City of Mississauga

District Energy in the Downtown: Feasibility Study

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By:

FVB ENERGY INC

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EXECUTIVE SUMMARY

Significant, large scale action is required in order for Mississauga to meet its greenhouse gas (GHG) reduction targets and to respond to the climate emergency. The largest source of GHG emissions in Mississauga is buildings: approximately 50% of the city's emissions come from heating and cooling residential, commercial, and industrial buildings. In addition, the City's own corporate buildings (e.g., community centres, libraries, fire stations) account for approximately 20% of the City's corporate emissions; that means it is critical for the City to focus on reducing GHGs from this sector.

As an efficient system for heating and cooling buildings, district energy (DE) has the potential to substantially reduce GHGs, particularly if it is fueled using renewable energy. A district energy system (DES) consists of three main components: (1) a central plant that produces thermal energy; (2) pipes that distribute the thermal energy (i.e., hot and cold water) to buildings; and (3) an energy transfer station at each building.

A DES has numerous benefits. To start, it is more efficient: thermal energy is produced at a central plant, rather than each building generating its own heating and cooling. This makes heating and cooling production more efficient. DE also provides flexibility with respect to technology and fuel sources, making it easier to switch from one fuel source (e.g., natural gas) to another (e.g., electricity, waste heat, geothermal). At the same time, since DESs are able to use local energy and fuel sources, they increase energy security, stabilize energy prices, and improve community resilience. While DESs come with some challenges such as high upfront costs, the clear benefits are some of the reasons why DESs are prevalent in every corner of the world, from college campuses to military bases to indigenous communities, to bustling downtown cores.

Study Purpose

The purpose of this study is to consider the feasibility of a low carbon DES in the City of Mississauga's Downtown. In 2019, City of Mississauga Council approved the City's first comprehensive Climate Change Action Plan (CCAP). That plan includes 89 actions, which are intended to help the City achieve its two main goals: (1) reduce GHG emissions 80% by 2050; and (2) increase resilience and the capacity of the city to withstand and respond to climate events. This study addresses one of the CCAP actions: "conduct a district energy feasibility study in the downtown…" FVB Energy Inc. (FVB) conducted the study.

Study Results

Estimated System Demand with a Phased DE Approach

FVB has developed a low carbon DES concept based on existing buildings and the forecasted new development in Mississauga's Downtown over approximately 30 years to 2050 – a period that could see upwards of 3 million m² (30 million ft²) of development. FVB recommends that the buildout of the DES take place over six major phases, with each phase taking approximately five years. The cumulative gross floor area (GFA) for each phase is shown in Table A.

Table A: Cumulative GFA Over the Six Phases

Phase	Cumulative GFA m²
Phase 1A	118,100
Phase 1B	641,700
Phase 2	1,439,900
Phase 3	1,929,700
Phase 4	2,729,200
Phase 5	3,197,900
Phase 6	3,718,700

FVB has split the first phase into Phase 1A and Phase 1B. Phase 1A includes three existing municipal buildings – Living Arts Centre, Mississauga Civic Centre, and the Hazel McCallion Central Library – as well as the three Sheridan College buildings. Phase 1B includes other privately owned buildings located in close proximity to the Phase 1A buildings. Phase 1A and Phase 1B together make up the same timeframe as the other phases, but this division in phasing allows for separate evaluation of the municipal and Sheridan College buildings. An overview map of the study area showing the phasing plan is included as an appendix to this report.

Three scenarios were considered to evaluate the benefit of a low carbon DES:

1. **Business-as-Usual (BAU) Standalone**: Buildings remain disconnected from a DES and are heated and cooled with their own stand-alone system.
2. **Low Carbon Standalone**: Buildings remain disconnected from a DES and are heated and cooled with their own standalone system. The Low Carbon scenario assumes that new buildings would be constructed to progressive Green Development Standards over the duration of the study period.
3. **Low Carbon DES**: Buildings are connected to a DES. The demand and energy of the buildings, as well as their emission targets, are the same as in the Low Carbon Standalone; however, the DES allows for increased system diversification, which reduces the total peak demand.

The cumulative heating and cooling demand as the system attains its full buildout are shown in Figure A and Figure B respectively. The reduction in demand for the Low Carbon DES compared to the standalone scenarios represents the fact that all of the buildings connected to the DES will not have their peak demand occur at the exact same time. This allows for equipment capacity savings for the DES compared to the standalone cases.

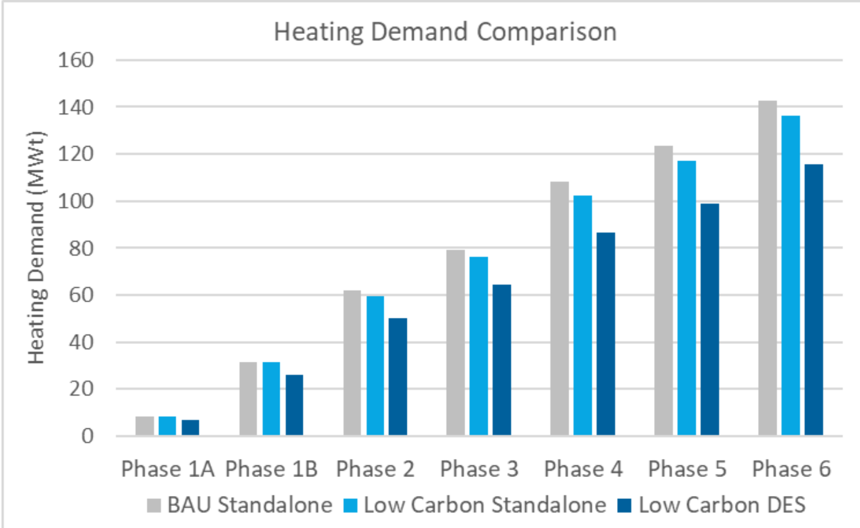

Figure A: Cumulative Heating Demand by Phase

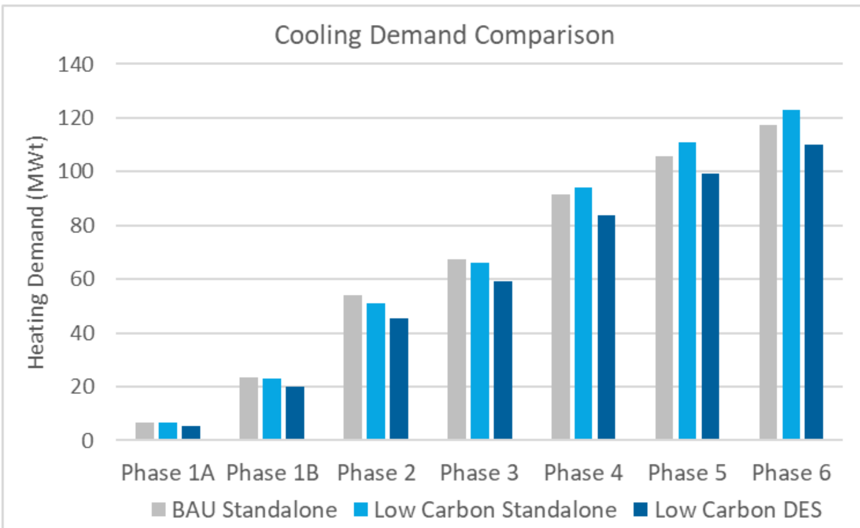

Figure B: Cumulative Cooling Demand by Phase

Low Carbon DES Concept

At full buildout, the low carbon DES would consist of geo-exchange, sewer heat recovery, electric boilers, natural gas boilers, and centrifugal chillers with associated cooling towers. This combination allows for a significant decrease in GHG emissions for the existing buildings, including the municipal buildings, while being financially competitive with current and future building standards. Thermal energy would be delivered from five (5) energy centres at full build out through a four-pipe distribution piping system (DPS). Each building would be connected to this distribution system indirectly through an Energy Transfer Station (ETS).

The first energy centre would be constructed to serve Phase 1A and would include a geo-exchange system along with boilers, chillers, and power generation systems to provide peaking capacity, system redundancy, and back-up power capabilities. As the system expands, additional geo-exchange systems as well as sewer heat recovery systems would be installed and interconnected to achieve the desired GHG emission targets. The details of these systems are outlined within the report.

Financial Analysis, Expected Costs, and GHG Reductions

The key financial results of this study and anticipated GHG emission reductions are summarized in Table B. These results are indicative of the system at full buildout. The unescalated annual expenses and revenue represent the costs to operate the system and the anticipated revenue from the buildings connected to the DES at full buildout. The internal rate of return (IRR) and the net present value (NPV) are metrics that can help determine the overall business case of a project. In this case, they show that there is a promising business case for implementing a DES in Mississauga's Downtown.

Table B: DES Financial Results and GHG Benefit

	Financial (Unescalated)		Financial (Escalated)		Reduction in GHGs vs. BAU Standalone @ Full Build-Out (tonnes)
Description	Annual Expenses ($/yr) 2022	Annual Revenue ($/yr) 2022	Projected IRR 25 Years (%)	25-Year NPV 3.0% ($)	
Low Carbon DES	$ 24 million	$ 44 million	8.3%	$ 300 million	28,288 (88%)

With a low carbon DES, there is an 88% reduction in GHG emissions compared to the business-as-usual (BAU) Standalone case and a 78% reduction over the Low Carbon Standalone case at the full buildout of the system (i.e., after the final phase is built).

The total estimated DES capital costs realized by the end of project buildout are summarized in Table C below.

Table C: DES Capital Cost Summary (Full Buildout)

Low Carbon DES Class D Preliminary (-25%/+50%)	Full Phased Buildout	
	Installed Capacity	Total (2022$)
Heating Plants	138.0 MW	$ 113.7 million
Cooling Plants	31,400 tons	$ 144.8 million
Energy Transfer Stations	85 ETSs	$ 65.7 million
Distribution Piping System	10,840 tm	$ 57.6 million
Total DES Capital Cost		**$ 381.8 million**

Table D shows a breakdown of the incremental capital spent in each phase to expand the Low Carbon DES. It also shows the estimated cumulative annual GHG emission reductions in each phase of the system buildout compared to both the BAU Standalone, where new buildings are constructed to current building code, and the Low Carbon Standalone, where new buildings are constructed to more aggressive standards.

Implementing low carbon standards will be a vital component of achieving GHG reductions in the Downtown. However, connecting buildings to a low carbon DES provides significantly more emission reductions than simply implementing the standards, as buildings that are already constructed can also benefit from the low carbon production of heating and cooling.

The BAU Standalone and Low Carbon Standalone emissions are very similar in Phase 1A and Phase 1B, as the majority of the buildings are existing buildings that would not incur a change to their demand and energy profile with increased restrictions on new building construction energy consumption and GHG emissions.

Table D: GHG Emission Reductions of DE Compared to BAU Standalone and Low Carbon Standalone

DES Summary		Incremental DES CapEx Spent	BAU Standalone Cumulative GHG Emissions	Low Carbon Standalone Cumulative GHG Emissions	Low Carbon DES Cumulative GHG Emissions	Low Carbon DES vs. BAU Standalone
Phase	**Year**	**2022 CAD$**	**tonnes/year**	**tonnes/year**	**tonnes/year**	**% Reduction**
Phase 1A	2025	$ 47.5 mil.	2,980	2,980	610	80%
Phase 1B	2028	$ 88.0 mil.	15,870	15,860	4,550	71%
Phase 2	2030	$ 83.3 mil.	30,620	23,930	5,100	83%
Phase 3	2035	$ 17.0 mil.	38,790	25,350	5,500	86%
Phase 4	2040	$ 76.7 mil.	51,300	27,070	6,230	88%
Phase 5	2045	$ 54.4 mil.	57,590	27,640	6,300	89%
Phase 6	2050	$ 14.9 mil.	65,990	36,030	7,750	88%
Total	**2050**	**$381.8 mil.**	**65,990**	**36,030**	**7,750**	**88%**

Connecting the three City buildings in Phase 1A reduces their combined emissions by 1,650 tonnes annually. Early action to kickstart the DES will be vital in driving this project forward and will provide a foundation for building out the rest of the system. Investments to make the City buildings “DE Ready” will benefit these buildings regardless of the final ownership.

Ownership Models

There are several different ownership and operation structures for a DES, each with their pros and cons. Three that were examined in detail in this report are: (1) 100% municipal ownership; (2) a joint venture model between the municipality and a private partner; and (3) 100% private ownership. These models will be further explored and a recommendation made in the detailed design stage for Phase 1A.

Next Steps: Critical Success Factors in Advancing DE in the Downtown

The development of a successful DES requires one or more anchor customers to start, and the City and Sheridan buildings provide this opportunity. It is important to keep in mind, however, that coordination with stakeholder groups and rigorous planning will be required to continually and sustainably grow and develop the DES beyond this initial phase. FVB recommends the following next steps:

1. Explore the development of a City of Mississauga standard for new buildings to be ‘DE Ready’ so that if DES in the Downtown moves forward, connecting the building will be feasible without having to complete a substantial retrofit to the building. This could be incorporated into the refresh of the Green Development Standards (GDS) for the City. (Timeline: Immediate. To be analyzed in conjunction with the refresh of the GDS).
    a. As the DES is implemented and becomes a facet of the Downtown, options that require new buildings with multiple towers or significant thermal demand to connect to the DES should be explored. Alternatively, providing incentives to developers to connect to the DES – such as what is currently being done in the City of Toronto – should be investigated.

2. Further develop the Phase 1A design to further optimize the energy centre, distribution piping, and energy transfer station design, system costs, and coordination between this phase and the other DE phases. (Timeline: In the short term). This would include:
    a. Schematic design of the first energy centre and building connections, along with refined capital costing

b. Presentation of an updated business case that would evaluate the presented ownership models in greater quantitative detail

c. The development of a detailed economic comparison report that present the avoided cost of the standalone solution required for the Phase 1A buildings to achieve their 80% GHG reduction target. This economic comparison report could be used to form the basis of Thermal Energy Service Agreements with the three City buildings, Sheridan buildings, and new developments near the proposed Phase 1A energy centre.

3. Develop a detailed drawing of the DE corridor for municipal roads and rights of way so, when new developments are being considered, there is consideration for DES infrastructure (Timeline: In the short term). In addition, this detail could be used for coordinating utility upgrades in areas where there could be synergies to install DE infrastructure to facilitate an existing or future DES.

4. Continue engagement with all relevant stakeholder group(s), including internal stakeholders (e.g., Building, Development & Design, Facilities & Property Management), Downtown landowners, developers, utilities, and other levels of government. Engage and educate the public about DE opportunities in the city and their benefits for GHG emission reductions, reliability, and resiliency (Timeline: Ongoing).

Provided all major stakeholders work together cohesively, there is an opportunity for the City of Mississauga to develop a world class low carbon thermal energy network in the City's Downtown that will make a significant contribution to the City meeting its GHG reduction targets.

