency of heat pumps drops significantly and requires additional support from either an electric heating coil, a natural gas burner or a larger heat pump capacity. For example, at sub-zero temperatures, a 20-ton heat pump may only produce the heating equivalent of a 15-ton heat pump.

Cooling

High efficiency heat pumps or DX units provide substantial energy and utility cost savings compared to traditional standard efficiency DX cooling applications, as demonstrated in the example below. Depending on outdoor air temperature, a heat pump can achieve IEER as high as 18.6 (COP of approximately 5.4), meaning the heat pump can produce 5.4kW of cooling for every kW of energy consumed.

The following table shows the difference in annual operating costs associated with using a 20-ton heat pump instead of an RTU that has 15-ton DX cooling and a natural gas burner, based on current electricity and natural gas utility rates. The case is based on a theoretical 5,000sq. ft. space with one exterior wall in the Greater Toronto Area. The assumed operating schedule is Monday to Friday from 7AM to 5PM.

Table 11: Cost performance example for a 20-ton heat pump. 20 ton is a typical commercial scale.

Technology	Cooling Energy ($)	Heating Energy ($)	Fan Energy ($)	Total Annual Energy Cost ($)
Rooftop Unit + Gas Boiler	$1,014	$1,026	$1,688	$3,728
20-ton heat pump	$460	$4,377	$434	$5,271
Heat Pump Savings	**$554**	**-$3,351**	**$1,254**	**-$1,543**

4.5 Carbon Offset Potential

There is a significant carbon saving in the move away from natural gas. The following figure shows the carbon emissions (gCO2e) associated with various fuels for equivalent energy output (ekWh). That is, an elimination of about 75% of the carbon footprint based on Ontario's current electricity carbon footprint.

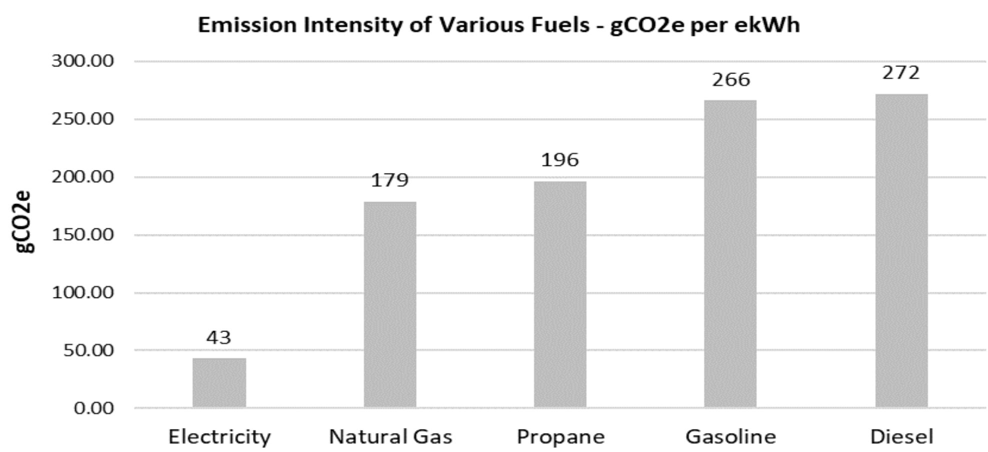


Figure 17: Emissions factors for fuels.

4.6 Energy Generation Potential

As with other heat pumps, this is not a generation system. It can, however, take advantage of waste thermal energy such as in an electrical or mechanical room. These are good candidates to remove thermal energy from a data centre.

4.7 Energy Modelling

Actual energy savings/generation calculations again are contingent on an accurate understanding of the building's energy loads at an hourly level. Manufacturers publish output and efficiency details for a full range or outdoor conditions. Therefore, if heat loads at various outdoor temperatures can be modeled – either by analysing gas bills or via an energy model, performance simulation is straightforward to predict. Either the manufacturer or an experienced design team will be capable of completing the required performance studies.

4.8 Procurement

For new construction, there are several contractors and consultants familiar with VRF-type systems. Manufacturer representatives tend to be closely involved in design work and may offer to do design directly but could make them ineligible for tendering. The procurement policies will need to be evaluated before allowing a vendor to provide both design services and product supply.

4.9 Barriers to Implementation

Replacing boilers/chillers with heat pumps in an existing facility does require careful construction staging during shoulder seasons when both heating and cooling may be required. Renovations may require the treatment of asbestos in ceiling spaces when replacing the plumbing and/or upgrading the ducting. Many existing HVAC systems are designed for peak heating and cooling loads that require large systems and high (heating) low (cooling) supply temperatures. Recall that heating and cooling peaks occur for 2-5% of the season. Sizing a HVAC system for these peaks causes inefficiencies and unnecessary costs. Combing a heat pump system with a side peaking heater/cooler is more efficient, possibly more expensive at first cost but would also operate more efficiently throughout the year. When selecting a consultant, The Town should determine how knowledgeable the firm is with balancing annual and peak loads effectively.

4.10 Current/ Future Implementation in Municipalities & Equivalent Organizations

VRF-driven systems run from ASHPs are now relatively common. As building energy performance improves the use of ASHPs for renovation will be recommended to take advantage of the lower GHG footprint.

- The Dundas West GO station is heated and cooled with ASHPs.
- The University of Toronto Huron Sussex renovation is considering ASHPs for the existing buildings as a part of the drive to lower temperature heating systems.

4.11 Strategic Direction

As with geoexchange heat pumps, air source heat pumps (ASHP) will play a large part in getting away from natural gas heating and achieve the GHG targets over time. ASHPs are an enabling technology in that they can be retrofitted into existing buildings. The Town should prepare a schedule based on replacements (trigger events), end of life or opportunities where the benefits of conversion match with GHG reduction goals.

As mentioned above, The Town should ensure the consultant selection process includes determining their expertise with system design with stipulation that over-sizing to meet the few hours per year when peak capacity is considered and explained in detail (hourly calculations and modeling).

5 Hydrogen & Fuel Cells

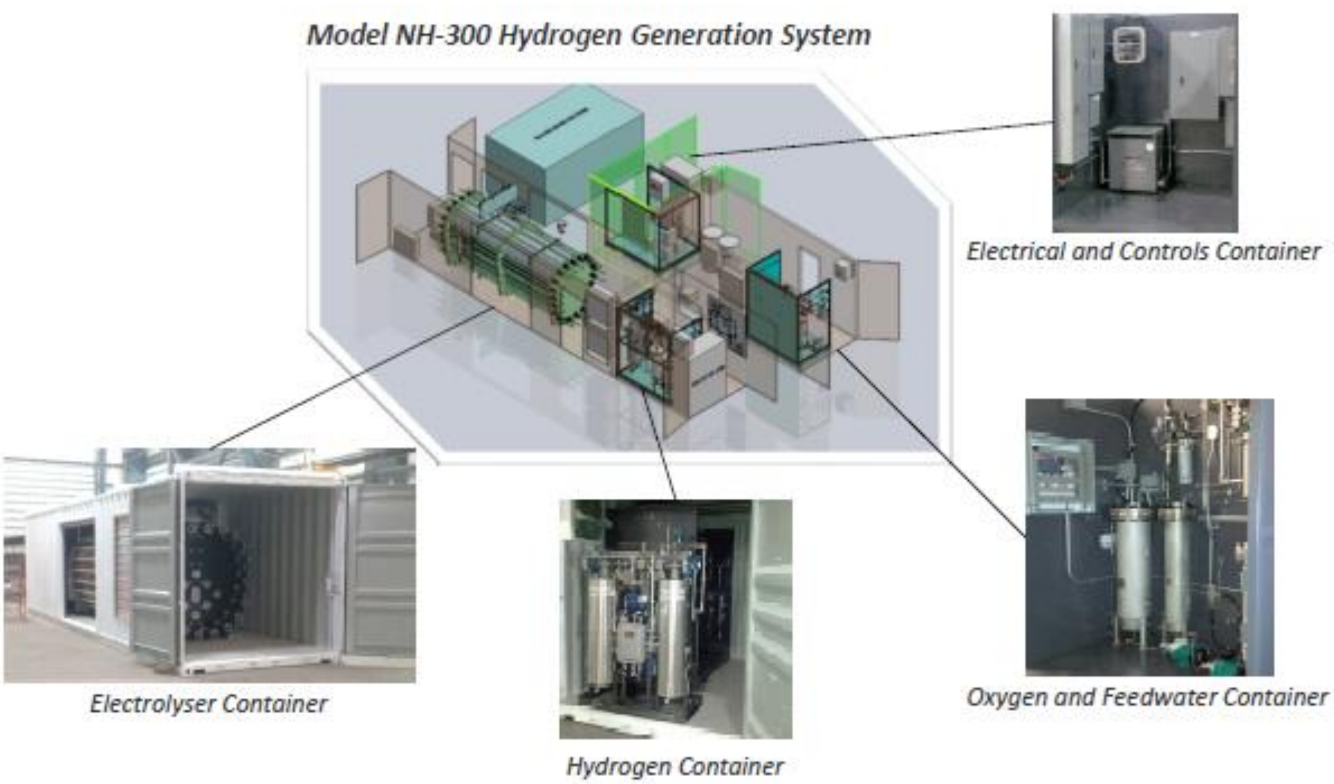
5.1 Market Overview

Hydrogen as a Fuel Source Replacement for Natural Gas

Hydrogen is an energy transmission method – it is not a source of energy but must be created to be used for any loads. Hydrogen is either generated from natural gas using a high temperature steam/methane process (very high carbon footprint), or from the electrolysis of water by means of electricity (low carbon, high-cost energy, though possible with renewable energy). It is an evolving energy resource and capturing attention around the world as a fuel source and a way to displace natural gas for combustion.