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ACRONYMS

AEF	Average Emission Factor
AHU	Air Handling Unit
ASHP	Air Source Heat Pump
BAU	Business-As-Usual
CCAP	Climate Change Action Plan
CWS	Chilled Water Supply
DE	District Energy
DES	District Energy System
DHW	Domestic Hot Water
DPS	Distribution Piping System
ETS	Energy Transfer Station
FVB	FVB Energy Inc.
GDS	Green Development Standards
GFA	Gross Floor Area
GHG	Greenhouse Gas
GSHP	Ground Source Heat Pump
HOEP	Hourly Ontario Energy Price
HWS	Hot Water Supply
IRR	Internal Rate of Return
LAC	Living Arts Centre
MCC	Mississauga Civic Centre
MCL	(Hazel) McCallion Central Library
NG	Natural Gas
NPV	Net Present Value
OAT	Outdoor Air Temperature
PE-RT	Polyethylene, designed for Raised Temperatures
PEX	Cross-linked Polyethylene
SHR	Sewer Heat Recovery
TAF	The Atmospheric Fund
TGS v3	Toronto Green Standards version 3
UN	United Nations
WACC	Weighted Average Cost of Capital
WSHP	Water Source Heat Pump

UNITS OF MEASUREMENT

Abbr.	Name	Description
GJ	Gigajoule	A unit of total energy, equivalent to 3.6 MWh. This unit is typically used for natural gas consumption.
kg CO_2/MWh	Kilograms of carbon dioxide equivalent emissions per megawatt-hour	A unit of emission density, used to calculate the emissions of consuming a certain amount of energy.
kg CO_2/GJ	Kilograms of carbon dioxide equivalent emissions per gigajoule	Same as above.
kPa	Kilopascal	A measurement of pressure
kW	kilowatt	A unit of energy, equivalent to 1 joule per second. Used to demonstrate instantaneous demand.
kWh	Kilowatt-hour	The total energy of using 1 kWt over the course of an hour Used to demonstrate energy use.
kWh/m²	Kilowatt-hour per Square Meter	A metric of energy density that allows buildings of different sizes to be compared.
L/s	Litres per Second	A unit of flow rate
MW	Megawatt	Equivalent to 1,000 kW
MWh	Megawatt-hour	Equivalent to 1,000 kWh
psig	Pounds per Square Inch (gage)	A measurement of pressure
tm	Trench Meter	A meter of trench containing a hot water supply and return pipe and a chilled water supply and return pipe. This is a different measurement from “meters of pipe”, as each trench meter contains a meter of each type of pipe installed within.
W/m²	Watts per Square Meter	A metric of demand density that allows buildings of different sizes to be compared.

1 INTRODUCTION

1.1 BACKGROUND

Approved by City Council in 2019, the City of Mississauga's Climate Change Action Plan (CCAP) sets out two ambitious goals: (1) reduce greenhouse gas (GHG) emissions 80% by 2050; and (2) increase resilience and the capacity of the city to withstand and respond to climate events. The City needs to take significant, large-scale action in order to meet these goals.

In Mississauga, the largest source of GHG emissions is buildings: approximately 50% of the city's emissions come from residential, commercial, and industrial buildings. Further, the City's own corporate buildings (e.g., community centres, libraries, fire stations) make up approximately 20% of the City's corporate GHG emissions.[1] That means that, in order to reach its GHG emission reduction targets, the city needs to focus on reducing GHGs from the building sector and, more particularly, on reducing the use of natural gas for space and water heating (note that over 30% of the city's **total** GHG emissions come from the use of natural gas in buildings).

District energy (DE) provides this opportunity. As noted in a United Nations (UN) publication on "District Energy in Cities," DE "is one of the least-cost and most-efficient solutions for reducing GHG emissions and primary energy demand." Indeed, a number of cities around the world are leveraging DE to help meet their GHG emission reduction targets. In Canada, DE is a key component of Toronto's climate action plan. Markham District Energy is looking to add low-carbon thermal generation to its system as part of the City of Markham's Municipal Energy Plan. And the City of Vancouver has developed a Neighbourhood Energy Strategy as part of its Climate Emergency Action Plan.

1.1.1 DISTRICT ENERGY IN THE CITY OF MISSISSAUGA

The City's interest in DE extends back at least a decade. For example, in the 2009 Strategic Action Plan, DE was identified as one of the "Strategic Actions for Future Consideration." In 2013, a District Energy Screening Study was completed. That study identified areas in the city that would be suitable for DE. The Downtown Core ranked the highest. As the study explained, there were a number of reasons for this ranking, including the Downtown's density, its significance, and its core anchor tenants. Other areas in the city that also received a high ranking include the Downtown Hospital, Central Erin Mills, Inspiration Lakeview (now Lakeview Village), and Inspiration Port Credit West (now Port Credit West Village).

More recently, actions that support the advancement of DE in the city were included in the CCAP. This includes an action to "conduct a district energy feasibility study in the downtown for community and municipal buildings to advance low carbon energy systems in Mississauga" (CCAP, Action 1-2). Consistent with the CCAP action, this study assesses the feasibility of implementing DE in Mississauga's Downtown.

The study includes a preliminary concept for the system, which was produced using the estimated demand and energy of existing and future buildings constructed from 2025-2050 in the study area. The preliminary concept includes phased energy centres containing geo-exchange and sewer heat recovery systems and a distribution piping system. The District Energy System (DES) concept is also compared against a "standalone" scenario, or how the buildings would function (e.g., GHG emissions, costs) if

[1] See Mississauga Climate Change Action Plan: Progress Report 2021 (December 2021).

they are not connected to the DES. This analysis will be used as part of the business case for the project.

1.2 ACKNOWLEDGEMENT

The information in this report is based on information and assistance provided by multiple project stakeholders, including members of the Downtown District Energy working group. This group included representatives from the City of Mississauga, Oxford Properties, Morguard, Region of Peel, City of Toronto, Enbridge Gas, Alectra Utilities, Sheridan College, and Metrolinx.

1.3 WHAT IS DISTRICT ENERGY?

District Energy Systems (DES) are a highly efficient method of providing heating and cooling to buildings. A DES consists of three main components:

Figure 1: District Energy Concept Pictorial

- **Central plant or "Energy Centre"** that produces thermal energy (1 in Figure 1). For a low carbon DES, this may include a variety of technologies and fuel sources such as geo-exchange, sewer heat recovery, deep geothermal, and biomass.
- Pipes that distribute the thermal energy (i.e., hot and cold water) to buildings (2 in Figure 1) called the **Distribution Piping System (DPS)**. This piping system is typically buried underground (see Figure 3).
- **Energy Transfer Station (ETS)** at each building (3 in Figure 1) where thermal energy is exchanged. ETSs eliminate the need for boilers, chillers, heat pumps, and cooling towers in each building (see Figure 4).

The concept of DE is not new: these piped systems were used by the Romans to heat dwellings and baths. In Canada, the first DES was constructed in 1880 in London, Ontario, to serve the university, hospital, and government buildings. In 1911, the University of Toronto launched its own district heating system, followed in 1924 by the first commercial system established in the City of Winnipeg.

Traditionally, the most common application of district heating and cooling in North America is in university, military, government and large industrial campuses. Since 1990, there has been significant growth in commercially operated systems, including in Toronto, Montreal, Ottawa, Markham and Vancouver.

We are currently in the 4th generation of district heating in Canada due to advances in building-side HVAC design and DE-side system design:

- 1st Generation: Steam Based Systems (1880 – 1930)
- 2nd Generation: Pressurized Super Heated Water above 100 °C (1930 – 1980)
- 3rd Generation: Pressurized Water at temperature typically below 100 °C (1980 – 2020)
- 4th Generation: Pressurized Water at temperatures typically between 50 – 70 °C (2020+)

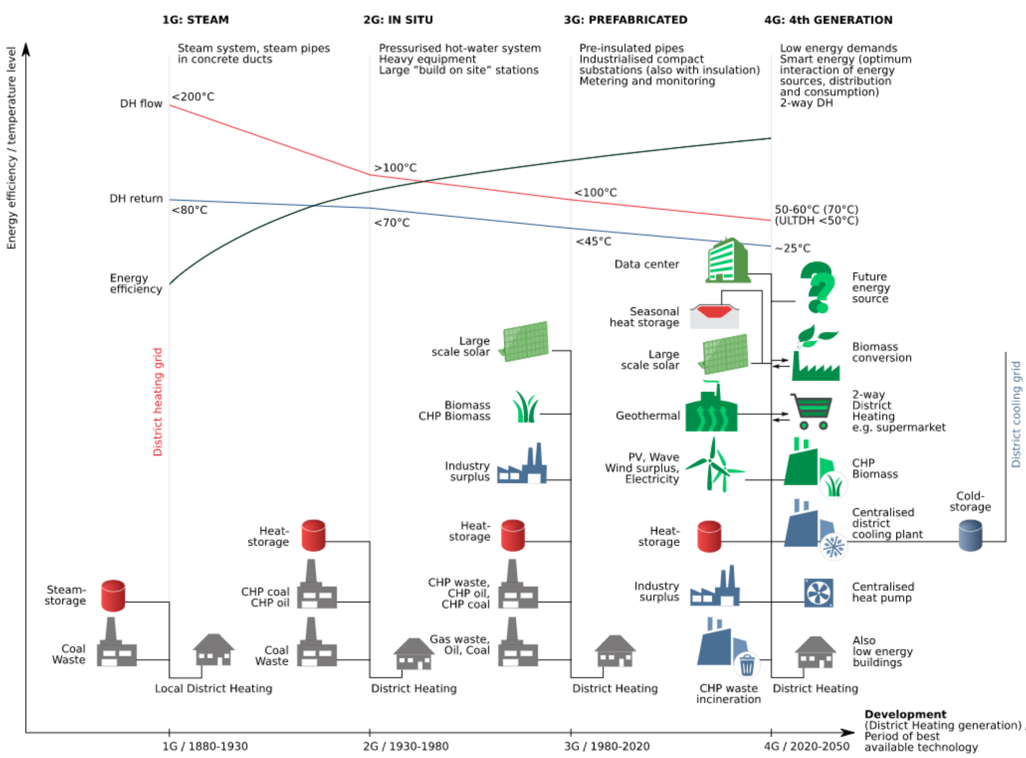


Figure 2: District Energy Evolution

DESs facilitate the sharing of energy and the implementation of community-wide energy solutions, which may not be achievable with individual buildings. Globally, the development of DES is recognized as a key to accelerating the transition to a low carbon economy and reducing GHGs[2]. There are a number of reasons for this. One major reason is that sharing low carbon energy production among several buildings means economies of scale during implementation and greater year-round use of low carbon energy compared to solutions that are implemented on an individual buildings scale. Another important reason is that DESs can be implemented with conventional fuel sources, such as natural gas, at the project onset while revenue is low and can begin incorporating low carbon technologies as more buildings are added to the system, building standards tighten, or more system capacity is needed. This

[2] District Energy in Cities Initiative, United Nations Environment Programme

allows for much greater flexibility than an individual building would have, and also allows older buildings to achieve GHG reduction benefits without having to replace their own equipment.

With the ongoing effort to reduce GHG emissions throughout Canada, more and more DESs that use low carbon thermal generation are being constructed. In Vancouver, the False Creek Neighbourhood Energy Utility has been capturing waste heat from the municipal sewer system since 2010 and now plans to expand its system. A net-zero DES is under development by Zibi in the National Capital Region, which will use waste heat recovered from industrial processes to fuel the system.

In addition to decreasing GHGs, there are numerous other benefits to DES. These include:

- **Enhancing resilience**: energy centres have redundancy built into their equipment capacity, and underground DPS piping allows for hot and chilled water to be distributed to buildings even during extreme weather events that may cause power outages.
- **Enhancing reliability:** professional operators monitor all aspects of the DES from the energy centre to the individual building energy transfer stations to ensure consistent operation. This contrasts a typical building, which is not generally monitored by professionals on a continual basis.
- **Lowering energy costs:** energy centres have access to economies of scale for natural gas and electricity purchasing, as well as cost avoidance measures such as peak shaving for Ontario's Class A rate structure. The energy cost savings are transferred to the connected customers.
- **Keeping energy dollars local:** DESs can use local fuel sources (e.g., waste heat, geothermal), which keeps energy dollars within the community and strengthens a community's resilience.

Figure 3 shows a four-pipe distribution system for hot and chilled water installed in the GTA. Figure 4 shows one of the heat exchangers that forms an ETS located within a building connected to a DES.

Figure 3: Example of a Distribution Piping System

Figure 4: Typical ETS Installation

There are, however, some challenges in implementing a DES. Constructing the energy centres and installing the distribution pipes generate a high, one-time capital cost. There are also logistical challenges with installing distribution pipes in congested rights-of-way (ROWs) and locating energy centres within densely populated urban areas. While the benefits largely outweigh the challenges, a successful DE project requires a champion that understands the long-term benefits of a system and can push its implementation.

1.4 STATEMENT OF WORK

The City of Mississauga retained FVB to conduct a feasibility study for DE in the Downtown, including developing the demand and energy profile of the DES, creating the conceptual design for the DES, conducting an analysis of the DES business case, and outlining an overview of the different owner/operator models and the City's role in DE.

1.5 APPROACH AND METHODOLOGY

The first step in developing this study was to establish the demand and energy profile of the DES. To accomplish this, the Downtown area was mapped based on existing buildings and site plan applications. Discussions with developers in the Downtown were undertaken to understand their plans for the short and long term and to estimate future densities. The District Energy Screening Study, which was completed by GENIVAR in 2013, was also reviewed. A phasing plan was developed based on the geographic location of existing buildings and the estimated timeline of future developments.

Once an understanding of the current and future densities was established, the current and future buildings' demand and energy projections were estimated based on Mississauga's planned green standards and the current Ontario Building Code. This information was compiled into three scenarios:

1. **Business-as-Usual (BAU) Standalone**: Buildings remain disconnected from a DES and are heated and cooled with their own stand-alone system. The BAU scenario assumes that all new buildings will be constructed to meet a 15% improvement over the current Ontario Building Code (OBC), which corresponds to the Toronto Green Standards version 3 (TGS v3) Tier 2, for the entire duration of the study period.
2. **Low Carbon Standalone**: Buildings remain disconnected from a DES and are heated and cooled with their own standalone system. The Low Carbon scenario assumes that new buildings would be constructed to progressive Green Development Standards over the duration of the study period (i.e., the new buildings would be constructed to meet TGS v3 Tier 2 starting in 2025, Tier 3 starting in 2030, and Tier 4 starting in 2035).
3. **Low Carbon DES**: Buildings are connected to a DES. The demand and energy of the buildings, as well as their emission targets, are the same as in the Low Carbon Standalone; however, the DES allows for increased system diversification, which reduces the total peak demand seen by the energy centres compared to a simple summation of all the building demands.

The demand and energy profiles over time were then used to develop the DES concept. To meet the required demand and energy while achieving the desired GHG emission targets, renewable thermal generation technologies will be required. The following were evaluated at a high level:

- Geo-exchange
- Sewer Heat Recovery
- Biomass
- Energy from Waste (EFW)
- Air Source Heat Pumps (ASHPs)
- Deep Geothermal
- Waste Heat Recovery

- Thermal Storage

It was determined that sewer heat recovery and geo-exchange were the most compatible with this DES based on available capacity, space constraints, and public perception. The buildout of the energy centres – including phasing of the energy centres and installed equipment types and capacities – was established, along with phasing and routing of the distribution piping system.

This concept was used to develop a high-level capital cost for the energy centres, distribution piping, and energy transfer stations at each connected building. Operation and maintenance costs of the low carbon DES were also estimated.

Revenues of the low carbon DES were also estimated. For buildings to connect to a DES, the cost must be competitive with what the building would pay if it were not connected to the system. Therefore, the revenue of the low carbon DES is based on the capital, operation, and maintenance costs of the Low Carbon Standalone scenario. Once this was estimated, a financial analysis of the system as a whole was undertaken.

Separately, a review of the available ownership and operation models, as well as opportunities for the City of Mississauga to be a champion of DE, was completed.

2 TECHNICAL ANALYSIS AND CONCEPT DESIGN

2.1 ENERGY PROFILES

Demand refers to the highest amount of instantaneous heating or cooling that a building requires over the course of one year.

Energy refers to the total amount of heating and cooling that a building requires over the course of one year.

The first step in developing a DE concept and determining the feasibility and business case is to develop energy profiles. This involves identifying a study area, defining how that area will be built out over time, and analyzing the thermal **demand** and **energy** requirements of that build out.

Due to the large number of buildings and the scope of the study, the demand and energy of the buildings were estimated based on gross floor area (GFA), building age, and building type (e.g., residential, office, retail). FVB uses a database of actual historical metered heating and cooling data from a wide array of building types and construction dates to determine demand and energy densities (W/m²; peak load and kWh/m²; energy respectively) for each building type in the study area.

The demand and energy for the three Downtown buildings owned and operated by the City – the Living Arts Centre, Mississauga Civic Centre, and Hazel McCallion Central Library – were determined through a more extensive analysis involving energy consumption data, drawing analysis, and site visits to develop a more thorough understanding of these buildings' energy requirements, as well as the potential for housing equipment for the early stages of the DES. As these buildings are within the top 10 highest GHG-emitting City buildings, a significant driver of the first stages of the DES will be providing these buildings with low carbon heating and cooling.

2.1.1 STUDY AREA BOUNDARIES

The study area, outlined in red in Figure 5 below, is bound by Highway 403 to the north, generally Hurontario Street to the east, generally Confederation Parkway to the west, and Webb and Elm Drives to the south, and roughly corresponds to the Downtown Core. The study area is largely the same as in the 2013 District Energy Screening Study and was chosen to include high density buildings. This optimizes the DES business case as less piping is needed to reach a higher heating and cooling demand.

The blue outline in Figure 5 represents the proposed Square One District redevelopment.[3] It is expected that – over the course of the next two decades or so – high-density, mixed-use developments will replace the existing surface level parking lots. These developments are expected to add approximately 1,740,000 m² (18.7 million square feet) of high-density mixed use floor area, creating an ideal environment for a successful DES. In addition, several other developments are planned in existing surface level parking lots outside the Square One District, potentially adding another 1.8 million m² (19.5 million ft²) of floor space within the study area over the next 25 years. As the existing buildings surrounding this development are also high-density, there is potential to connect these buildings to the DES, which will expand the GHG emission reductions and other benefits of the system.

3 Source: Square One District Website (https://sq1district.com/)

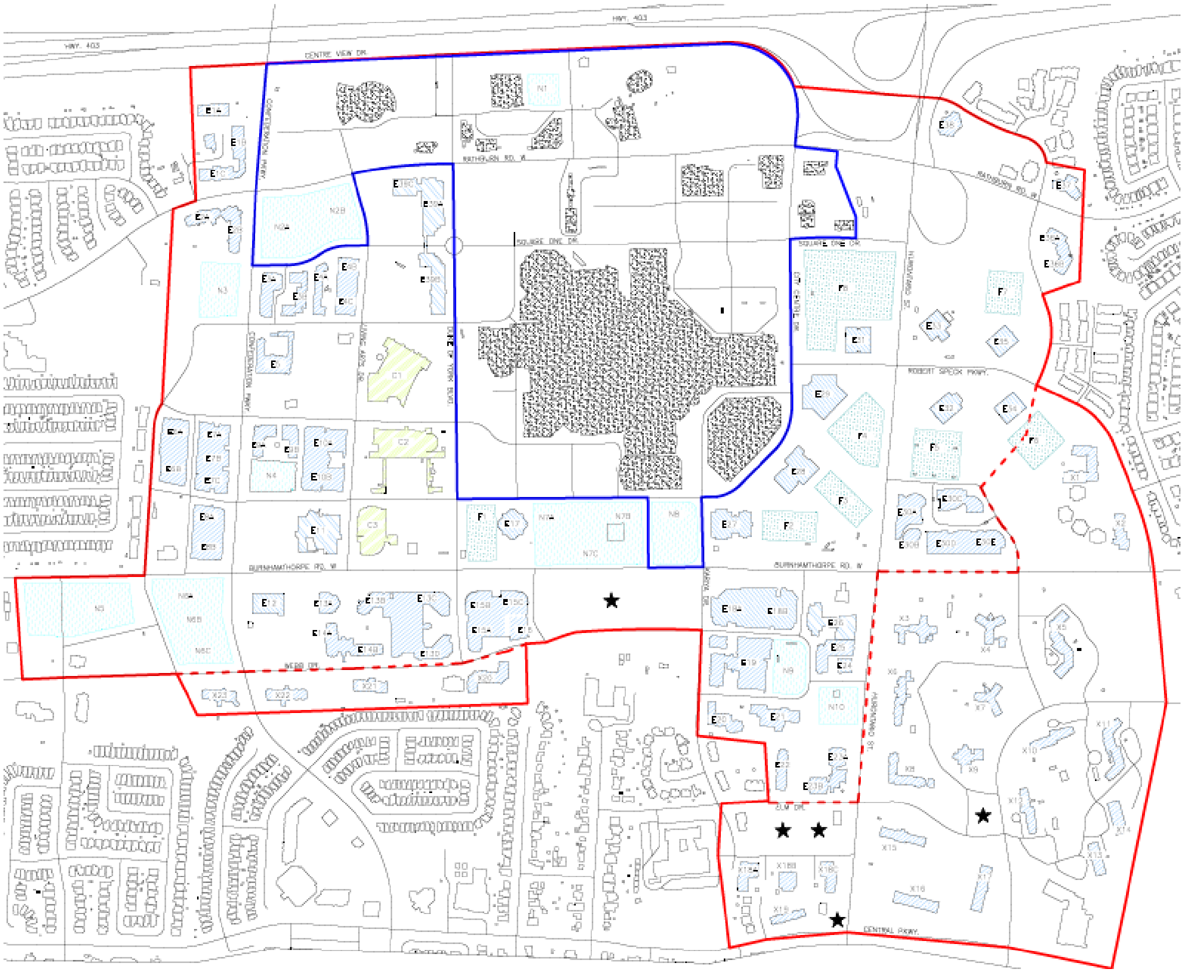


Figure 5: Study Area Boundaries

A drawing showing the surrounding area and colour/shading legends can be found in Appendix A. The dashed red line represents the study area from the 2013 District Energy Screening Study.

2.1.2 DISTRICT ENERGY SYSTEM PHASING

The study area consists of four types of buildings:

- **Existing Buildings:** these are buildings that are occupied and operational at the time of the study. They are typically 5+ years old (some nearing 50 years) and would require retrofits to connect to the DES.
- **New Developments**: these are buildings that are currently being designed or constructed and are expected to be occupied before the first phase of the DES becomes operational. It is anticipated that these buildings would be unlikely to connect before their newly installed heating and cooling systems reach their end-of-life (in approximately 25 years).
- **Proposed Developments:** this encompasses the proposed buildout of the Square One District, excluding the blocks currently under design and construction. It is estimated that 1,503,000 m² (16,000,000 ft²) will be developed in four phases beginning in 2028 and extending to 2045. It is assumed that these buildings would be constructed to optimize a connection to the DES, also referred to as being "DE Ready." This category also includes buildings outside the Square One

District that are planned for densification, particularly around office buildings with surface-level parking lots.

- **Future Developments**: these are buildings outside of the Square One District where developers have expressed plans for densification (often within surface level parking lots) but are still in the very early concept stages.

For the development of the DES and financial model, the study area was divided into six (6) phases, each spanning five years. All phases of the DES are interconnected. A map showing the study area with phasing can be found in Appendix A.

Phase 1A

Phase 1A includes the three City-owned buildings, namely the Living Arts Centre, Mississauga Civic Centre, and the Hazel McCallion Central Library (C1, C2, and C3 respectively in Figure 1), as well as the Sheridan College buildings (E39 in Figure 1). A nodal plant[4] that serves these buildings could be the first part of the DES that is constructed.

Phase 1B to Phase 5

Phases 1B to 5 will connect the surrounding existing buildings. Each phase is divided roughly based on geographic location. Proposed and Future Developments will also be connected as they are designed and constructed. As the timelines for the Future Developments are unknown, it is assumed they will be connected in Phase 5.

Phase 6

In Phase 6, the New Developments that are being designed and constructed at the time of this study (2022) will have reached the end of life of their heating and cooling equipment, which will provide an opportunity for them to connect to the DES rather than replacing this equipment. Retrofits will be required for these buildings, but the DES will be well established and allow for a resilient, competitive option for these buildings.

2.1.3 MARKET PENETRATION

Since there is no guarantee that Existing Buildings will connect to a DES, a market penetration factor has been assumed for each phase. This factor represents the percentage of the Existing Buildings in that phase that are estimated to connect to the DES. It is unlikely that all Existing Buildings will be connected to the DES. A 50% adoption rate was chosen as a conservative estimate to avoid overstating the business case. It is assumed that all of the Phase 1A buildings will connect. To model this, a sample set of buildings was arbitrarily selected across the study area in each phase to make up approximately 50% of the total GFA available in that phase (see Market Penetration Map, Appendix A). The resulting market penetration is shown in Table 1.

[4] A "nodal plant" is a small DES serving only a handful of buildings. As the full DES is developed, it can be connected to the larger system to help serve all buildings connected to the DES.

Table 1: Estimated Market Penetration

Market Penetration	Phase 1A	Phase 1B	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Year	2025	2028	2030	2035	2040	2045	2050
City Buildings (3 Buildings)	100%	-	-	-	-	-	-
Sheridan (3 Buildings)	100%	-	-	-	-	-	-
Existing Buildings	-	51%	54%	54%	52%	52%	-
New Buildings	-	-	-	-	-	-	52%
Proposed & Future Developments	-	100%	100%	100%	100%	100%	-

2.1.4 TOTAL GFA BY PHASE

Based on the estimated market penetration, the total GFA connected in each phase is shown in Table 2.

Table 2: Connected GFA by Phase

GFA (m^2)	Phase 1A	Phase 1B	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6	Total
Existing	118,103	253,067	437,199	210,953	206,532	105,160	0	1,331,014
New	0	0	0	0	0	0	520,772	520,772
Proposed & Future	0	270,500	361,000	278,850	593,000	363,528	0	1,866,878
Total	**118,103**	**523,567**	**798,199**	**489,803**	**799,532**	**468,688**	**520,772**	**3,718,664**

2.1.5 BAU STANDALONE DEMAND AND ENERGY PROFILE

The Business-as-Usual (BAU) Standalone Case outlines how a building's heating and cooling requirements would be provided without connecting to a DES (i.e., each building has its own heating and cooling generation equipment). For existing buildings, metered data from buildings connected to DESs in the GTA were used to estimate the demand and energy profile. For new, proposed, and future buildings, the demand and energy for the BAU Standalone Case is based on the National Energy Code of Canada for Buildings (NECB) and Ontario Building Code, with a slight increase in standards projected to 2030. For modelling purposes, it was estimated that these standards would correlate approximately to the Toronto Green Standards version 3 (TGSv3) Tier 2, which represents a 15% improvement in energy performance over the current Ontario Building Code standards for all building types. It should be noted that Level 1 of Mississauga's Corporate Green Building Standard (CGBS) is also an approximation of TGS v3 Tier 2, and it applies to all new construction and major renovations of City buildings.

Table 3 outlines the demand and energy for the BAU Standalone. It should be noted that these values are not connected to any type of generation equipment; these values are the heating and cooling the buildings require to maintain occupant comfort year-round. An overview of the equipment used to provide this thermal energy will be outlined in subsequent sections.

Table 3: BAU Standalone Scenario Demand and Energy

BAU Scenario		Demand		Energy	
Phase	GFA m²	Heating kWt	Cooling kWt	Heating MWht	Cooling MWht
Phase 1A	118,103	8,360	6,510	13,050	7,810
Phase 1B	523,567	23,020	16,920	61,070	23,190
Phase 2	798,199	30,410	30,630	70,140	53,560
Phase 3	489,803	17,450	13,454	41,120	16,660
Phase 4	799,532	28,810	24,130	66,620	26,670
Phase 5	468,688	15,310	13,849	34,950	14,580
Phase 6	520,772	19,370	11,980	47,200	21,360
Total	**3,718,664**	**142,730**	**117,473**	**334,150**	**163,830**

2.1.6 LOW CARBON STANDALONE CASE DEMAND AND ENERGY PROFILE

In addition to the BAU Standalone, a Low Carbon Standalone scenario was modelled to reflect an increased ambition for buildings in Mississauga. For this analysis, the existing, new, and City buildings were modelled identically to the BAU Standalone as the new standards would only apply to Proposed and Future Developments. The TGSv3 standards outlined in Table 4 were used to model the proposed and future developments.

Note that the TGS are among the most aggressive targets for building performance in Canada and represent what reasonably can be achieved with the local climate conditions. The TGS provides a graduated approach to improving building energy performance in Toronto, with TGSv3 Tier 2 representing the minimum building standard in 2022, Tier 3 the minimum building standard in 2026, and Tier 4 the minimum building standard in 2030. It is assumed that the City of Mississauga would be slightly delayed in implementing these standards, and that they would come into effect as outlined in Table 4.

Table 4: TGSv3 Standards by Phase

Phase of Proposed Developments	Phase 1A	Phase 1B	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Connection Year	2025	2028	2030	2035	2040	2045	2050
Estimated TGSv3 Tier	N/A	Tier 2	Tier 3	Tier 4	Tier 4	Tier 4	N/A

The demand and energy targets for each tier are shown in Table 5.

Table 5: TGSv3 Demand and Energy Targets

Demand and Energy Targets	Tier 1		Tier 2		Tier 3		Tier 4		All Tiers
Energy Targets (kWh/m²)	T1 Heating	T1 Cooling	T2 Heating	T2 Cooling	T3 Heating	T3 Cooling	T4 Heating	T4 Cooling	DHW
Residential (>90%)	70	30	50	30	30	30	15	40	40
Retail	60	40	40	40	25	40	15	40	25
Office	70	40	30	40	22	40	15	40	30
Community	70	50	100	150	70	100	60	80	230
Demand Targets (W/m²)	T1 Heating	T1 Cooling	T2 Heating	T2 Cooling	T3 Heating	T3 Cooling	T4 Heating	T4 Cooling	DHW
Residential (>90%)	30	20	30	30	30	30	25	40	10
Retail	70	50	60	40	50	40	40	40	4
Office	40	50	40	50	40	50	30	40	6
Community	80	80	70	80	50	70	40	50	30

Applying the TGSv3 demand and energy targets to the Proposed and Future Developments results in the demand and energy estimates shown in Table 6 for the Low Carbon DES in Downtown Mississauga.