Hydrogen Fuel Delivery

While there is a significant amount of hydrogen generated for a range of industrial processes, there is yet no Canadian retail or US delivery mechanism, other than trucked-in as a compressed liquid fuel, or by on-site natural gas conversion at the point of use. For short to medium term considerations, gaseous hydrogen is mixed with natural gas to a maximum of about 15% by volume thereby reducing the carbon content while taking advantage of existing pipeline infrastructure. This is currently being investigated by natural gas distribution companies to lower their GHG levels to meet targets. It may be possible for The Town to purchase hydrogen injected by the utilities and take credit for the reduced carbon, like a renewable electricity contract through the electrical utility.



(Source: Next Hydrogen, 2020)

Figure 18: Sample of system components for a H2 generation plant (~300 m^3/hr).

Electricity/Heat Generation: Stationary Fuel Cells

Fuel cells have been considered, particularly within the transportation sector to offset diesel fuels and the carbon content. Hydrogen is used to generate electricity at the fuel cell with the waste product being water and heat. For stationary applications, this requires an inexpensive source of hydrogen and be competitive with natural gas even taking the carbon content into consideration.

5.2 Application to Building Portfolio/Grid Connectivity

There are currently no commercially available products on the market that could provide heating and electricity generating services at the building scale. Currently and for the foreseeable future, there does not appear to be applications for hydrogen in Oakville in stationary applications. Note that diesel fueled vehicles such as buses and large industrial trucks are currently being converted to operate with hydrogen. The Town is currently investigating the use of electric buses to replace some of their diesel bus fleet.

5.3 Application as Retrofit vs. New Construction/Major Renovation

Currently, hydrogen is being used in short-haul trucking operations. Some municipalities (Japan, California) are piloting hydrogen waste pick-up trucks, again short-haul application. The advantage is that these operations typically have land available to store hydrogen and install filling stations. They also have ready access to renewable energy to make the low carbon hydrogen through electrolysis. Hydrogen is more like diesel in that the tanks can be refilled relatively quickly (versus electric trucks). However, until a cost-effective source of hydrogen becomes available, the potential role for a hydrogen fuel cell-driven project at Oakville would be as a demonstration project, and likely for their waste pick-up fleet

5.4 Economics

The cost per unit of delivered energy is higher than that of electricity and natural gas (2020). This is not expected to approach parity for another 5+ years. The generation and distribution are not currently developed to the point where there is an economic case to be presented for other than on-site use such as for tow-motors. The Town may want to revisit this energy source as hydrogen generation becomes more available for on-site plants and distribution suitable for transportation opportunities within The Town – e.g. garbage trucks, delivery trucks.

As hydrogen is introduced to the natural gas grid, the economics of carbon content will change according to the fraction and carbon rates. These factors will need to be taken into consideration as the information is provided. This will be apparent as the natural gas grid introduces renewable hydrogen energy (RNG) and will impact the emissions factor the Town can use for any natural gas used.

5.5 Carbon Offset Potential

Fuel cells driven by hydrogen sourced from electrolysis, such as renewable energy-based supplies (green hydrogen) and can be a very low to zero carbon fuel. Natural gas-based fuel cells generate significant emissions and not a viable choice (grey hydrogen). Hydrogen will be introduced into the natural gas grid which will reduce the carbon content for conventional heating system use. As mentioned, The Town is considering electric buses versus hydrogen or fuel cell fleet transportation conversions which contributes a large portion of the GHG footprint in The Town.

5.6 Energy Generation Potential

As pointed out, hydrogen is not a source of energy like solar is. A fuel cell can convert between 40% and 60% of the energy in the hydrogen to electricity. In comparison, a typical internal combustion engine is ~30% efficient. The conversion efficiency of renewable electricity as an input fuel for the generation of hydrogen (green hydrogen) to useful output (heat and electricity) is in the region of 30% given the solar panel efficiency is ~17%.

Most of the hydrogen used now for stationary and mobile applications (>95%) is made from natural gas (grey hydrogen). The conversion efficiency of the hydrogen to useful energy must be considered after it is injected into a heating system (natural gas line to boiler) or fuel cell (generates electricity plus some heat). These efficiencies reduce the overall system efficiencies further.

(Source: https://www.fuelcellenergy.com/wp-content/uploads/2017/02/Product-Spec-SureSource-1500.pdf).

5.7 Energy Modelling

Not applicable. Any fuel cell and hydrogen generation system would have output predicted by its manufacturer. Subject matter experts should be retained to assess any hydrogen applications.

5.8 Procurement

The marketplace is currently confined to large scale operations for fleet conversion, some natural gas injection for low carbon fuel supply and some commercial vehicle infrastructure development. Commercial scale systems outside of these applications, though being developed, are not yet suitable for The Town's scale of operation.

The results from municipal pilot projects will be presented and should be followed to make sure The Town is aware of the status of the technology, acceptance, and costs.

5.9 Barriers to Implementation

The main barrier is the lack of available green hydrogen generation and infrastructure for widespread use. As hydrogen is introduced into the gas grid, The Town should be aware of the timing to capture the carbon reduction benefits and emissions factor changes. Technologies that burn hydrogen are being developed with two CHP vendors reviewed (Caterpillar and 2G Energy) that is capable of minimum 25% and potential to go to 100%% hydrogen burn at a scale suitable for municipal facility scales. This restricts competitive pricing though there are other companies developing or releasing hydrogen CHP units at scales suitable for municipal loads These will be similar to conventional gas CHP units and will need specialized operator training for operations and maintenance.

5.10 Current/ Future Implementation in Municipalities & Equivalent Organizations

Other than the use of hydrogen to offset carbon in natural gas distribution, none known of in the building sector yet. There is hydrogen based combined heat and power systems being developed for commercial markets. There are municipalities starting pilot projects for hydrogen powered short haul trucks. A program in north BC is making 65 diesel short haul trucks able to use 40% hydrogen. As hydrogen is introduced into the distribution infrastructure, these will be available for consideration. Any consideration for the use of hydrogen in Oakville should start with short haul trucks such as garbage pick up and as a pilot. A hydrogen generation plant would be required at the main truck operations yard.

5.11 Strategic Direction

Currently, hydrogen delivery and infrastructure are not widespread. The technologies for burning hydrogen as a heating and/or combined heat and power system are being brought to market for commercial applications.

Until there is a more robust distribution system for hydrogen there are no widespread applications that can not be addressed with electrification to achieve GHG goals. Continue to be aware of CHP technologies as they prepare for hydrogen fuel blends. Understand how the carbon reduction of blended fuels will impact the carbon loads and therefore the cost of carbon in conventional heating systems.

Prepare a cost calculation for fuel that includes the defined carbon content for natural gas and the carbon costs that result each year. Carry and monitor these along with the standard utility tracking metrics.