Table 6: Low Carbon Standalone Demand and Energy

Low Carbon Scenario		Demand		Energy	
Phase	**GFA m²**	**Heating kWt**	**Cooling kWt**	**Heating MWht**	**Cooling MWht**
Phase 1A	118,103	8,360	6,510	13,050	7,810
Phase 1B	523,567	23,009	16,572	61,040	22,720
Phase 2	798,199	28,234	27,870	63,390	51,760
Phase 3	489,803	16,450	15,310	34,580	18,330
Phase 4	799,532	26,100	27,610	51,050	30,350
Phase 5	468,688	14,750	17,040	26,940	17,510
Phase 6	520,772	19,370	11,980	47,200	21,360
Total	**3,718,664**	**136,274**	**122,892**	**297,250**	**169,840**

2.1.7 LOW CARBON DES DEMAND AND ENERGY PROFILE

The energy required for a group of buildings is the same whether they use stand-alone systems or are connected to a DES. The overall peak demand seen by the DES is, however, lower: while the peak demand of each individual building does not change, the timing of when those peaks occur is likely to be different among buildings. The overall system peak demand is therefore lower than the simple summation of each building's peak demand. The difference between the simple summation of the peak demand of every individual building in the system and the actual peak demand seen by the system is called the **diversification factor**.

A **diversification factor** of 85% means that the actual peak demand seen by the DES is 85% of the demand obtained by simply adding the individual building demands together.

The diversification factor is important for right-sizing DES equipment and allows for an overall decrease in the thermal generation equipment capacity compared to each building having its own infrastructure. Typically, the heating diversification factor is 85% and the cooling diversification factor is 90%.

As the goal of the Downtown Mississauga DES is to be low carbon, the diversification factor was applied to the Low Carbon Standalone demand and energy to arrive at the Low Carbon DES demand and energy, with the results shown in Table 7. For the purposes of determining the business case and GHG analysis, the Low Carbon DES case will be compared to the Low Carbon Standalone case.

Table 7: Low Carbon DES Demand and Energy

Low Carbon Scenario		Demand		Diversified Demand[1]		Energy	
Phase	**GFA m²**	**Heating kWt**	**Cooling kWt**	**Heating kWt**	**Cooling kWt**	**Heating MWht**	**Cooling MWht**
Phase 1A	118,103	8,360	6,510	6,690	5,210	13,050	7,810
Phase 1B	523,567	23,009	16,572	19,560	14,920	61,040	22,720
Phase 2	798,199	28,234	27,870	24,000	25,080	63,390	51,760
Phase 3	489,803	16,450	15,310	13,980	13,780	34,580	18,330
Phase 4	799,532	26,100	27,610	22,190	24,850	51,050	30,350
Phase 5	468,688	14,750	17,040	12,540	15,340	26,940	17,510
Phase 6	520,772	19,370	11,980	16,460	10,780	47,200	21,360
Total	**3,718,664**	**136,274**	**122,892**	**115,420**	**109,960**	**297,250**	**169,840**
Hourly Model Cumulative Peak Demand[2]				**110,890**	**106,260**		

Note 1: Diversification factors used are 85% for heating and 90% for cooling, except for Phase 1A which uses 80% for both heating and cooling due to the varied use types of the buildings in that phase.
Note 2: After completing the hourly energy model for the entire system, there is additional diversification between the phases as the building types vary and peak demands do not necessarily occur in the same hour across all phases.

A comparison of the heating and cooling demand between the BAU Standalone (no energy/GHG targets), Low Carbon Standalone (escalating energy/GHG targets), and the Low Carbon DES (escalating energy/GHG targets, buildings connected to DES) as described in the previous sections are shown in Figure 6 and Figure 7.

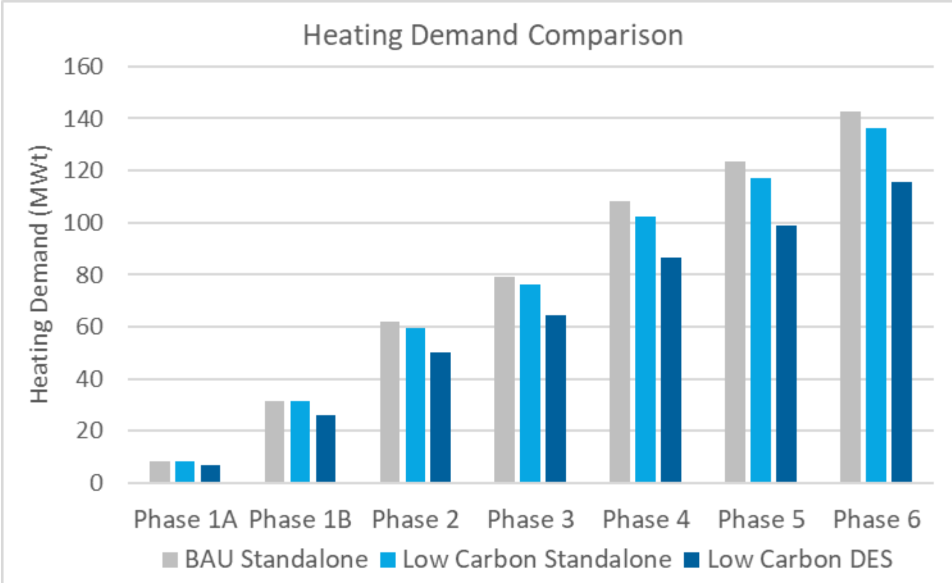


Figure 6: Cumulative Heating Demand by Phase

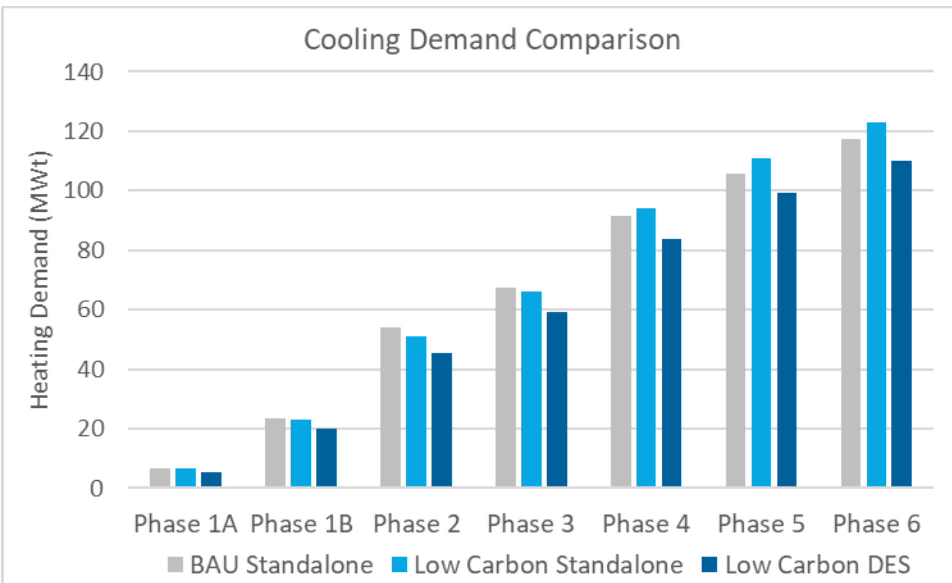


Figure 7: Cumulative Cooling Demand by Phase

3 STANDALONE SCENARIOS

The standalone scenarios are used as a comparative analysis outlining what would be done in absence of connecting to a district energy system. The standalone capital and operating costs provide an estimate of the DES revenue, as the DES rates charged to the connected buildings must be competitive with the costs they would otherwise pay for heating and cooling.

3.1 BAU STANDALONE

3.1.1 GENERAL

In the BAU Standalone, it is assumed that – in the Existing Buildings – space heating and domestic hot water is provided by natural gas boilers and cooling is provided by electric chillers with wet cooling towers. All New, Proposed, and Future Developments are expected to meet TGS v3 Tier 2 requirements (i.e., a 15% improvement over the current Ontario Building Code). It was assumed that this could be achieved by installing an electric domestic hot water (DHW) heater instead of a natural gas heater. City buildings are modelled to utilize their current equipment. The demand and energy used to calculate the equipment capacities and energy consumption are outlined in Section 2.1.5.

3.1.2 GHG EMISSIONS

Table 8 outlines the estimated GHG emissions produced from the BAU Standalone case each year as development in the Downtown progresses. The emissions are driven by natural gas consumed for space heating and domestic hot water, while electricity is primarily consumed for chilled water, though the proposed and future developments also consume some electricity for domestic hot water. Note that these emissions only relate to heating, cooling, and domestic hot water, and do not include emissions related to natural gas and electricity consumption for other building uses (e.g., plug loads, cooking appliances, ventilation).

Table 8: Annual GHG Emissions from BAU Standalone

Phase	Cumulative Natural Gas Consumption (MWh gas)	Cumulative Electricity Consumption (MWh elec.)	Cumulative BAU Standalone GHG Emissions (tonnes/year)
1A	16,090	2,460	2,980
1B	85,270	15,440	15,870
2	163,040	38,410	30,620
3	206,360	49,980	38,790
4	271,850	72,330	51,300
5	304,460	85,890	57,590
6	347,480	104,490	65,990

The GHG emissions are estimated based on a GHG emission factor of 50.1 kg/GJ (180 kg/MWh) of natural gas consumed as per the 2020 National Inventory Report and hourly The Atmospheric Fund (TAF) Average Emission Factors (AEF) for grid electricity from 2018 (see Table 9).

Table 9: Hourly Electricity Emission Factors

Average Emissions Factors for Grid Electricity from The Atmospheric Fund							
Hour	g CO_2/kWh$_e$	Hour	g CO_2/kWh$_e$	Hour	g CO_2/kWh$_e$	Hour	g CO_2/kWh$_e$
1	14	7	26	13	39	19	42
2	13	8	28	14	41	20	40
3	14	9	31	15	42	21	36
4	16	10	34	16	43	22	30
5	19	11	36	17	43	23	23
6	23	12	38	18	43	24	17
Overall Avg: 30.5 g CO_2/kWh$_e$							

This emission factor was used for all years of the study. The emission factor of the Ontario electricity grid is anticipated to increase in the near future and decrease in the long term. As this emission factor is used for both the Standalone and DES scenarios, it provides a fair comparison.

3.2 LOW CARBON STANDALONE

3.2.1 GENERAL

In the Low Carbon Standalone, it is assumed that the Proposed Developments are constructed to the standards outlined in Table 4 above. Note that, in addition to the demand and energy targets outlined in Table 5, the TGS also imposes limits on the Greenhouse Gas Intensity (GHGI) of buildings (Table 10). This restricts the thermal generation equipment that can be installed in buildings since the use of conventional equipment, particularly natural gas boilers, results in the building exceeding the GHGI limits.

Table 10: Greenhouse Gas Intensity limits by Tier (TGS v3)

Greenhouse Gas Intensity Limits from Toronto Green Standards version 3				
GFA Type	Tier 1 GHGI (kg/m²)	Tier 2 GHGI (kg/m²)	Tier 3 GHGI (kg/m²)	Tier 4 GHGI (kg/m²)
Residential	20	15	10	5
Retail	20	10	5	3
Office	20	15	8	4
Community	20	15	10	5
Plug Loads[1]	1.6	1.6	1.6	1.6

Note 1: Plug Loads include lighting, elevators, secondary-side building pumps, and other electrical loads that are not associated with the DES. These factor into the total GHGI limit for a building and must be taken into account when calculating the GHGI limit for the DES. It is estimated that the plug loads create 1.6 kg/m² of CO_2 for each phase based on standard electricity use factors and the Ontario electrical grid emission factor.

To meet these GHGI limits, the Proposed and Future Developments are assumed to install heating and cooling equipment that is above and beyond a simple combination of natural gas boilers and electric chillers. This low-carbon equipment will be used to meet the demand and energy requirements outlined in Section 2.1.6. The equipment proposed for buildings constructed in each phase is outlined in Table 11.

Table 11: Proposed Standalone Equipment by Phase

<table>
<tr><th>Phase</th><th>Year</th><th>Energy Tier</th><th>Proposed Standalone Equipment</th></tr>
<tr><td>1A*</td><td>2025</td><td>Current</td><td>Natural Gas Boilers
Chillers + Cooling Towers</td></tr>
<tr><td>1B</td><td>2028</td><td>Tier 2</td><td>Natural Gas Boilers
Electric DHW Heaters
Chillers + Cooling Towers</td></tr>
<tr><td>2</td><td>2030</td><td>Tier 3</td><td>Natural Gas Boilers
Electric DHW Heaters
Air Source Heat Pump sized to 30% of Peak Heating Demand
Chillers + Cooling Towers</td></tr>
<tr><td>3</td><td>2035</td><td rowspan="3">Tier 4</td><td rowspan="3">Electric Boilers for Heating and DHW
Ground Source Heat Pump + Geoexchange Field sized to 75% of Peak Heating Demand
Chillers + Cooling Towers</td></tr>
<tr><td>4</td><td>2040</td></tr>
<tr><td>5</td><td>2045</td></tr>
<tr><td>6*</td><td>2050</td><td>Current</td><td>Natural Gas Boilers
Chillers + Cooling Towers</td></tr>
</table>

* These phases only include existing buildings.

3.2.2 GHG EMISSIONS

The annual GHG emissions at each phase of the study are shown in Table 12. The same emission factors were used as for the BAU Standalone case. In this scenario, the demand and energy of the new, proposed, and future developments are reduced due to improved building envelopes and construction standards, which reduces the overall energy consumption. The proposed and future buildings have greater system electrification through the use of air source heat pumps (ASHPs) and ground source heat pumps (GSHPs) in this scenario, leading to greater electricity consumption than the BAU Standalone scenario, with an associated reduction in overall GHG emissions. As in the BAU Standalone case, the fuel consumption and resulting GHG emissions shown in Table 12 only relate to heating, cooling, and domestic hot water.

Table 12: Annual GHG Emissions From Low Carbon Standalone

Phase	Cumulative Natural Gas Consumption (MWh gas)	Cumulative Electricity Consumption (MWh elec.)	Cumulative Low Carbon Standalone GHG Emissions (tonnes/year)
1A	16,090	2,460	2,980
1B	85,240	15,320	15,860
2	124,800	45,760	23,930
3	129,310	64, 240	25,350
4	133,770	94,740	27,070
5	133,770	112,390	27,640
6	177,070	131,290	36,030

4 LOW CARBON DES – CONCEPT DESIGN

4.1 POTENTIAL FUEL SOURCES: RENEWABLE TECHNOLOGIES

To optimize the GHG reduction potential of the DES, renewable thermal generation technologies must be used. These technologies must be chosen to best leverage the local resources of the system, which are different for each system. Low carbon technologies that have been implemented for district energy systems are:

- Geo-exchange
- Sewer Heat Recovery
- Biomass
- Energy from Waste (EFW)
- Air Source Heat Pumps (ASHPs)
- Deep Geothermal
- Waste Heat Recovery
- Thermal Storage

A wide view of the study area is shown in Figure 8. The grey buildings and parking lots in the Downtown are surrounded by low density residential buildings such as single-family dwellings, duplexes, and townhomes.

Figure 8: Satellite View of Downtown Mississauga

Because of the urban and residential nature of the study area, as well as the size of the full system buildout, the choice of technology is limited. For example, since no electricity generation plants or similar heat-generating plants are nearby, waste heat recovery is not a viable option for this system. Similarly, because of the dense, residential nature of this area, technologies such as Energy From Waste (EFW), which involves incinerating solid waste to generate heat and potentially electricity, and biomass are not considered good options due to concerns over fuel transportation, storage, odour, and negative public perception.

The size of the system also limits the technology that can be used. With the heating demand potential of the system being around 130 MW, technologies designed for smaller loads (e.g., ASHPs, thermal storage) would not be able to scale effectively enough to make a meaningful contribution to GHG reductions.

FVB identified three renewable generation technologies that have the potential to be incorporated into a DES in Mississauga's Downtown based on the features of the study area, expected system demand, and low carbon requirements: Sewer Heat Recovery (SHR), geo-exchange or Ground Source Heat Pumps (GSHP), and deep geothermal. A high-level overview of the technologies and their compatibility with the study area is shown in Table 13.

Table 13: Renewable Technology Screening Matrix

Category	Sewer Heat Recovery	Geo-exchange	Deep Geothermal
Energy Potential	Medium	Medium	Unknown
Site Impact	Low	Medium	High
Capital Cost	Medium	Medium	High
Fuel Cost	Medium	Medium	Low
Public Perception	Good	Good	Good
Overall Fit	**Best**	**Good**	**Medium**

An important aspect of DE is that, once the distribution piping and energy transfer station infrastructure are installed, the thermal generation equipment can be altered over time as technologies improve and become more widely commercially available. The technologies identified above represent the best for the DES at the time of this report. However, part of the ongoing success of the DES will be adapting the system as technologies evolve. It is much easier to adapt technologies in a DES compared to standalone buildings, which allows buildings to achieve GHG reductions that they might not have been otherwise able to achieve – with no capital investment on their end.

4.1.1 SEWER HEAT RECOVERY

Sewer heat recovery involves utilizing the heat from municipal waste water. To use this energy source, the wastewater passes through heat exchangers connected to heat pumps, which boost the temperature so that the water can be used in the DES. The waste water can also be used for cooling by acting as a heat sink, but this is less common due to the high efficiency of conventional chillers. An example diagram from the False Creek Neighbourhood Energy Utility project in Vancouver, which utilizes this technology, is shown in Figure 9.

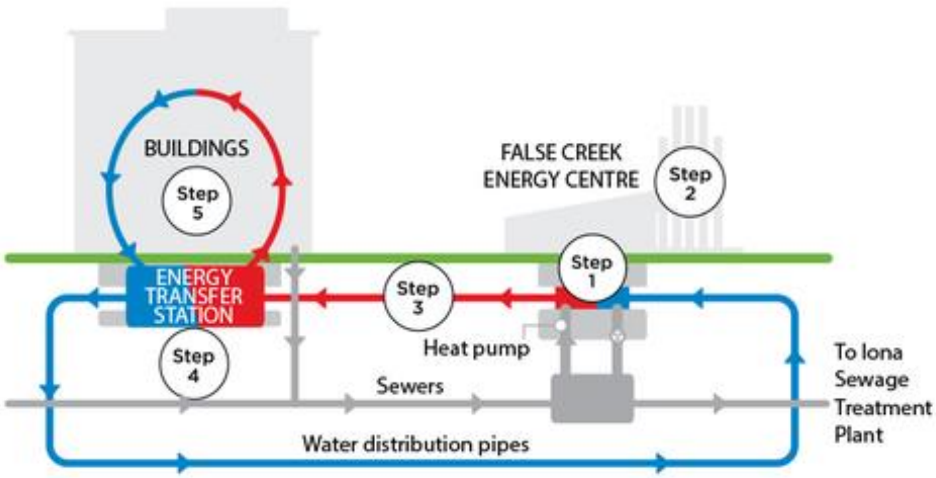


Figure 9: Sewer Heat Recovery Diagram[5]

The capital cost of a sewer heat recovery system is comparable to a geo-exchange system of the same capacity. The fuel cost is directly tied to the price of electricity, and the electricity use is tied to the efficiency of the overall system. Currently, utilities that own the sewer heat do not charge a market rate to use this heat; this may, however, change in the future.

Public perception of sewer heat recovery projects tends to be positive, though care must be taken to ensure the point at which the DES intercepts the sewer is fully isolated and contained. This is a standard offering for commercially available sewer heat recovery systems. The system will be carefully designed so that there is no impact to waste water system operations due to the capture of waste heat.

Figure 10 shows the approximate location of sewer mains in and around the Study Area (note that the Study Area is outlined in red). The yellow lines represent existing sewer mains, while the green lines represent an extension that is currently under construction on Duke of York Boulevard. Based on discussions with the Region of Peel, it is expected that the wastewater will be diverted from the existing eastern branch through the new piping to allow for greater downstream capacity once the branch down Centre View Drive is complete. Operation of the system may impact available heat energy and discussions are warranted to determine diversion rates and timelines.

It is currently estimated that the yellow branch along the east side of the Study Area has up to 5 MW of sewer heat recovery capacity available (based on an estimated flow rate of 130 L/s). The Region of Peel expects the flow in this trunk to approximately double in the future. As there is limited information at this point regarding timelines and exact routing of the flow, it was assumed that this future flow would be split evenly between the existing infrastructure and the new infrastructure. The doubled capacity would be approximately 10 MW of sewer heat recovery potential.

Further monitoring of the sewer flows and temperatures would be required to get a more accurate understanding of the sewer heat recovery potential at each of the proposed plant locations before detailed design is undertaken.

5 Source: City of Vancouver(https://vancouver.ca/home-property-development/how-the-utility-works.aspx)

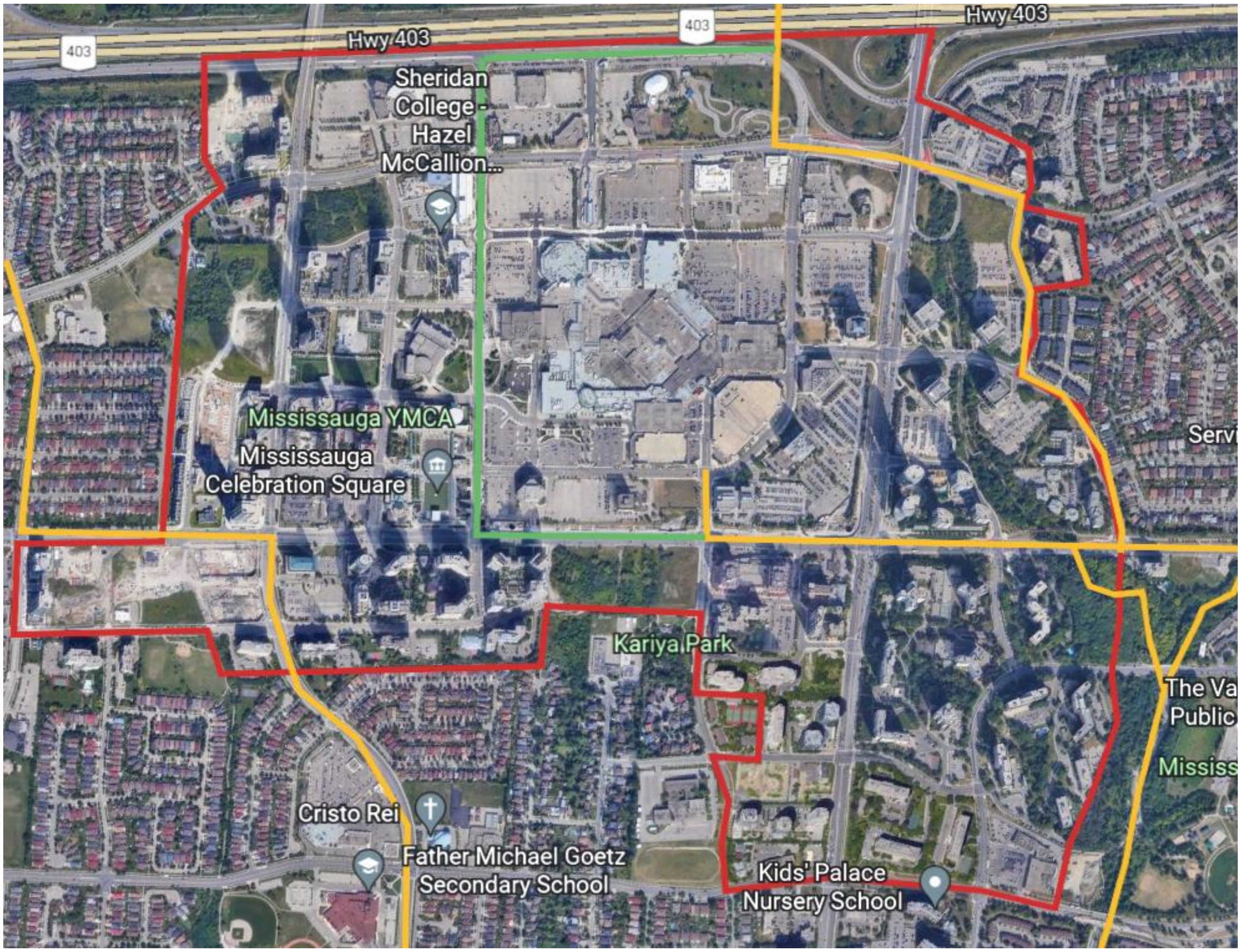


Figure 10: Sewer Mains In and Around Study Area
(Red = Study Area boundary; Yellow = Existing Sewer Mains; Green = Sewers in Design/Construction)[6]

To utilize sewer heat recovery, the energy centres would have to be located in close proximity to the new or existing major sewer lines. The exact location would be determined through coordination with the stakeholders and developers near these sewer lines. Further details on the proposed energy centres will be discussed in Section 4.2.2.

For sewer heat recovery, the only space needed outside the energy centre is the wet well, where the wastewater line is intercepted. This could be a satellite plant with the clean outflow from the heat exchangers pumped to the energy centre, or it could be part of the energy centre itself. This would depend on the land available near the main sewer line.

4.1.2 GEO-EXCHANGE

Geo-exchange, also referred to as Ground Source Heat Pumps (GSHP), generates thermal energy by utilizing the relatively constant temperature just below the Earth's surface. Boreholes are dug into the

[6] Map from Google Earth, Accessed April 2022

ground and pipes are placed in them. The pipes circulate water or a glycol mixture, which returns to the energy center at a temperature of around 4°C in the winter and 20°C in the summer. In the heating season, heat pumps boost the water temperature to 80°C to feed the DES's hot water loop and, in the cooling season, the boreholes act as a heat sink for the heat pumps (i.e., heat is rejected to the borefield), which cool the DES's cold water loop.

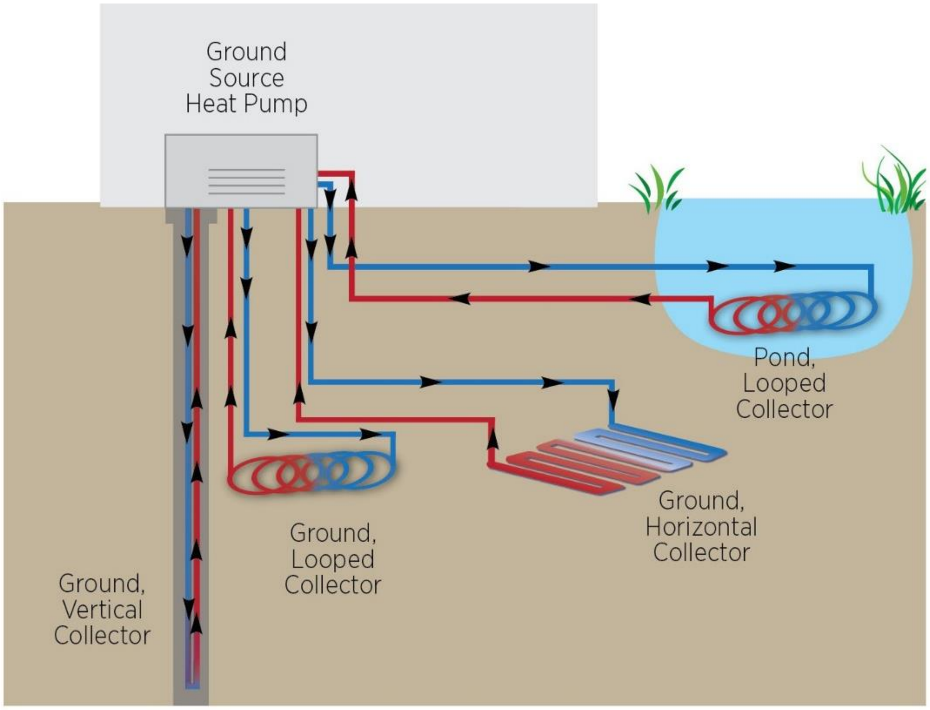


Figure 11: Geo-exchange Diagram[7]

The available capacity of a geo-exchange system depends on the space available for the borehole field, the depths of the boreholes, and – to a lesser extent – the soil conditions. Because of this, geo-exchange requires much more space than a sewer heat recovery system. Borehole fields are commonly installed under park areas or similar greenspace. While borehole fields have a long useful life and require very minimal maintenance, having them under greenspace allows for easier access and installation. However, it is becoming increasingly common for boreholes to be installed underneath buildings or parking areas.

The capital cost for a geo-exchange system is tied to the installation of the borehole field and the heat pumps used to raise or lower the ground source temperature. The fuel cost is tied to the electricity cost and the efficiencies of the heat pumps.

Geo-exchange systems tend to have more flexibility in terms of their location compared to other technologies. Boreholes can be installed below the energy centre, below other buildings, or below open areas (e.g., sports fields, parks without trees) with no change to the above-ground use of the space. This has the added advantage of few above-ground visual impacts, which has led to a positive public perception of this technology.

For the Mississauga DES, it is recommended that the first geo-exchange borefield be installed below the footprint of the first energy centre serving Phase 1A, proposed for the south parking lot of Sheridan College, and underneath the Community Common Park for the second energy centre serving Phase

[7] Source: Building America Solution Centre (basc.pnnl.gov)

1B. These areas are highlighted in blue in Figure 12. Once the borefields are installed, there would be no impact on the use of the park and no above-ground structures other than one or two manholes for maintenance purposes. Areas with established trees would be avoided.

There would, however, be some impacts. For one, the park cannot be used while the boreholes are being installed, though these impacts could be lessened if the boreholes are installed section-by-section allowing the rest of the park to be used. The time it takes to construct the borefield depends on the size of the field, the depths of the boreholes, and the number of machines being used, but it typically takes between two and six months depending on the scale of the project. In addition, trees could not be planted in the areas where the boreholes are installed. The planting plan would need to be adjusted accordingly.

Any future geo-exchange installations would be coordinated with new developments, where borehole construction could be planned from the onset. In these developments, boreholes would likely be installed underneath a new building or in an adjacent open green space.