6 Bio-Energy

6.1 Market Overview

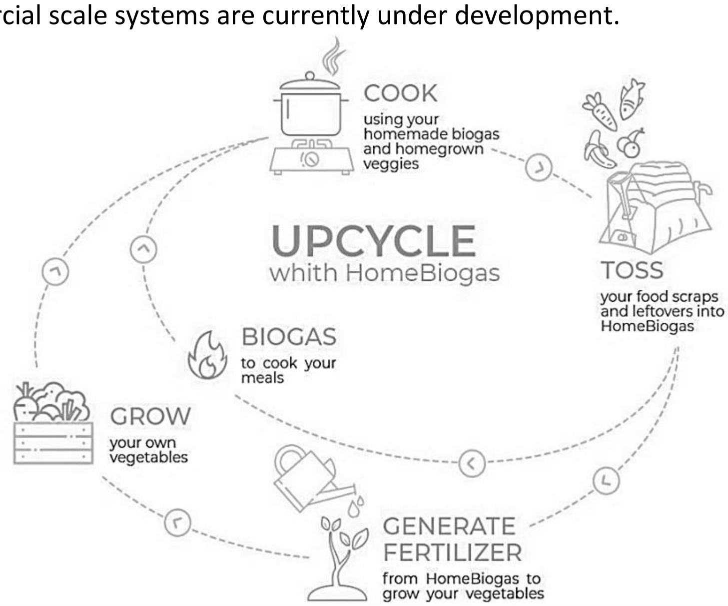
Bio-power can be split into two parts: a point of use heating device or a primary fuel source. These include wood chip/pellet heater/boilers and biogas generation that is burned to generate thermal or electrical energy. Both require large equipment and transportation areas.

Bio-fuels as a Fuel Source

Localised biogas digesters are being used in Ontario, where the gas is generated from organic waste and burned to generate electricity like a natural gas electrical generation system. It can also be captured from a landfill and converted to electricity or produce Renewable Natural Gas (RNG). With appropriate treatment, locally generated methane can be injected into the natural gas grid to offset natural gas consumption. For the end user, this is analogous process to the purchase of wind power for greening electricity consumption. There are companies in Ontario including Bullfrog Power who sell 'renewable natural gas' via this process *(source: https://biothermic.ca)*.

Biofuel can also be naturally produced from the decomposition of organic waste. When organic matter, such as food scraps and animal waste, breaks down in an anaerobic environment (an environment absent of oxygen) it releases a blend of gases, primarily methane and carbon dioxide. Due to the high content of methane in biogas (typically 50-75%), it is flammable and can therefore be captured and used as an energy source

HomeBiogas is an Australian company that has created an efficient and durable biogas generator for domestic cooking and farming that is easy to install and operate. The operation of their biogas system is illustrated in the following figure. Commercial scale systems are currently under development.



Source: https://www.homebiogas.com

Figure 19: example of biogas use cycle

Purchased Bio-fuels for On-site Heating

Figure 20: example of small woodchip/pellet boiler

Wood pellets (a manufactured wood product) or wood chips can be purchased and used as a fuel for stationary boilers, replacing the use of natural gas. The fuel is stored close to the boiler and fed mechanically into the boiler. The boiler itself is similar in footprint and style to a conventional gas boiler, with venting, combustion air and ventilation requirements being comparable. A one-for-one replacement may be possible, with the need for additional space for fuel storage and potentially a pathway for fuel transfer.

Woodchips are significantly cheaper than wood pellets – about 1/3 of the cost, but only at larger scales (>500kW). Either fuel source requires storage and a way to transfer the fuel from storage to the boiler, which is automated. The fuel must be trucked to the storage facility. The larger the storage bin, the less frequently that fuel needs to be delivered.

Ash is generated as a by-product and is a harmless by-product that can either be put in the garbage or used as fertilizer.

6.2 Application to Building Portfolio/Grid Connectivity

These can be considered for buildings at any scale and are possible for a DES design provided appropriate (and reliable for long terms) supply can be found. Adequate fuel space is required as well as the ability to truck the fuel into the storage site regularly all year.

6.3 Application as Retrofit vs. New Construction/Major Renovation

Other than space requirements for the boiler, fuel handling, shipping and fuel storage, there is no reason why either could not be applicable.

6.4 Economics & Carbon Impact

A price of $450-600 per kW capacity installed including fuel storage is typical. This would represent a premium over an equal performance gas boiler. Annual utilization efficiencies are around 85%, similar to non/near-condensing gas boilers. The following figure shows the cost and carbon intensity (gCO2e/ekWh) for various fuels.

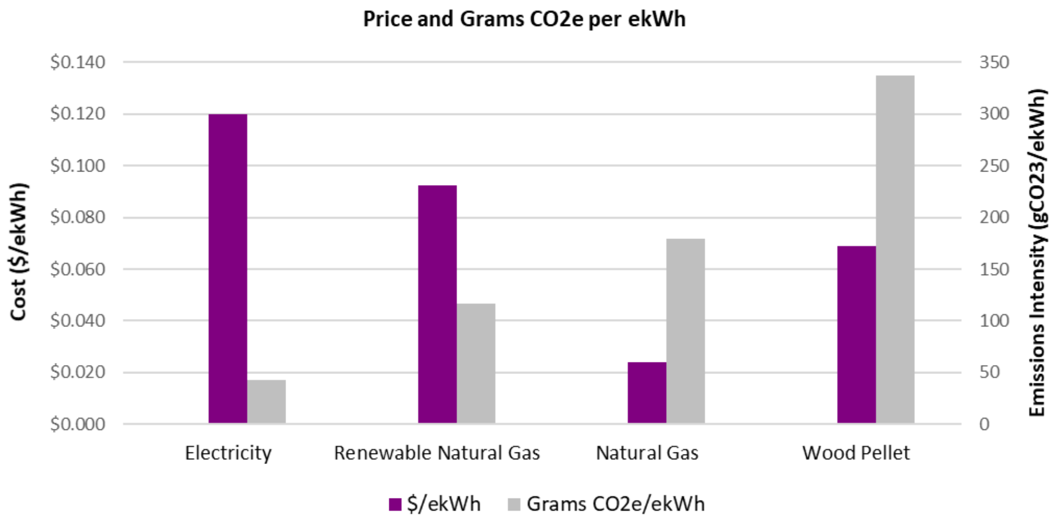


Figure 21: Cost and carbon intensity of various fuels

We can clearly see from the previous chart that bio-fuel extracted from organic and landfill is about 35% less emissions intensive compared to traditional natural gas. However, the cost for RNG is higher compared to traditional natural gas. We also see that the cost of wood pellets is between traditional natural gas and RNG, but it holds the highest emissions intensity among all fuel sources. Hence, landfill gas sequestration or RNG would be a more viable option when considering the emissions impact alone.

6.5 Energy Generation Potential

This is a 1:1 replacement of existing boiler heat. The efficiency of any pellet or woodchip boiler would be comparable to an efficient gas-fired boiler and subject to similar regulation.

6.6 Procurement

There will be a lower number of products available as compared to gas boilers, given the relatively small size of the market in Ontario for commercial applications. The same will be true of installation contractors. There are a limited number of fuel providers and so this needs to be addressed as part of any evaluation. A Feasibility Study is therefore recommended before proceeding with any tender process.

6.7 Barriers to Implementation

One area to be aware of is that sign off from the Ministry of the Environment, Conservation and Parks is required for the installation due to flue gas dispersion. While not expected to be an impediment, this is an additional step over a conventional gas-fired system.

There will be space required to store the fuel. Access to the storage area will be required and for a large plant means large transport trucks arriving regularly. This could face resistance from residents who are along the route to the plant. Storage must be provided to carry through any transportation disruptions due to extreme weather (typically in the winter).

6.8 Current/Future Implementation in Municipalities & Equivalent Organizations

There are a few examples of this application:

- La Cite Verte is a new mixed residential community with a central heating plant comprising 5MW of pellet boilers plus thermal energy storage *(source: http://www.quebecwoodexport.com/images/stories/pdf/ficheEN_cite_verte_WPAC.pdf)*
- The Our Lady of Mercy Catholic School in Bancroft, ON has a wood pellet-driven boiler system.
- The OPG BioEnergy Learning and Research Centre at Confederation College in Thunder Bay, ON is a 275,000sq. ft. educational facility running off 1MW of wood chip boilers.

6.9 Strategic Direction

Due to delivery and storage needs, this is a technology best suited for district energy system applications. Transportation and storage criteria must be included in any feasibility studies and include sufficient fuel to carry through delivery disruptions.

Maintain awareness of the technologies and applications for consideration against other fuel supplies. Consider a more in-depth feasibility study to fully assess the capabilities and application criteria for The Town.

Not perceived as a long-term option or application for large corporate assets. There are technologies that may appeal to some sites for either pilot or awareness projects that can be addressed as they appear.

7 Solar Thermal Hot Water

7.1 Product Background

Solar thermal hot water is the conversion of solar energy directly into heat, usually with a storage to heat the loads. This is a well-established market and technology – easily the most efficient of all pure renewable energy technologies with panel efficiencies of over 80% and sun-to-delivered heat efficiencies close to 60%.