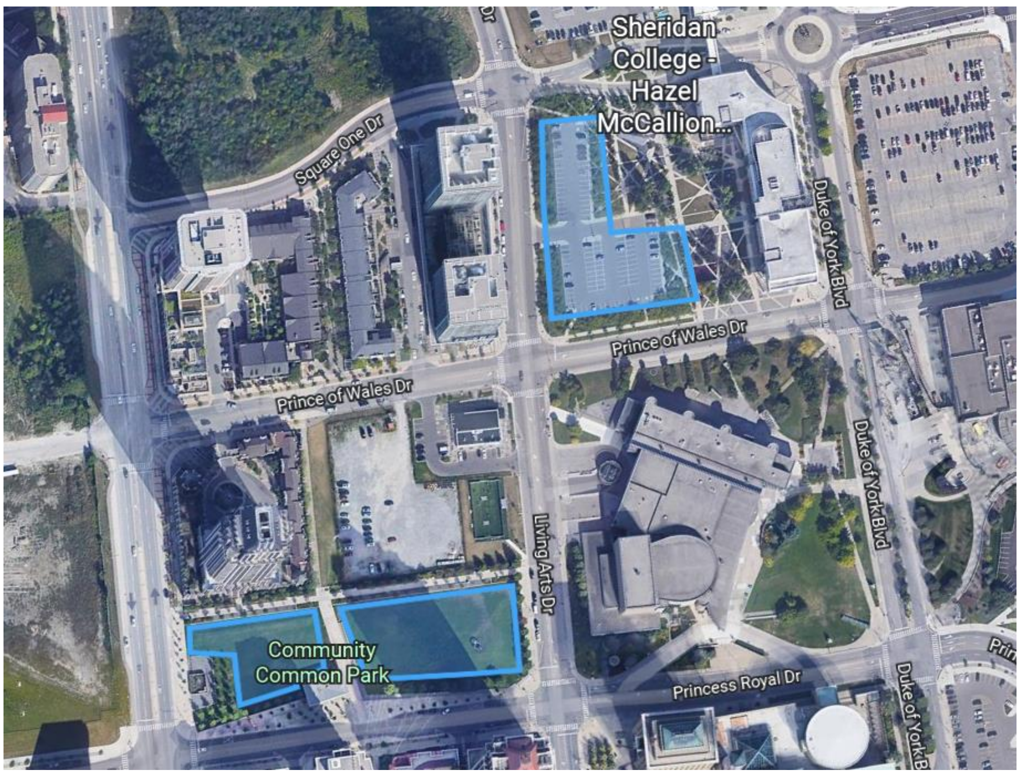


Figure 12: Potential Geoexchange Borefield Locations (Phase 1A and Phase 1B)

4.1.3 DEEP GEOTHERMAL

Deep geothermal has yet to be implemented in Canada, but is gaining popularity as a renewable resource option. To date, it has been used in more active geothermal zones – such as in Iceland, Italy, and Turkey – for the generation of electricity and hot water. However, an increasing number of parties, including district energy providers in Canada, are interested in leveraging this technology. FVB chose to highlight this particular technology as it may become a commercially viable option over the course of the full DES buildout.

Unlike geo-exchange, which leverages constant, low temperatures just below the Earth's surface, deep geothermal involves drilling down to where the ground temperature reaches above 90°C. Water is injected through one borehole and removed from another, heated by its passage through the Earth's mantle.

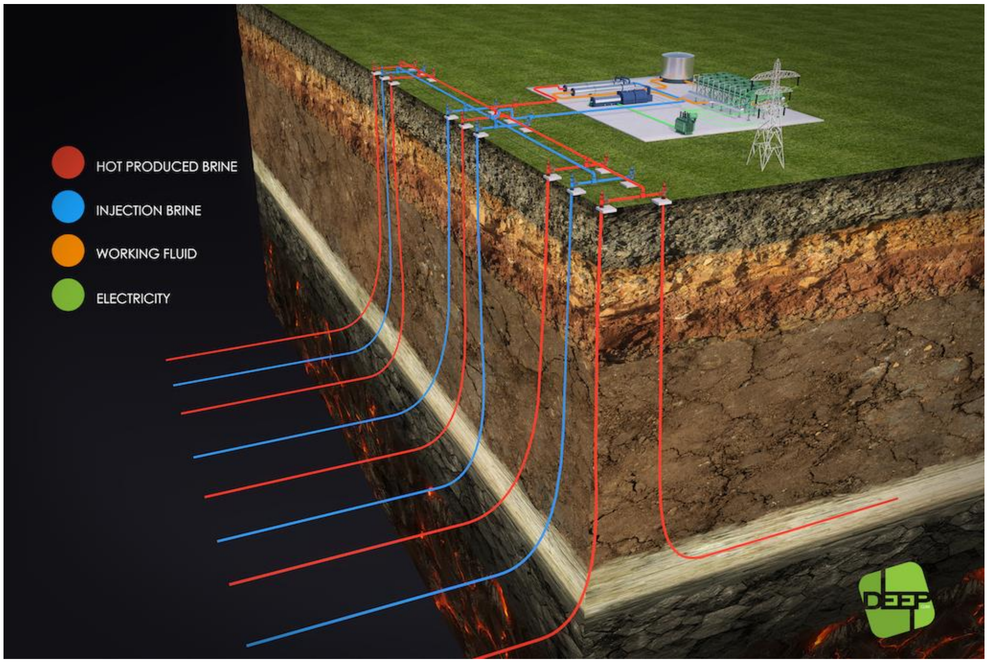


Figure 13: Deep Geothermal Boreholes[8]

As with any technology, there are advantages and disadvantages to deep geothermal. The main advantage of deep geothermal is that the fuel cost is limited to the pumping cost of injecting and extracting water from the boreholes, as no supplemental fuel is needed to heat the water. The main disadvantage is that it can be very expensive to install. Test boreholes would have to be drilled to determine the depth required to achieve the desired temperatures, and it is likely that the final boreholes would have to be over 4,500 m deep.[9] In addition, the energy capacity of the deep geothermal system can only be determined from the test boreholes, making preliminary modelling difficult. Rigorous evaluation of the seismic impact, soil consistency, nearby aquifers, and other geographical features must be considered before the system is implemented and represents high sunk costs if the project does not move forward.

There are no deep geothermal projects currently operational in Canada, and public perception is therefore unknown. Such a system would not have significant above-ground visual impacts after it is built and would emit extremely low amounts of GHGs. It is therefore fair to assume that the reaction would be generally positive.

4.1.4 COMPLEMENTARY TECHNOLOGIES

There are other renewable technologies that can be used by the DES to enhance GHG reductions, lower operational costs, and increase resiliency. These technologies can provide electricity, such as peak shaving generators, solar panels, and battery storage, which reduces the DES's draw on the electrical grid. This translates to cost and/or GHG savings. Separately, technologies like thermal storage can complement other low-carbon technologies as a value-add, but would not be able to provide

8 Source: DEEP Saskatchewan
9 Source: Geothermal Maps of Canada (2009), S.E. Grasby, J. Majorowicz, and M. Ko

low carbon thermal energy themselves. A brief review of biomass is also included as it is a commonly used low-carbon technology, but it is not recommended for the Downtown DES at present.

Peak Shaving Electricity Generators

Peak shaving electricity generators are conventional electricity generators typically run off of natural gas, which reduce the peak electricity demand of a building or plant. They can also serve as emergency power generators to increase the resiliency of the plant. With Ontario's Class A system, the electricity cost is tied to the electricity demand of the consumer during the five (5) hours in which the total electricity demand of the province is at its highest. A peak shaving generator coupled with some tracking/forecasting allows the consumer to reduce its net demand on the grid during those five hours, and therefore reduces its electricity price for the full year. Typically, the generator only needs to be deployed for 30 hours over the entire year to ensure the five peak hours are captured. This is particularly helpful for consumers with a significant electrical baseload, such as those with heat pumps or electric boilers. This study assumes that the electricity generators installed would be used for emergency back-up power as well as peak shaving to significantly reduce the electricity cost of the DES.

Solar Photovoltaic Panels

Solar Photovoltaic (PV) panels are another common method of reducing a consumer's electricity demand. These panels can be installed on rooftops or open spaces near the energy centre and can serve as a **behind-the-meter** electricity source.

> **Behind-the-meter** means the electricity is generated on the customer side of the electrical utility meter. This reduces the amount of electricity drawn from the grid (i.e., the amount measured by the meter), which in turn reduces electricity cost and the amount of GHG emissions associated with grid electricity consumption.

The amount of electricity that can be generated by the solar PV panels depends on the available space and consequently the number of panels that can be installed, as well as the solar irradiance conditions at the given location. Based on these factors, it is estimated that the roof of Living Arts Centre can house 375 kW_e of solar PV capacity, the Mississauga Civic Centre roof can house 144 kW_e, and the Hazel McCallion Central Library roof can house 72 kW_e. This adds up to a total peak electrical output of 590 kW_e and an annual electrical output of 740 MWh_e. Assuming a capital cost of $2.00/W, electricity costs of $0.18/$kWh_e$, and a GHG emission factor for electricity of 30 kg CO_{2e}/MWh_e, the installation of these solar panels would have a simple payback of 8.9 years and GHG emission reductions of 22 tonnes annually.

The installation of solar panels would be dependent on a structural engineer's review of the City buildings to determine the viability of an installation. Currently, solar panels are not included in the financial analysis.

Battery Storage

Battery storage can lead to cost savings for the energy centre as it can reduce the instantaneous electrical demand on the grid. It can also store excess electricity produced from solar PV panels for use when the building requires it. While battery storage is becoming more and more popular, the technology is still quite expensive. This option may be worth considering in future stages of the DES, but is not considered as part of the current concept.

Thermal Storage

Thermal storage is another tool that can be used to maximize the potential of renewable technologies. It can be used when the hot or chilled water generation does not correspond with system demand. As space is generally limited in the Study Area and the technologies studied can be operated to match system demand, thermal storage was not considered in the initial concept. This technology should nonetheless be kept in mind as a potential future addition to the system, as it could be used to shift electric boiler or heat pump operation to times of lower cost or less GHG-intensive electricity.

Biomass

Biomass is another renewable generation technology that is commonly used, often when the thermal generation plant is removed from the living and working spaces of the general population, as the smoke from the biomass plant could interfere with the surrounding community. A biomass plant also has significant space requirements for fuel storage, ash removal, and truck loading and unloading. Given the urban setting of the Study Area, biomass is not considered to be a good fit for the Mississauga DES.

4.2 DISTRICT ENERGY SYSTEM CONCEPT

The DES concept is comprised of the energy centre, the distribution piping system, and the building connections. It is important that the energy centre and distribution piping are sized properly to meet the demand and energy of the system. It is also important that the equipment, such as natural gas boilers, electric boilers, and heat pumps, is sized to meet the GHG emission targets for the system – all while keeping the operating costs as low as possible. A tool that can help with sizing the energy centres, their contained equipment, and the distribution piping is a load duration curve.

4.2.1 LOAD DURATION CURVES

Load Duration Curves (LDCs) show the hours a system is predicted to operate at a specific heating or cooling demand. They are helpful for visualizing the build out of a system over several phases, as well as determining the **peak load** and **base load** of a system. The peak load, synonymous with the peak demand, is represented on the LDC by where the curve meets the vertical axis. From the LDC, it can be seen that the peak demand occurs less than 100 hours per year, and may not occur every year. The base load represents the system demand for the majority of the year, which is typically around 7,000 hours per year. For example, in Figure 14, the base load for Phase 6 is just under 20 MW.

Determining the base load is important for sizing renewable thermal generation equipment (e.g., heat pumps, biomass boilers). Since this equipment has a high capital cost that is tied to its capacity, it is imperative to select the size that allows the equipment to offset the largest amount of energy year-round with the lowest capacity. Sizing the renewable thermal generation equipment to meet the base load of a system ensures that it can be operated year-round to reduce GHG emissions without paying for insufficiently used capacity. Note that, in systems aiming for more aggressive GHG reductions, the renewable thermal generation equipment will be sized larger than the base load so that it can contribute more to the system.

The heating and cooling load duration curves for the Low Carbon DES are shown in Figure 14 and Figure 15 respectively.

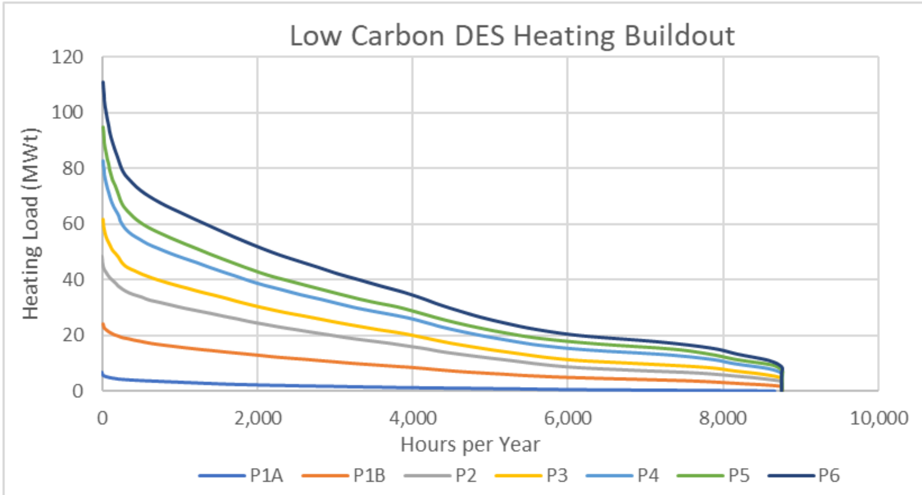


Figure 14: Low Carbon DES Heating LDC

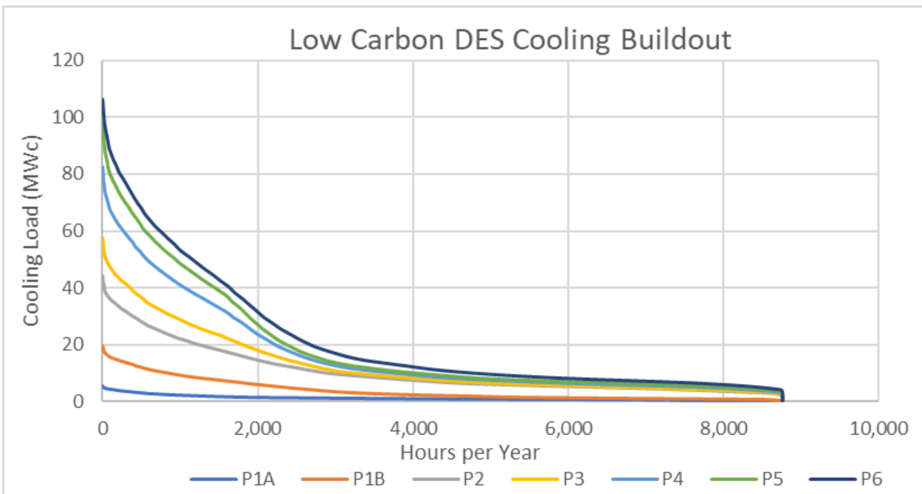


Figure 15: Low Carbon DES Cooling LDC

4.2.2 ENERGY CENTRE LOCATION(S)

It is expected that multiple energy centres will be constructed over the course of the DES buildout. Because of the land value in the Downtown, a stand-alone energy centre was not considered feasible. It was assumed that these energy centres would be incorporated into new or existing buildings. Using several smaller energy centres also allows for better synergy with the development buildout, as well as the possibility of integrating the first plant(s) into existing City buildings. For each energy centre, an environmental review will be needed to determine the stack height and drift impact on the surrounding buildings, and to ensure minimal impacts on current and future residents. It should be noted that while these energy centres are constructed on the same timeline as the DES phases, all energy centres will be interconnected and will work together to meet the system demand and energy. The phase associated with each plant indicates when it will first come online, not which phase it will serve. Not all phases require a new energy centre; for some, the demand can be met by installing equipment within an existing plant, which will be designed with adequate space to accommodate future equipment.