Rooftop or wall-mounted panels collect the sun's energy through a heat transfer fluid – glycol or water – and then transfer it to a storage tank (or is some cases, directly to the loads). Solar thermal hot water acts as a pre-heating system for the hot water loads. It is possible for the system to offset up to 100% of daily hot water needs or provide partial heat to incoming cold water with the existing hot water heating system providing the balance.

Solar Collector & Storage Tank Types

There are two prevailing technologies: flat plate collectors and evacuated tubes. Each have their benefits depending on the load, temperatures, and applications. Both typically use an antifreeze transfer fluid and transfer the heat to a storage tank. Storage tanks can be either conventional pressurised tanks, or non-pressurised systems. The latter are associated with 'drain back' systems, whereby collectors are only filled with heat exchange fluid when solar energy is available, and more typical in residential applications.

(Source: Elgin West Community Centre, Richmond Hill)

Figure 22: Typical, low angle, solar panel array connection

Outdoor Pools

The systems used for outdoor pools are much simpler and cheaper. There is no heat exchanger; pool return water is diverted into a bank of non-glazed collectors – essentially a black rubber matt with hollow tubes – where heat is picked up before the fluid is returned to the hot water heater intakes.

7.2 Market Overview

Solar thermal's popularity is dependent on natural gas prices and government incentive programs. Currently there are few if any supports for solar thermal in Ontario and the long-term low level of natural gas prices has made systems economically difficult to compete though systems are being installed in particular for indoor pools and high make-up water loads (car washes, process loads, recirculation loads).

The industry separates out components and installation services. A vendor will carry a selection of solar components and provide complete turn-key designs and installations. The residential pool heating market has remained robust in response to consumer demands due to its relatively cheap prices.

While many aspects of solar thermal are familiar to any plumber or structural contractor, the nuances of system selection, design and operation tend to lead to problems when installed following conventional mechanical system procurement methods. The consulting industry tends to have limited experience with solar hot water systems which must be evaluated before selecting a firm.

7.3 Application to Building Portfolio/Grid Connectivity

Swimming Pools

Both indoor and outdoor pools offer large and steady loads highly suitable for solar thermal pre-heat systems as well as large roof areas. Care is required in terms of how make up water is piped into the pool to maximise load reductions. Combined with drain water heat recovery and well-functioning de-humidification heat recovery systems can significantly reduce heating loads.

Arenas

An arena running through the summer as well as the winter provides a sufficiently large hot water source when combined with shower usage – Zambonis use in the region of 500-800 litres per flood or the equivalent hot water usage for 5-8 people per day. Many ice melt pits are heated by natural gas systems that can be supplemented or replaced with a solar hot water system. Many rink ice refrigeration plants make use of heat recovery from the compressors to provide hot water and improves the overall ice plant efficiency.

Other Uses

Offices, libraries, and administrative type buildings do not have sufficiently high loads to warrant the use of solar hot water. Senior residences, fire halls and community centres may have laundry and DHW loads that justify a solar hot water system. Careful analysis of the loads through the year is needed to ensure there is sufficient hot water load to justify a solar hot water system.

Installation Criteria

Rooftop constraints for solar thermal are like solar photo-voltaic in terms of the available space. Solar thermal is ideally installed at an angle of approximately 30-45° from the horizontal to maximise annual energy generation, and thus pitched or flat roofs are the best places for installation. While shading is an issue, partial shading of one collector is not as critical as it is for solar PV. The major difference between the two systems is that given the much larger size of solar thermal collectors – typically 4'x8' for flat plate type – that are almost always fixed directly to the roof-structure which tends to increase the cost as compared to a ballasted array. Vacuum tube arrays are lighter and have been installed using a ballasted racking where the loads justify a solar array.

The pipes need to be insulated and protected from the elements and run efficiently to the mechanical room. Most systems use a blend of anti-freeze (food grade polypropylene) for year-round use. Within the mechanical room there needs to be space for storage tanks. Tank sizing is dependent on both the volume and timing of the load: swimming pools are typically installed without storage given the high and continuous loads available, while an office, community centre or arena would require storage.

All roof installed solar will require a structural assessment by a professional engineer to determine that the roof is able to handle the additional dead and live (wind) loads. Wall mounted installations are an option where large areas of space are available and access from a zoom boom/cherry picker is possible. Care needs to be taken regarding shade to the south, given low sun angles during the Fall to Spring.

District Energy

As mentioned in the District Energy section, solar thermal can provide a source of renewable heat into a geo-exchange system. This is a common DES model in Europe and with careful review of the ground's seasonal energy balance between heating and cooling loads should be considered where land is also available.

Metering

It is important to specify thermal metering as a key system component, given heat is the delivered product. This is possible using conventional flow meters and temperature sensors – either through an existing building automation system, or as a stand-alone system.

7.4 Application as Retrofit vs. New Construction/Major Renovation

Solar thermal works well for both new construction and for retrofit. For any major renovation or new construction projects, clearly the greater the roof area available, the better. If the intent is to optimise a buildings' design for solar, then a south-facing pitched roof of 30-45°, facing no more than 45° of due south would be ideal. For a flat roof, ensuring large areas clear of mechanical equipment or shading form penthouses is required along with the structural considerations.

7.5 Economics & Carbon Impact

A small commercial-scale system about 10 collectors (approximately 20kW$_t$-equivalent) and upwards in size would cost in the region of $2,000 to $3,000 per collector including engineering costs. There can be a significant cost difference, depending on the installation methodology and volume of storage required, with flat roofs tending to be the more expensive.

The costs and generation information for a typical 100 kW system holding about 50 collectors, is summarized in the following table. The calculation assumes offsets from a 75% efficient sealed combustion/non-condensing hot water heater or about 13,800 m^3 of natural gas and a cost of $0.24 per m^3 of natural gas.

Table 12: Example of performance and costs for a glazed solar array

Metrics for a typical 10 kW Solar Thermal System	
System Size (kW)	100
Space Required (sq. m)	1,500
System Cost ($)	$150,000
Estimated Annual Generation (ekWh)	110, 000
Annual Cost of Generation ($/ekWh)	$1.36
Maintenance Cost ($)	$30
Natural Gas Savings ($)	$3,312
Annual GHG Offset (tCO2e)	26.08

Given this is a fuel offset technology, the cost and efficiency of the base building hot water heating system needs to be well understood. These range seasonally from a low of about 60% for atmospheric hot water heaters to close to 95% for well-designed condensing hot water heaters. Some pump replacement and piping repair can also be expected. Systems that use an anti-freeze (i.e., polypropylene mixture) will need to be checked each year and refreshed/topped up.

When these systems do not have sufficient hot water loads/storage, the glycol mixture can degrade and require replacement more often (~5-7 years). For an outdoor swimming pool system, the numbers would be much better given the installation and component costs are lower than glazed modules and do not require anti-freeze mixtures.

7.6 Energy Modelling

Commercial grade software can estimate the energy generation to about 95% accuracy. This is similar to the accuracy limits of weather data measurements (ekWh/yr. of insolation) which is limited by satellite readings' accuracy in the absence of local weather station data. Note also that year to year weather variations can result in production swings of about 5-10%. F-Chart, T-Sol are good examples of well proven commercial software. As with PV energy estimating, the output is only as good as the person using the software and needs to have a good understanding of the tool for accurate interpretation. Note that RETScreen is not recommended as a final estimating tool it cannot capture temperature variations properly and does not model the ancillary equipment to the detail needed to make investment grade decisions. It is used for early estimations and comparison of a wide range of technologies.

Solar hot water systems provide energy year-round. They do not supply as much during the winter (vacuum tube are better than flat glazed panels for cold weather use). One performance metric is the annual solar fraction. This represents the amount of solar heat provided divided by the annual hot water demand. I.e., the solar fraction can be as high as 80% during the summertime but will drop to 15% in the winter. The annual fraction will be around 25-30%. A higher solar fraction requires a larger array though over-sizing for the summer is to be avoided. A commercial fraction of around 30% is considered a good metric to design for with a DHW load scenario.

7.7 Procurement

Given there are not as many solar thermal installers to select from, the procurement process should include pre-qualification. It is recommended to retain a specialist firm to generate the design and tender documents, and have a very clear method of choosing between potential design-build solar thermal firms based on previous experience with follow up to past projects as a part of the evaluation. It is recommended the vendor provide training to staff on the operation of the system and how to determine if it is not performing properly.