Plant #1 (Phase 1A)

FVB recommends that the first plant be located in the south Sheridan parking lot. The plant does not need to be a standalone structure, but could be co-located with other uses (e.g., future parking infrastructure, commercial space, residential units). In this scenario, it is assumed that the energy centre would be located in the basement of this building which may require additional below-grade levels, with cooling towers located on the roof of the building. Boreholes would be installed underneath the entire building to allow GSHPs to be the primary source of energy for the first phase of the DES. The floor area required for the equipment and auxiliary spaces for Plant #1 is approximately 1,800 m² (19,400 ft²).

It should be noted that this energy centre provides an opportunity to showcase a low-carbon DE plant in the Downtown. This could promote education for both Sheridan College students and the community in Downtown Mississauga. Figure 16 shows examples of this at (from left to right) the University of Victoria, the University of British Columbia, and the Magna Skilled Trade Centre at Sheridan College (Davis Campus).

Figure 16: DE Plants Designed for Education

Plant #2 (Phase 1B)

FVB recommends that the second plant be installed in the same building as Plant #1. This plant would add additional geo-exchange capacity, as well as natural gas boilers and centrifugal chillers. This would reduce the total amount of piping needed and decrease the amount of space required for non-equipment rooms (e.g., washrooms, meeting rooms). Further coordination and discussion with relevant stakeholders about the potential for expansion should be undertaken during the design process of Plant #1. The equipment-only floor area required for Plant #2 is approximately 1,570 m² (16,900 ft²).

If it is not possible to add another level to the Plant #1 building, the second plant could also be installed in the Living Arts Centre's parking garage. Initial assessment of this garage indicates that there is enough space with adequate ceiling heights (3 meters) to house a good amount of equipment. A number of parking spaces would be needed to make room for the energy centre, but this is unlikely to have an adverse impact on the building's users as the parking lot is rarely near full capacity. The floor area required for the equipment and auxiliary spaces for Plant #2 at the Living Arts Centre is approximately 1,760 m² (19,000 ft²), as it would require non-equipment spaces.

Plant #3 (Constructed in Phase 2, includes space for Phase 2 and Phase 3 equipment)

The third plant would be the first to incorporate sewer heat recovery. It would need to be located along Burnhamthorpe Road so that the new sewer line along that road could be used. The floor area required for the equipment and auxiliary spaces for Plant #3 is approximately 1,600 m² (17,200 ft²). The exact equipment layout and plant size requirements would need to be refined once there is a better understanding of the sewer heat recovery potential.

The preferred option for siting this plant would be to use public lands or acquire land to locate the plant. The second option would be to partner with a developer to house it within one of its buildings; this agreement could be similar to a long-term retail tenant. The City can also look at developer contributions to the neighbourhood (e.g., park land, community centres) and include the energy centre within these conveyed lands. Coordination of this will be a key part of the City's role in implementing a DES in the Downtown.

Plant #4 (Phase 4)

The fourth plant would also incorporate sewer heat recovery, though it would intercept the existing branch that runs along the northeast side of the Study Area. This plant could also be incorporated into a new building, ideally near the intersection of Centre View Drive and Rathburn Road West. The floor area required for the equipment and auxiliary spaces for Plant #4 is approximately 1,600 m^2 (17,200 ft^2).

Plant #5 (Constructed in Phase 5, includes space for Phase 5 and Phase 6 equipment)

The location of the fifth and final plant is more flexible, as it will incorporate geo-exchange rather than sewer heat recovery. It would likely be incorporated into a new building. It is assumed that as many boreholes as possible would be installed underneath the new building that houses the plant. The floor area required for the equipment and auxiliary spaces for Plant #5 is approximately 1,700 m^2 (18,300 ft^2).

4.2.3 ENERGY CENTRE PHASING

The proposed phasing for the thermal generation equipment and their associated plant location are outlined in Table 14. The installed equipment capacity includes an N+1 redundancy[10] for heating and N+0.85 for cooling. The diversified peak demand indicates the highest demand that will be seen by the system, and the cumulative installed capacity indicates the nominal capacity of the installed equipment that will meet that demand. The difference between these two numbers indicates the safety factor and incorporated redundancy.

[10] An N+1 redundancy means that the plant can still meet 100% of the demand even if the largest piece of equipment is unable to be used. This is essential for heating. Cooling equipment is generally sized to meet 85% of the peak cooling demand without the largest piece of equipment.

Table 14: Energy Centre Buildout - Heating

Heating Energy Centre				
Phase	Diversified Peak Heating Demand (MW)	Cumulative Installed Capacity (MW)	Capacity Added in Phase	Plant Housing Equipment
1A	6.7	13.0	2 x 1.5 MW Geo Heat Pumps 2 x 5 MW Natural Gas Boilers 1 x 0.9 MW Electric Generator	Plant 1: Sheridan South Parking Lot
1B	26.3	46.0	1 x 10 MW Natural Gas Boilers 2 x 1.5 MW Geo Heat Pumps 1 x 10 MW Electric Boilers 1 x 10 MW Natural Gas Boilers 1 x 2 MW Electric Generator	Plant 2: Sheridan South Parking Lot (preferred) OR Living Arts Centre Parking Garage
2	50.3	73.5	1 x 10 MW Natural Gas Boilers 2 x 3.75 MW SHR Heat Pumps 1 x 10 MW Electric Boilers 1 x 2 MW Electric Generator	Plant 3: Burnamthorpe Rd W & Kariya Gate
3	64.2	83.5	1 x 10 MW Electric Boilers	
4	86.4	111.0	2 x 3.75 MW SHR Heat Pumps 1 x 10 MW Natural Gas Boilers 1 x 10 MW Electric Boilers 1 x 3 MW Electric Generator	Plant 4: Centre View Dr. & Rathburn Rd. W
5	99.0	126.0	1 x 5 MW Geo Heat Pumps 1 x 10 MW Electric Boilers 1 x 3 MW Electric Generator	Plant 5: Within New Building
6	115.4	136.0	1 x 10 MW Electric Boilers	
Total	115.4	136.0	4 x 1.5 MW Geo Heat Pumps 1 x 5 MW Geo Heat Pumps 4 x 3.75 MW SHR Heat Pumps 6 x 10 MW Electric Boilers 2 x 5 MW Natural Gas Boilers 3 x 10 MW Natural Gas Boilers 1 x 0.9 MW Electric Generator 2 x 2 MW Electric Generator 2 x 3 MW Electric Generator	

Figure 17 shows load duration curves for each phase, with the area under the curve highlighted to show the contribution of each technology type. The geo-exchange heat pumps make up the majority of the base load, with sewer heat recovery also contributing to the heating load once there is sufficient capacity available. Electric boilers make up the bulk of the remaining demand, and natural gas boilers are used on the peak demand days and for added redundancy should the electricity source become unavailable. Note that the area under the curves shows the **nominal equipment capacity** and may vary depending on actual operating conditions.

The **nominal equipment capacity** is the manufacturer's stated capacity of the equipment installed. When system demand is larger than this, the equipment will output this amount. When the system demand is less than this, or when there are limitations on the renewable source, the equipment might output less than this amount.

Figure 17: Heating Energy Contribution by Technology

The energy centre buildout for cooling is shown in Table 15. This equipment would be installed in the same energy centre as the heating equipment.

Table 15: Energy Centre Buildout - Cooling

Cooling Energy Centre				
Phase	Diversified Peak Cooling Demand (tons)	Cumulative Installed Capacity (tons)	Capacity Added in Phase	Plant Housing Equipment
1A	1,480	2,460	2 x 230 tons Geo Heat Pumps 2 x 1,000 tons Chillers + Towers	Plant 1: Sheridan South Parking Lot
1B	5,700	8,060	2 x 2,800 tons Chillers + Towers	
2	12,900	16,320	2 x 230 tons Geo Heat Pumps 3 x 2,600 tons Chillers + Towers	Plant 2: Sheridan South Parking Lot (preferred) OR Living Arts Centre Parking Garage
3	16,800	20,320	1 x 4,000 tons Chillers + Towers	Plant 3: Burnamthorpe Rd W & Kariya Gate
4	23,800	24,320	1 x 4,000 tons Chillers + Towers	Plant 4: Centre View Dr. & Rathburn Rd. W
5	28,200	27,870	1 x 950 tons Geo Heat Pumps 1 x 2,600 tons Chillers + Towers	Plant 5: Within New Building
6	31,270	31,470	1 x 3,600 tons Chillers + Towers	
Total	31,270	31,470	6 x 150 tons Geo Heat Pumps 1 x 950 tons Geo Heat Pumps 2 x 1,000 tons Chillers + Towers 2 x 2,800 tons Chillers + Towers 5 x 2,600 tons Chillers + Towers 2 x 4,000 tons Chillers + Towers	

Load duration curves showing the contribution of the geoexchange heat pumps, as well as the chillers and cooling towers, for the first phase and last phase are shown in Figure 18. Again, this shows the nominal capacity of equipment installed and the annual contribution may vary based on the actual demand and energy.

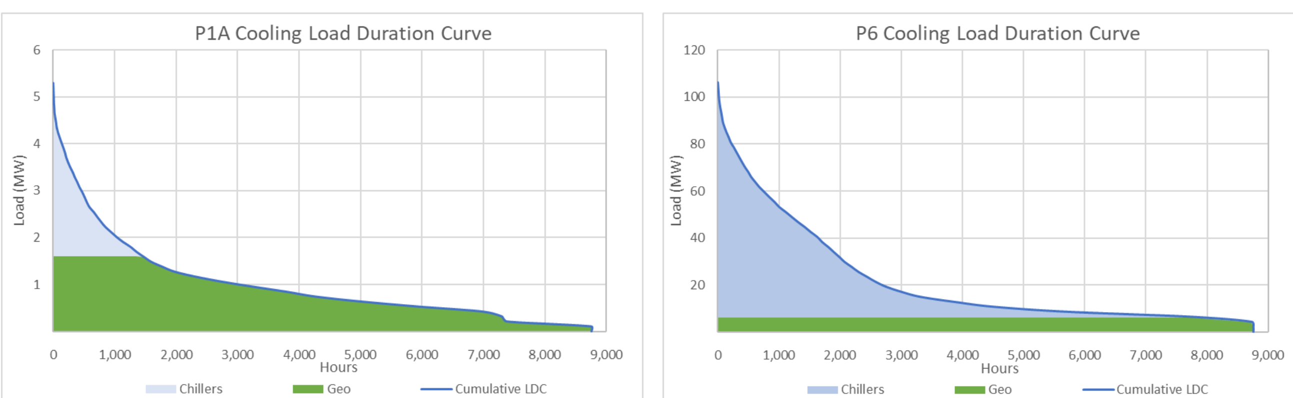


Figure 18: Cooling Energy Contribution by Technology

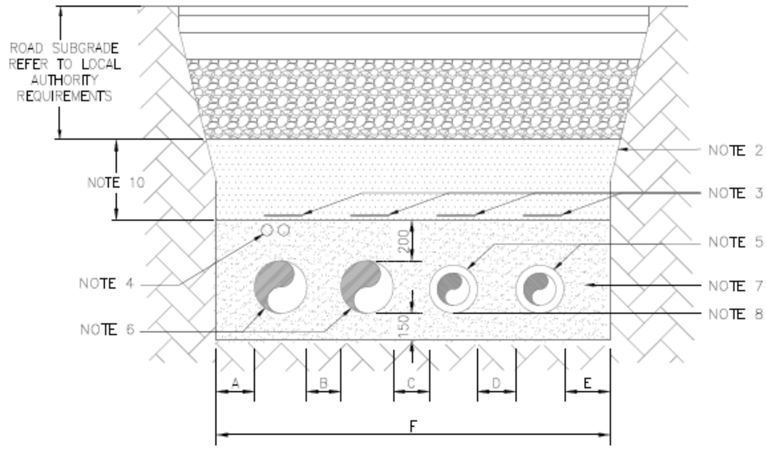
4.2.4 DISTRIBUTION SYSTEM: THERMAL GRID LAYOUT

The distribution piping system (DPS) is the physical link between energy demand (customers) and supply (energy centres). It is assumed that the DPS in the Downtown would be a below-ground 4-pipe system with supply and return piping for hot and chilled water. Both the heating and cooling piping would generally be installed in the same trench in a parallel configuration. Stacked configuration (e.g., hot water pipes on the top of the cooling pipes) would be considered where there is not enough room for the standard parallel configuration. This is not the preferred option as it is cost and time intensive and is more challenging to access and maintain.

A preliminary distribution piping concept was developed, including routing and sizing to provide district heating and cooling services to the targeted building developments. The layout of the distribution piping network is based on the phased installation of five (5) nodal energy centres. The exact layout of the distribution piping will depend on existing infrastructure within ROWs, though care was taken in the preliminary concept to avoid areas where it is known that large utility infrastructure is installed (e.g., main sewer trunks).

The DPS installation generally uses open trench construction, where a trench 2.0 to 4.0m wide is excavated down to the installation depth (generally 1.2 to 2.0 m of cover), piping is installed, and then the area is backfilled and the road surface is reinstated.[11] The DPS has been designed to minimize the total installed length. This, however, results in the installation of piping on several high-traffic roads, such as Burnhamthorpe Road, Hurontario Street, and Rathburn Road. Installation of piping in these areas will be costly, but costs can be decreased if installation is coordinated with other projects (e.g., utility service upgrades, roadway improvements). Because of the expected densification in the Study Area, it is assumed that DE piping could be designed and installed in conjunction with upgrades/installation of other infrastructure in the area.

[11] Note that it is possible to use trenchless or boring technologies for areas that are sensitive to open trench construction (e.g., highways, railways, transit lines). Trenchless construction is very expensive, however, costing upwards of 3x that of open trench construction. It is therefore generally limited to “crossings” perpendicular to sensitive roadways and is not considered for parallel road construction. Within the study area, it is expected that trenchless construction will not be required.



	COOLING PIPE FBE OR DR11 HDPE		HEATING PIPE PRE-INSULATED		DIMENSIONS (RECOMMENDED MINIMUMS)					
	PIPE SIZE (ID / OD)	NPS(in)	PIPE SIZE (ID / OD)	NPS(in)	A(mm)	B(mm)	C(mm)	D(mm)	E(mm)	F(mm)
MAINLINE	457	18"	273ø/450ø	10"	150	275	250	250	150	2890
BRANCH A	356	14"	219ø/355ø	8"	150	275	250	250	150	2500
BRANCH B	273	10"	168ø/250ø	6"	150	200	200	200	150	1950

Figure 19: Typical Open Trench Cross Section Detail

When designing the DPS alongside other utilities, it is possible to establish mutually beneficial routing and incorporate elements such as “utility crossing zones,” which are vertical sections below grade in which utility mains cannot be installed, but all utilities can use these zones to cross each other at intersections or to branch off the main piping. DES planning requires extensive cooperation with local utilities, municipal works, and road construction. These groups need to be aware that there is planning around DE infrastructure in the next 1-5 years.