7.8 Barriers to Implementation

As with PV, the roof structure is the most important criteria. Some roof contractors may not maintain a roof warranty if it has been recently upgraded or replaced. There are not many experienced solar thermal installation companies that can develop large scale system applications. Mechanical permits and final sign off are required and local inspectors may not be familiar with the unique details for a solar hot water system. This lack of understanding can lead to improper plumbing requirements that can significantly impact the performance. It is very important to ensure that maintenance staff are well trained on the system's operation and functionality. Entering a long-term maintenance contract with a reputable company is recommended.

7.9 Current/ Future Implementation in Municipalities & Equivalent Organizations

There are a few examples across the Greater Toronto Area:

- The City of Mississauga has installed solar thermal at its Lions Club of Credit Valley outdoor pool.
- The City of Toronto has many solar thermal systems at many pools, the Toronto Zoo, cooperatives, and a fire hall.
- The central YMCA in Toronto has solar pool heaters on its indoor pool.
- University of Toronto, St. George has a large flat panel and three vacuum tube systems to support the athletic centre and ice rink DHW loads.
- The Town of Richmond Hill has two solar thermal systems serving indoor pools at its community centres.
- The Town of Okotoks has a very well-known geo-solar system whereby solar thermal is used as an additional heat source feeding into a geo-exchange system for a sub-division. In 2015, 100% of the required heating energy came from the sun (source: https://www.dlsc.ca/)

7.10 Strategic Direction

Solar hot water reduces natural gas use directly. When there are annual hot water loads such as in pools, community centres, long term care, athletic centres, and operations facilities, solar hot water systems should be considered to supplement the conventional heating plants. The temperatures delivered are best suited for process laundry, truck/bus washing, and DHW loads. It is also a good match for supporting geoexchange and DES applications.

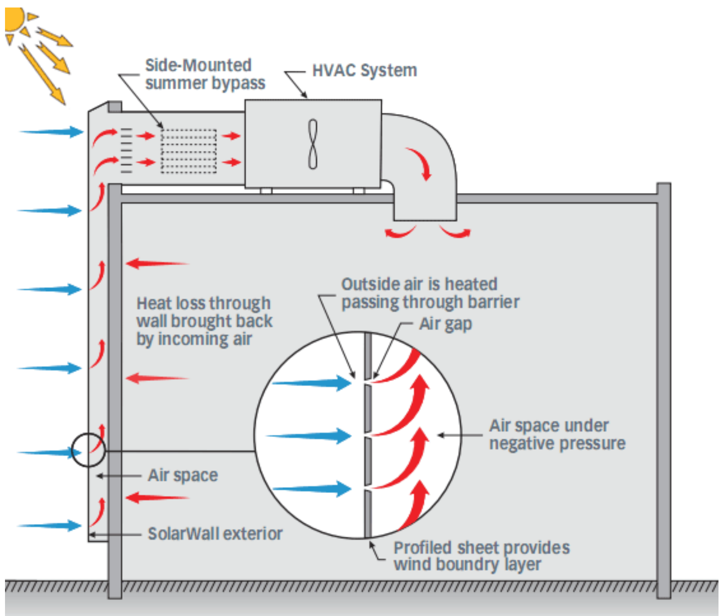
Blackstone recommends encouraging the evaluation of solar hot water applications for any new building or renovation where process hot water is required year-round. The aim is to get a minimum solar fraction of 30% should be targeted. Consider making new buildings with “solar ready” capacity with plumbing (and electrical) chases from the roof to the mechanical rooms.

Solar hot water systems are recommended for on-going consideration.

8 Solar Thermal Air

8.1 Product Background

Solar thermal air heating is often referred to by a trade name – Solarwall – owned by Conserval, a well-known Ontario manufacturer of solar air collectors. These are passive, panelized solar collectors that are connected to the outside air intake of existing air handling or make up air units, usually vertically mounted on a south facing wall.



(Source: Schematic layout – Conserval)

Figure 23: Typical solar air heating arrangement. Note that these pre-heat the air used in ventilation.

The collectors are known as transpired air collectors and are simply a dark coloured (they now offer a wide range of colours), perforated cladding material that is mounted onto an existing façade. Air is drawn through small holes in the cladding via the existing HVAC fan. When the sun shines, the dark metal heats up that air, providing pre-heating to the ventilation air.

This is also available as a roof-mounted product – rows of low-sloped collectors are ballasted and ducted into the air intake.

Control of a bypass damper prevents the system from operating during the summertime. Performance estimations are typically done by Conserval. RETScreen does have solar air heating capability which is sufficient enough for early assessments and to give an indication of the required area to make an impact.

Suitable HVAC Systems

The product is ideally suited for 100% make up air units, as might be found on a maintenance garage, community centres with large air handling units or long-term care facilities. They are connected to the fresh air intake of an air handling unit and offset pre-heating of the air and in some circumstances supplies all required heating.

Seasonal Operations & Orientation

This is a heating season-only product. Theoretically a domestic hot water pre-heat could make use of the warmed air in the summer but is not common practice. As the sun is concentrated to the south much more so than in the summer, it is important that a systems orientation is facing close to due south. The economics favour applications with 7 day/week operations and high fresh air loads. There is little maintenance required for the panels themselves.

Figure 25: Typical wall-mounted installation

Figure 24: Typical roof-mounted installation

8.2 Market Overview

Like solar thermal hot water, the number of installations has been dependent on natural gas prices and government incentive programs. While economics are more favourable for solar air, it tends to be a longer-term investment proposition. Solar air pre-heating is popular in the agriculture sector in Quebec where there are a couple of manufacturers. Ontario is limited to a single supplier (Conserval) who have been active in the market for decades. They support the design services for the consultants selected.

The industry separates out collector product supply and installation services, although suppliers tend to be involved in sizing and design questions. On the installation side there are firms who do work regularly with the product and given it's essentially a cladding layer added to the outside of the building and then connected via ductwork to an existing air system, there is little concern about the ability of an installer to work with the product. As the system is either wall or roof mounted, a structural engineering review is required. The wall mounted system connects to structural components, not just to the existing cladding material.

8.3 Application to Building Portfolio/Grid Connectivity

Locations with 100% Make-Up-Air

The system is suitable to any location where there is a 100% make up air system, particularly those that operate 7 days/week. These work best on a clear south-facing wall. It is possible to install an array on a flat roof area where the air heating loads justify the application. Maintenance garages, such as the Transit Centre, are typically good locations as would be facilities with 100% outside air loads. Lately, consideration is being given for use to upgrade the envelope and increase insulation levels while adding solar heat where loads can be connected.

Metering

This is not typically part of a solar air pre-heat system. However, a flow station and temperature sensors would allow energy calculations to be made and recommended as a commissioning step as a minimum to certify operation and savings potential.

8.4 Application as Retrofit vs. New Construction/Major Renovation

Solar air pre-heat can work in either application. Any project with large outside air loads and looking to get close to net zero should consider solar air, given the ability to offset gas heating of make-up air.

8.5 Economics

The systems' efficiency ranges from approximately 30-65%, depending on the outside temperatures and windspeeds, both of which increase heat loss. Seasonal efficiencies are likely to be closer to 35%. The costs and generation information for a typical 100 kW system holding about 50 collectors, is shown in the table below. The calculation assumes an 80% efficient make up air unit and $0.24/m^3 of natural gas. This equates to about 9,600 m^3 of gas saved per annum. The estimated costing is ~$350/m^2 of installed surface area.

Table 13: Example of solar wall air pre-heat system cost and performance

Metrics for a typical Solar Wall System	
Space Required (sq. ft)	2,500
System Cost ($)	$87,500
Estimated Annual Generation (ekWh)	90, 000
Annual Cost of Generation ($/ekWh)	$0.97
Maintenance Cost ($)	N/A
Natural Gas Savings ($)	$2,304
Annual GHG Offset (tCO_2e)	18.14

Given this is a fuel offset technology, the cost and efficiency of the base building ventilation heating system needs to be assessed. A gas-fired make up air unit is usually around 60-80% efficient depending on the age (lower efficiencies favour the use of solar air systems). As this is a passive system, maintenance costs are zero to low annually. The summer switch-over damper would need to be checked to make sure its functioning and sealing properly.

8.6 Energy Modelling

The only modeling software used is RETScreen. Its accuracy is expected to be 80-90% accurate. The vendor has experience predicting the performance and should be retained for a complete evaluation.

8.7 Procurement

A design phase should involve working closely with a manufacturer to understand sizing and location constraints. A structural engineer will be required to confirm suitability, while the existing make up air unit will also need review to make sure its fan has sufficient pressure to overcome the additional losses through the wall. A competent general contractor should be able to work with this product. However, it may make sense to have an invited bid process with contractor names based on prior product experience or a list sourced from the product supplier.

8.8 Barriers to Implementation

Procurement process needs to be thought through carefully given there are not many suppliers (one in Ontario). As with the other solar arrays, structural capacity needs to be done early to make sure the system can be installed without undue costs. The application is on the exterior of the walls and changes the colour and “look” of the wall. Given the product’s very long-life cycle, this should be a consideration when reviewing project economics.

8.9 Current/ Future Implementation in Municipalities & Equivalent Organizations

There are a few examples of this in the Greater Toronto Area:

- The CANMET building at McMaster University was constructed with a solar air pre-heat system.
- The Peel Regional paramedic service station was also constructed with a solar air pre-heat system.
- Apartment building, south wall, ~25 stories tall – near Parliament and Queen St.

8.10 Strategic Direction

Solar thermal air systems are more often mounted onto vertical walls and where there are outside air heating loads. The opportunities in The Town may be present at existing sports and operations facilities where there are large SE to SW facing walls. As these systems pre-heat air, they are best suited for locations with high winter outside air heating loads. Review sites with outside air heating loads and access to vertical walls with rooftop air distribution systems. An estimated performance can be calculated and reviewed for carbon and natural gas benefits. Solar thermal air systems should be considered where outside air is required and must be pre-heated.

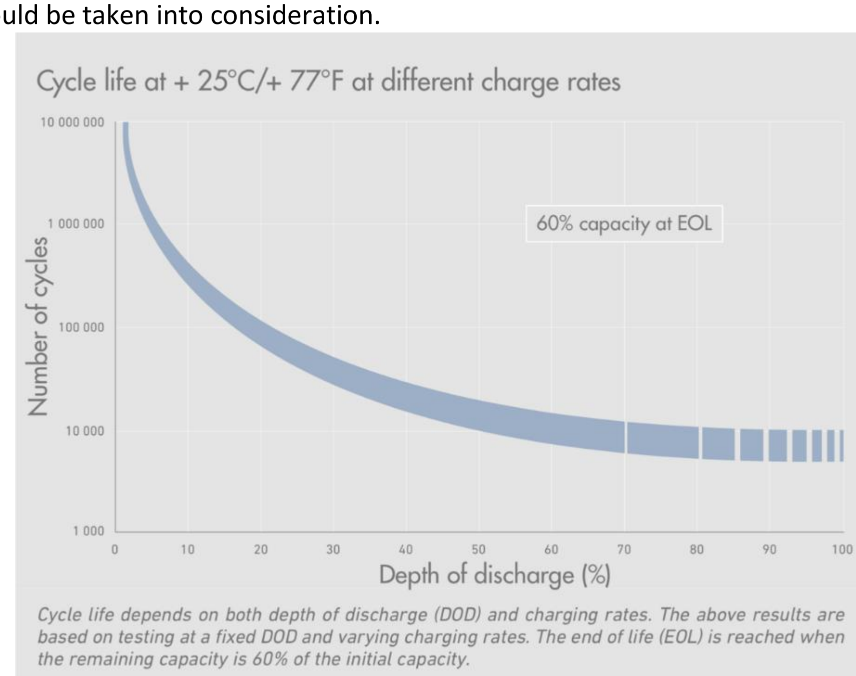
9 Energy Storage

9.1 Product Background

This section will focus on electricity storage using battery technology. While there are a number of competing technologies for the electricity energy storage sector, including aqueous chemical flow batteries and nickel metal hydride or lead acid solid batteries, lithium-ion (Li-ion) batteries have rapidly become the default technology choice.

Li-ion batteries would be connected to the main electrical feed and switchgear coming into a building and so proximity to that location will limit costs. The batteries themselves do require a thermally stable environment, so a ventilated indoor environment is ideal. Fire suppression is also a requirement. There are also containerized systems that can be installed outside with appropriate HVAC. The overall storage capacity – measured in kWh – will decline on a well understood degradation curve over time, based purely on the number of charge and discharge cycles. The following image shows a Li-ion battery with a defined End Of Life when the battery can only store 60% of its original capacity and is reached after 10,000 charge/discharge cycles, or 27 years with a single charge/discharge cycle per year.

Given the massive interest and investment in the battery sector, costs have dropped significantly while energy density (kWh stored per kg of battery) has improved. Batteries are not 100% efficient. That is, energy is lost on both the charge and the discharge cycle, with losses in the 10-15% range. These design factors are well understood and would be taken into consideration.



Source – SAFT

Figure 26: Performance example of commercial batteries showing life cycle due to discharge use

kW vs. kWh

A battery stores power (kW_{DC}) and energy (kWh_{DC}) as direct current (DC) compared to the power and energy used from the grid which is alternating current (AC). As with solar photo-voltaic, an inverter is required to convert the DC to alternating current (AC) to enable grid connection and use. The peak kW capacity of the system is defined by the inverter and defines the grid power reduction such as in demand reduction applications. The kWh factor defines how long the system will displace power (and energy).

A large capacity battery can discharge its stored energy (kWh) over a short time-period with a high resulting kW output, or a low kW output over a long period of time. Each has applications depending on the desired benefit.

The first application uses the battery to reduce the kW at certain times during the day and avoid power peaks with savings when demand reduction is rewarded. This typically requires a relationship with the LDC who want certain peaks to be avoided each year. The second application, large kWh storage, offers energy shedding during expensive electrical rate periods, typically late in the afternoons. It also offers a resiliency option to provide energy at a site that can be used as a "safe haven" site during power outages.

9.2 Market Overview

Stationary Batteries

The Li-ion battery market has been led by the growing electric vehicle industry and increasingly in utility grid applications. Stationary batteries typically provide a range of electrical grid support services:

- Short term grid support: voltage and frequency support for when a grid becomes unstable due to variance in supply and demand. This is measured in <15-minute intervals.
- Peaking grid support: batteries store power off peak and reinject that power into the grid for a fixed number of hours to meet peak grid demand – for example on a very hot or cold day. This would be measured in hours – typically less than 6 hours per occasion.
- Uninterrupted power supply (UPS) or back-up generators – batteries provide emergency power supply for short or long periods of time, replacing diesel-fired emergency generators.
- Grid services are independent of the building sector and driven by local utility or grid needs. They are often paid-for services and this is a trend that is expected to increase with the electrification of both transportation and heating. Several systems have been installed in Ontario as part of government-driven procurement processes.

Vehicle-To-Grid Technologies (V2G)

Their batteries store power and can be use by providing power to the EV. However, cars sit idle for most of the day. What if that "idle" power could also be used to help meet peak power loads like a large-scale battery does? An electric vehicle connected to the grid can act as an energy storage system, provided the inverter within the car is capable of two-way power flow. As a result, the same services detailed above can be provided by electric vehicles connected to an EV charging station with appropriate controls and signaling systems in place. This concept is called Vehicle-to-Grid (V2G) and all auto manufacturers are beginning to incorporate the concept into their EV designs.

Blackstone believes strongly in this opportunity and is working with Natural Resources Canada to work on the transaction elements that will be required to turn this concept into a reality. Starting later this year, Blackstone and members of its client base will be hosting "near-commercial", V2G demonstration projects.

This is expected to increase as parking lot EV combined with PV arrays grows and should be a consideration for The Town as they develop communities.

9.3 Application to Building Portfolio / Grid Connectivity

Large Buildings

To take advantage of demand reduction programs, the facility needs to classify as Class A for the Global Adjustment. This would have to be assessed for any large facilities to understand whether a demand reduction (DR) program can be applied. The batteries are charged during the evening and discharged during peak hours typically late in the afternoon. Combining PV and batteries can be combined and used as a DR program. Though as mentioned above, it currently does not make a good business case unless the site is a Class A location. The combination of costs suggests a PV array would be better as a net meter application and reduce the energy. Combining PV and batteries at a "safe haven" centre ensures there is power/energy available when power is shut down.

Time of Use Rates

While in theory a battery could store energy off peak (at night) then discharge into the building during peak rate hours, there is currently no economic case for this in Ontario. The rate structures will increase with time making this an option at some point. A study of what the economics and rate structure is should be completed before this is considered.

Demand Charge Avoidance

Again, there is no economic case for using batteries to limit monthly kW peak charges unless the facility can be classified as Class A for global adjustment.

Back Up Generation

These would work well for any of The Town's buildings. However, given the small quantities of diesel ever consumed there would be no economic case for this. It is also suspected that the overall carbon impact of diesel used within generators is negligible in terms of The Town's carbon footprint. This concept would best be considered for new developments where near to net zero carbon designs are being pursued. This is also a consideration for "safe haven" designs as a resiliency measure, typically in community centres.

9.4 Application as Retrofit vs. New Construction/Major Renovations

Installation in a new building would be straightforward as the electrical rooms can be designed to accommodate. For retrofits, the only requirement would be sufficient space in a ventilated interior location, or space for a ground-mounted container within a reasonable distance to the main electrical room. The battery room usually requires approvals from the Fire Marshall and a fire suppression system installed.

9.5 Economics

An economic case for batteries requires a more detailed evaluation. The application determines the economic performance. If it is to be for demand reduction, the local distribution company may sign an agreement to bring the battery online when there is a grid peak. This only applies for Class A facilities. These can have good returns with paybacks under 5 years in some cases. The LDC will require a connection impact assessment and follow many of the rules for a grid connected renewable system.

9.6 Carbon Offset Potential

Minimal, and large levels only for offsetting emergency diesel generators. If they are used to offset peak hours during the day, they offset the marginal emissions for the grid during those hours which unfortunately is not accounted. Some jurisdictions are using batteries to shift the "grid duck curve" while solar energy systems wind down at the end of the day. These tend to be in areas where the electricity rates are much higher than those in Oakville.

9.7 Energy Generation Potential

No energy is generated – it is stored. They are increasingly combined with solar PV and wind energy systems. The capacity to shift the energy loads during the day is based on the power and stored electricity (kW and kWh). A load shifting system will require high kWh capacity to displace electricity for a long period, i.e., 3 -4 hours. A peak reduction battery will need high kW to offset the power during the expensive peak periods but only for an hour or so.

9.8 Energy modeling

Energy aspects of battery operation are well understood and easily modeled by vendors and a good selection of consultants. The analysis takes into consideration the operation of the batteries – are they for peak reduction and so not called upon very often or for load shedding and shifting the "duck curve" during expensive electricity times. The performance and life of the battery system will depend on the cycles of operation each year.

9.9 Procurement

This is a small but growing market in Ontario. Utilities are driving the market of large-scale systems. However, design-build contractors are available, while the consulting community would not have difficulty in integrating batteries into an electrical design.

9.10 Barriers to Implementation

Significant co-ordination with the utility would be required. Space for the batteries is required and they are heavy. Utilities and their inspectors are gradually getting familiar with the applications. The financing does not favour batteries (or PV combined with batteries) unless the facility is Class A for global adjustment. Rates are not sufficiently high yet to warrant shifting energy loads during peak periods. A net metered PV array would be a better investment for the foreseeable future.

9.11 Current/Future Implementation in Municipalities & Equivalent Organizations

Any project involving a large government or other entity would be driven purely by the grid situation in that specific location. When there is an opportunity to participate in a demand reduction program, batteries can be considered. They are a good choice for resiliency planning at community centres.

9.12 Strategic Direction

Consideration for batteries should first be given a “safe haven” system, for example, in community centres. They can be used there as peak shedding during the year to offset expensive time of day rates where applicable.

Battery technology and the controls for integration into the buildings and grid are improving rapidly. The costs are also dropping making batteries a reasonable energy system to reduce costs during peaks as well as avoid marginal emissions when the grid is carrying gas fired peaker plant power.

Recommendation is to consider battery storage for peak shedding and possible demand reduction schemes in new buildings. Consider for use in buildings with high demand periods and develop a demand reduction plan to capture the grid peak times each year. Consideration for “safe haven” application is recommended.

10 Wind Turbines

10.1 Market Overview

Small Wind

Small wind has been around for many years, both building, ground and tower mounted, mostly for remote sites where the grid is not readily available. Lately there has been an increased use with PV and batteries on parking and street lighting poles which removes the need for electrical grid connections. There are a wide range of suppliers for small turbines. The nature of wind energy and the small profile of these turbines is such that they need high wind speeds to generate consistently.

There are two basic configurations – horizontal and vertical axis turbines. Each have their benefits and considerations when deciding which to use. In both cases the annual wind speed is the determining factor with an average > 5m/sec usually required. The length of the blades is another factor in determining the amount of electricity a wind turbine can generate. Small wind turbines that can power a single home may have an electricity generating capacity of 10 kilowatts (kW). The largest wind turbines in operation have electricity generating capacities of up to 10,000 kW, and larger turbines are in development.

Source: https://www.anthropocenemagazine.org/2017/03/new-model-could-help-make-vertical-wind-turbine-farms-practical/
http://emag.directindustry.com/ai-inspection-routines-siemens-gamesa-fujitsu/

Figure 27: Examples of a large horizontal axis wind turbine (left) and vertical axis turbine (right)

Horizontal-axis turbines have blades like airplane propellers, and they commonly have three blades. The largest horizontal-axis turbines are as tall as 20-story buildings and have blades more than 100 feet long. Taller turbines with longer blades generate more electricity. Nearly all the wind turbines currently in use are horizontal-axis turbines. Horizontal axis turbines prefer steady winds from one direction.

Vertical-axis ("eggbeaters") turbines have blades that are attached to the top and the bottom of a vertical rotor. They can operate in winds that come from a variety of directions relatively easily. Small scale applications are typically less than 10kW. Some versions of the vertical-axis turbine are 100 feet tall and 50 feet wide. Very few vertical-axis wind turbines are in use today because they do not perform as well as horizontal-axis turbines.

Past experiences point out that an existing building rarely has the structural capability to retrofit a roof or structure mounted system. The main issue, other than large loads is vibration which can be transmitted through the building and difficult to remedy. In some designs, the turbines are integrated into the structure as illustrated in the picture below. This requires significant pre-planning and structural design to accommodate. The elevation of the turbines puts them into higher wind regimes.

Figure 28: Example of building integrated wind turbine.

Utility Scale Wind

Large (>150kW) turbines have increased in capacity and performance significantly over the last 10 years with a few large-scale manufacturers installing very large (>2MW) systems around the world in utility scale arrangements. They require a complex connection process to the grid, with significant planning, grid connection and public acceptance concerns.

While The Town's location on the shore of Lake Ontario provides good quality wind resources and likely very good project economics, there are significant public concerns around the use of wind energy in or close to urban settings. Exporting excess power to the grid would provide an opportunity to generate carbon offsets for existing natural gas-associated emissions. Large turbines must connect to the grid directly rather than to a building's electrical system.

Both large and small wind energy systems could be considered for new developments with sufficient setbacks, but this would likely run up against public push-back. At some point virtual power production (VPP) may become possible and The Town could then consider purchasing or partnering in a large-scale wind turbine farm outside of the community.

At this time, the small turbines mentioned above for use on parking and road streetlights (LED) are a good example of wind energy suitable for urban application. It has the benefit of showcasing renewable energy use within the community at a scale that does not cause much concern. They can be installed without connection to the grid saving trench and cabling costs. They are capable of being monitored remotely to track energy generated and avoid down time when repairs are required.

An example of such a system is the Sanya Skypump system. It harnesses the power of the wind and sun to charge EVs. Developed by Urban Green Energy and GE Energy Industrial Solutions, the Skypump utilizes a UGE-4K wind turbine harnesses wind power, while solar panels on the Skypump's roof generate electricity from the sun's rays. The combined energy produced by the wind turbine and solar array is enough to significantly offset the charging station's electricity use. At lower wind speeds, or higher level 2 charging loads, it can be connected to the grid to pull additional energy as required.

(Source: http://www.apsglobalcorporation.com/sanya-skypump.html)
Figure 29: Example of a stand-alone vertical axis wind generation system for a parking light.

10.2 Application to Building Portfolio/Grid Connectivity

Wind energy systems are not recommended for installation onto buildings. The structural and vibration issues cannot be overcome easily or inexpensively. There are systems that can be built into the structure of a new building but not in many sites. There are small systems that power street or parking lights that might be applicable and used typically for awareness of renewable energy for the most part. In some situations where access to grid power is not available and wind powered lighting system can be warranted.

The Town may be able to participate in a virtual power plant venture where they invest in a remote wind farm to partner in a long-term power purchase agreement to offset their conventional grid purchases and collect the carbon credits. Though The Town sits on the shore of Lake Ontario, installing turbines in the Lake or close to urban centres would be unlikely.

10.3 Application as Retrofit vs. New Construction/Major Renovation

As mentioned above, attaching a small wind energy system to an existing building is not recommended. In new construction they can be incorporated into the structure but again, concern for vibration will make the costs for the system high and not easily justified.

Wind turbines work efficiently in winds that are free from disturbances from urban structures. Retrofitting a wind turbine amongst buildings will not operate efficiently.

10.4 Economics

The economics for large scale wind turbine applications are favourable over long term agreements or power purchase agreements (PPAs). Large wind farms are required to take advantage of scale and the amount of generation needed to make the low cost of electricity possible. Small systems will not be favourable when compared to small photovoltaics for loads such as remote lighting.

10.5 Carbon Offset Potential

Wind energy systems displace electricity and so reduce the carbon according to the current emissions factors for the grid. Large scale farms generate the levels of electricity to cause significant carbon emissions reductions.

10.6 Energy Generation Potential

The average winds in Oakville, close to the Lake are about 15-18 km/hr (4-6 m/s) between October and April. These averages will be found above 30 m and where there are few buildings. Wind turbines require average speeds above >6 m/s typically before they can start to generate power at a reasonable level. The higher the turbine hub is above the ground, the more power available in the winds and less turbulence from the urban buildings. The power produced is related to the third power of the wind speed – for a doubling of the wind there is an eight-fold increase in the power. For example, a 600kW wind turbine (45m diameter at 50m hub height) starts to produce power at 5m/s but only 45kW. It only reaches the nameplate power when the wind is at 14 m/s (about 55-60 km/hr). The wind turbine near the CNE in Toronto is ~600 kW and produces about 1,200,000 kWh/yr.

10.7 Energy Modelling

Wind energy modelling should be completed by an experienced engineer conversant with wind system performance. There are many variables that an experienced modeler needs to understand before an accurate estimate of performance can be completed.

10.8 Procurement

There are several wind energy system providers for a large range of generation capacities. A specialist should be retained to estimate the performance, propose a system type, prepare the specifications, and oversee the request for proposals as well as to review the responses when selecting a vendor/installer. When selecting a consultant for the structural design, a team familiar with wind energy systems should be hired.

If a wind system is being considered, begin connection impact and environmental studies early and retain experts in these fields.

10.9 Barriers to Implementation

Public pushback has been strong against wind turbines in most jurisdictions. Other than a virtual power plant arrangement a wind turbine close to The Town is not likely to be received well by the public. As with any other renewable energy system, the generated power would be injected into the grid or building as net metered energy and require the same connection impact studies. An environmental impact study would also be required. The turbines will need specialized staff to operate and maintain them.

10.10 Current/ Future Implementation in Municipalities & Equivalent Organizations

The opportunity for The Town is to partner with a virtual power plant operation where a power purchase agreement is in place, typically for 20+ years.

10.11 Strategic Direction

Wind energy can be either active or passive. Active wind energy capture using a turbine is not applicable within The Town but may be possible through a virtual power plant and PPA. Small turbines such as used for remote lighting standards are possible though likely not as efficient as a small PV system.

Passive use of wind through design is recommended to assist with ventilation and directing to prevent uncomfortable wind tunnels and snow build up. We recommend a wind study be completed for new buildings to ensure passive wind energy is being used to benefit energy and comfort.

Wind energy is not recommended for urban applications other than small scale, stand-alone systems. Consideration for a partnership in a VPP should be investigated.

Net Metering and Virtual Power Plants

Rooftop and on-site ground mount PV (such as car port systems) will typically be connected to the local grid through a “net meter”. This means the power generated is used within the facility only. The recommendation for a PV fraction (as shown in the table above) would be net metered. This connection format is standard with the local utility. A recommendation for future electricity generating applications, at the urban scale level, is to be net metered. A follow up consideration that may become possible for the Corporation are “virtual power plants” (VPP). These are RE systems that are not on or not close to The Town with the output allowed to offset the energy delivered to The Town from the grid. For example, The Town could participate in a large PV or wind facility many kilometers away. A VPP would generate the electricity and inject the power into the transmission or distribution grid and be considered as an energy used within The Town. This concept has been considered for a few years in many jurisdictions though usually not possible due to the architecture of the grids – the power cannot be shipped from where the generation sites are to the region it is needed. That and a robust accounting process has yet to be developed. It is recommended The Town maintain awareness of this concept through discussions with the local distribution company and their peers in other jurisdictions and relevant associations.

Suggested Policy Considerations:

1. Develop net metering ready standards for new construction and large renovations, i.e., room for electrical equipment, sub-meters, junction boxes, etc.
2. Participate with industry and municipal associations for VPP updates and lobbying

Appendix A: RE Technology Rubric

In this section, we have consolidated the technologies reviewed in the study and have formulated a rubric to showcase the implementation potential relative to Oakville's corporate portfolio. The rubric contains two matrices – the Technology Assessment Matrix and the Applicability Matrix.

The Technology Assessment Matrix evaluates and ranks the RE options based on the following metrics:

- ✓ Market performance
- ✓ Applicability for Oakville
- ✓ Ease of procurement
- ✓ Carbon offset potential
- ✓ Energy generation Potential
- ✓ Ease of modelling & engineering
- ✓ Implementation barriers

The Applicability Matrix evaluates and ranks the RE options based on their relevance and feasibility to The Town's corporate building archetypes and to the larger Oakville community:

- ✓ Non-building application
- ✓ Administration and Office buildings
- ✓ Community Centres
- ✓ Indoor Arenas
- ✓ Transit Facilities
- ✓ Fire Halls
- ✓ Other Buildings

Table Methodology

Scale

0 – 3: be aware of this negative impact

4 – 6: worthy of consideration if other factors are more positive

7 – 10: should be a significant driver for reviewing potential for use

Economics Methodology

<= 5 is more expensive than the base case

>=5 is cheaper than the base case

Energy Generation Methodology

- No mark given for technologies not generating additional energy e.g. biofuel
- For direct energy generation projects e.g. solar, ranked based on useful energy generation potential and energy efficiency. 10 >= 100% energy conversion.

Carbon Offset Methodology

- For substitution technologies, score based on % reduction per technology
- For energy generation e.g. solar, score based on cost per tonne generated per $ invested over life cycle ($50 per tonne base case = 10)

Technology Assessment Matrix

	Market	Portfolio Application	Economics	Carbon Offset%	Energy Generation&	Modelling	Procurement	Implementation Barriers+	TOTAL	RANK
Solar Photovoltaic	9	9	10	6	7	9	8	8	8	1
Solar Thermal Water	8	7	6	7	8	8	8	8	8	2
Air Source Heat Pumps	7	8	5	7	2	7	7	8	6	3
Solar Thermal Air	7	6	5	4	5	8	8	5	6	4
District Energy Systems*	7	3	5	8	2	7	8	5	6	5
District Energy Heat Pump Based System@	7	3	5	8	2	5	7	4	5	6
Geo-Exchange Heat Pump Systems	5	7	2	6	2	8	6	4	5	7
Wind Energy	5	3	5	4	4	6	6	6	5	8
Bio-Energy	6	6	5	4	0	6	5	5	5	9
Energy Storage	4	2	1	1	0	5	5	4	3	10
Hydrogen & Fuel Cells	1	0	0	0	0	2	1	0	1	11

* Assumes conventional gas boiler/electric chiller system
@ Assumes electrically driven heat pumps connected to a geo-exchange borehole system
+ A high mark means low barriers to implementation
& Note that heat pumps require significant energy input but convert that to heat with efficiencies >200%
% Solar Photovoltaic can offset peak electricity emissions which have a much higher carbon intensity as compared to the average. Solar thermal assumes base fuel case of natural gas, else same applies.

Applicability Matrix

	Non-Building Application	Administration/ Office	Community Centres	Indoor Arenas	Transit Facilities	Fire Halls	Other Buildings	TOTAL	RANK
Solar Photovoltaic	7	8	9	9	9	8	6	8	1
District Energy Systems*	0	7	9	9	7	7	7	7	3
District Energy Heat Pump Based System	0	7	9	9	7	7	7	7	3
Air Source Heat Pumps	0	8	8	8	6	8	8	7	3
Solar Thermal Water	4	3	8	7	7	8	8	6	5
Geo-Exchange Heat Pump Systems	0	5	8	8	8	4	3	5	6
Solar Thermal Air	0	3	4	6	9	6	2	4	7
Energy Storage	0	4	6	5	5	1	2	3	8
Wind Energy	3	3	3	3	4	3	2	3	9
Bio-Energy	5	2	3	0	0	0	3	2	10
Hydrogen & Fuel Cells	0	0	0	0	2	0	0	0	11
Total									

* Assumes conventional gas boiler/electric chiller system

@ Assumes electrically driven heat pumps connected to a geo-exchange borehole system