The district heating piping system assumes the use of pre-insulated steel installed in accordance with ANSI B31.1 and CSA B51 designed for 1,600 kPa (232 psig) at maximum 95°C (203°F) design temperature. It is not expected that the system will operate at these pressures and temperatures, but these design ratings provide room to increase system capacity. Because the system being proposed is a $3^{rd}/4^{th}$ generation DES with medium to low temperature hot water, plastic piping such as pre-insulated polyethylene designed for raised temperatures (PE-RT) (Maximum 80°C) or pre-insulated cross-linked polyethylene (PEX) (Maximum 95°C) may be used. These pipe materials eliminate the risk of corrosion damage and can be installed more efficiently. They do, however, have pressure, temperature, and size limitations.The district cooling piping assumes the use of butt fusion DR11 high density polyethylene (HDPE).

The pipe sizes for the selected route will be determined by the following four key factors:

- Supply and return temperature differentials, referred to as ΔT (delta T);
- Maximum allowable fluid velocity;
- Distribution network pressure at the design load conditions; and
- Differential pressure requirements to service the most remote customer.

The temperature of the DES is dictated by the customer buildings and the thermal generation technologies being used. The design of each building’s internal heating system will need to be coordinated to achieve the district side return temperatures. A high hot water return temperature or a low chilled water return temperature can reduce the efficiency of the DES. This is because of equipment requirements at the energy centres and increased flow requirements through the distribution piping, which leads to increased pressure losses and pumping requirements.

The proposed DES concept assumes that the system will be a low temperature hot water system, with a maximum district supply temperature of 90°C and an associated district return temperature of 45-50°C. A higher district heating supply temperature was selected to accommodate connections to existing buildings. As newer buildings are connected and older buildings are renovated, it is recommended that the district heating temperatures continue to be lowered to maximize the opportunities to use heat pumps and other renewable heating sources.

A district heating supply temperature reset schedule – based on outdoor air temperature (OAT) – would be employed. This means that, for 85% of the year, the hot water supply temperature would not exceed 70°C. The system would only operate above 82°C for less than 5% of the year. An example of an OAT reset schedule is shown in Figure 20. Utilizing a temperature reset schedule ensures that the system is at the lowest possible temperature, reducing distribution losses and enabling the most efficient use of low carbon and lower grade energy sources (e.g., wastewater heat recovery).

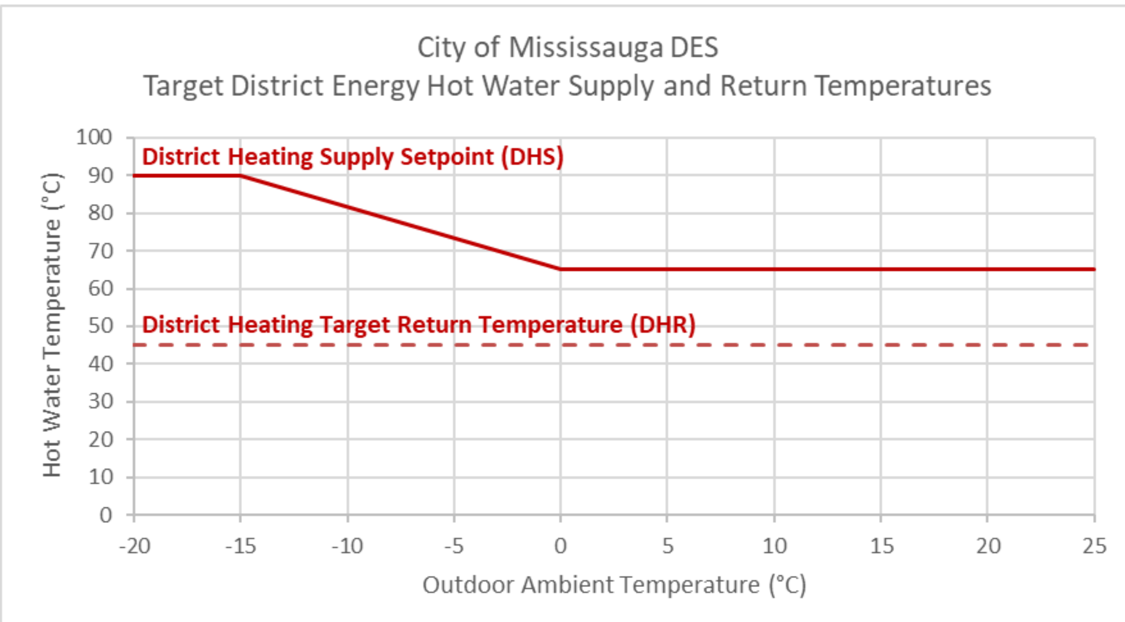


Figure 20: Sample District Heating OAT Reset Schedule

It is assumed that the chilled water supplied to each building from the DES would reach its minimum of 4°C in the summer, with an associated return temperature of 12°C. A district cooling supply temperature reset schedule would also be employed as shown in Figure 21.

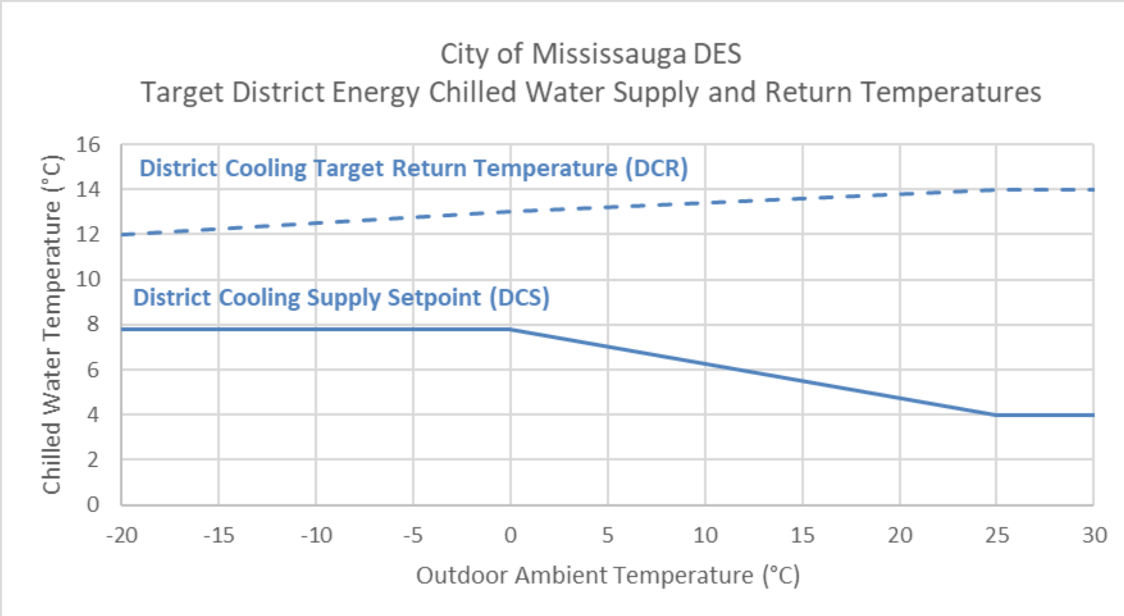


Figure 21: Sample District Cooling OAT Reset Schedule

Based on the system demand and the temperature requirements outlined above, the main pipes are estimated to be 350 mm for heating and 700-800 mm for cooling. For main lines of this size, the trench width would be approximately 4,000 mm wide. Branch sizes vary from 65 mm to 150 mm on the heating piping and 100 mm to 400 mm on the cooling piping, depending on the assumed building connection load. Trench widths for branches are narrower, generally closer to 2,000-2,500 mm.

4.2.5 CUSTOMER CONNECTIONS: ENERGY TRANSFER STATIONS

Each building will install an Energy Transfer Station (ETS) to connect the building indirectly to the hot water and chilled water distribution system. Generally, an ETS is comprised of a hot water heat exchanger, a domestic hot water heat exchanger, and a cooling heat exchanger, along with all necessary piping, valves, metering equipment, and auxiliary fixtures. The integration of an ETS into an existing building will be determined on a case-by-case basis. The DE owner or operator will be responsible for proactively contacting existing building owners to ensure that they are aware that a competitive district energy heating and cooling solution is available in their area. Specific connections for the City buildings in Phase 1A are outlined in Section 4.3.

New buildings connecting to the DES will be constructed to be “DE Ready.” This means that the mechanical rooms and secondary systems of the building are designed to interface optimally with an ETS. “DE Ready” buildings must have connection points to the building heating and cooling systems in an accessible location, ideally below grade, near existing DES distribution piping. The buildings should also have heating and cooling systems designed to minimize hot water return temperature and maximize chilled water return temperature. This will allow the DES to maximize the use of low-carbon and high-efficiency heating and cooling generation equipment. In this regard, FVB recommends that a document outlining the required building heating and cooling design temperatures for a “DE Ready” building be provided to all Downtown developers. The DE owner or operator typically has ongoing conversations with these developers to ensure the design is compatible with a DES.

An ETS requires less space than stand-alone thermal generation equipment. This allows for more space in parking areas as well as on rooftops. ETSs also require very little maintenance and are actively monitored by the DE operator. Issues are most often resolved before the building is even aware of them.

4.3 PHASE 1A BUILDING CONNECTIONS

There are three City of Mississauga buildings located in the Downtown: Living Arts Centre (LAC), Mississauga Civic Centre (MCC), and Hazel McCallion Central Library (MCL). These buildings provide the City with a unique opportunity to connect to the proposed DES in the first phase (Phase 1A), allowing the City to reduce its GHG emissions from those buildings. At present, each of the three building generates its own heating and cooling, generally through boilers and chillers. The locations of these buildings can be seen in Figure 22.

It should be noted that Table 16 represents only what is required for generating heating and cooling and does not include fuel consumption or resultant GHG emissions from other building processes such as plug loads or auxiliary equipment.

Figure 22: Location of Downtown City Buildings

Table 16 provides a summary of each building, including age, size, peak demand and energy consumption, current estimated annual GHG emissions, costs to install replacement self-generation heating and cooling equipment, and costs to connect the building to a proposed DES. The self-generation heating and cooling replacement costs are based on installing updated boiler and chiller plants in each building. No low-carbon technologies have been assumed to be installed in each building and will result in minimal GHG emission reductions compared to the currently installed equipment. If the City were to install new, low carbon self-generation equipment, the replacement costs would be higher than what has been assumed for boilers and chillers.

The peak heating or cooling demand is the amount of heating or cooling needed on the coldest or hottest day to maintain a comfortable environment. The demand determines the capacity required by a utility or self-generation boiler or chiller plant. Energy is the usage or consumption of heating or cooling energy over a period; annual energy is usage over one year.

Peak heating and cooling demand estimates for the three City buildings were determined based on FVB's analysis of monthly utility consumption data (gas, electricity and water consumption), building operator feedback, and FVB historical data for similar building types in the GTA.

It should be noted that Table 16 represents only what is required for generating heating and cooling and does not include fuel consumption or resultant GHG emissions from other building processes such as plug loads or auxiliary equipment.

Table 16: Existing Downtown City Buildings Summary

	Living Arts Centre	Mississauga Civic Centre	Mississauga Central Library
Construction Year	1997	1987	1987
Gross Floor Area	19,510 m^2	43,220 m^2	16,354 m^2
Peak Heating Demand[1]	1,366 kW	2,593 kW	1,080 kW
Peak Heating Load Density	70.0 W/m^2	60.0 W/m^2	66.0 W/m^2
Peak Cooling Demand[1]	1,136 kW	2,518 kW	774 kW
Peak Cooling Load Density	58.2 W/m^2	58.3 W/m^2	47.3 W/m^2
Annual Heating Energy Consumption[2]	2,720 MWh	3,942 MWh	1,624 MWh
Annual Heating Energy Density	139.4 kWh/m^2	91.2 kWh/m^2	99.3 kWh/m^2
Annual Cooling Energy Consumption[2]	2,068 MWh	4,961 MWh	1,071 MWh
Annual Cooling Energy Density	106.0 kWh/m^2	114.8 kWh/m^2	65.5 kWh/m^2
Self-Generation Annual GHG Emissions[3]	770 tonnes	927 tonnes	374 tonnes
Self-Generation Annual GHG Intensity	39.5 $kgCO_2e/m^2$	21.5 $kgCO_2e/m^2$	22.9 $kgCO_2e/m^2$
Self-Generation System Replacement Cost	$ 2,736,000	$ 2,794,000	$ 1,320,000
DES Connection Cost (ETS and Building)	$ 610,500	$ 962,500	$ 478,500

Note 1: FVB established peak demands using metered monthly energy from utility bills and operator feedback in conjunction with FVB load density metrics (i.e., W/m^2) established over 25 years of district energy experience in Canada.
Note 2: FVB used historical metered data from the building to assess annual energy consumption. These values were validated against FVB energy density metrics (i.e. kWh/m^2, EFLH, etc.) from an FVB proprietary database corresponding to the design, age, and use of the building.
Note 3: Annual heating- and cooling-related GHG emissions are estimated based on standard emissions factors (natural gas and electricity emissions factors from 2020 National Inventory Report) as well as energy consumption from metered data (2018-2019). Emissions are based on the efficiency of the self-generation boiler and chillers.

4.3.1 LIVING ARTS CENTRE

Building Description

The Living Arts Centre is a multi-use complex that opened in 1997. The building includes three theatres, meeting/event spaces, visual arts studios, and a large atrium. The building has a gross floor area (GFA) of 19,510 m^2 (210,000 ft^2) and has two levels below grade (P1 and P2 parking levels) and three levels above grade.

Heating for the building is provided by two gas-fired boilers located in the P1 boiler room. These units are at end of life with several maintenance issues and are scheduled for renewal in 2023. The heating system has hot water and glycol loops and operates at relatively low temperatures (50/45°C HWS/HWR).

Cooling for the building is provided by two centrifugal chillers with wet cooling towers. The chillers are in the P2 chiller room, adjacent to the P1 boiler room and the cooling towers are located on the building roof. The smaller chiller and cooling tower are designed to provide free cooling during the winter. The chillers and cooling towers are original to the building and are nearing end of life. The status of the chillers will be re-evaluated in 2027 for renewal.

A centralized domestic hot water heating system is in the boiler room, with two gas-fired hot water heaters and storage tanks.

District Energy Connection

The proposed DE connection would require removal of existing boilers, chillers, cooling towers, and domestic hot water heaters. The chilled water distribution pumps would remain and the hot water distribution pumps would be replaced. Minimal rework to the existing building system would be required.

DE pipes (district heating and district cooling) would enter the north side of the building at the P1 level from Prince of Wales Drive. The branch would be sized to serve the LAC, Mississauga Civic Centre, and Hazel McCallion Central Library, and would continue through the P1 level of the building, exiting the south side of the building to cross Princess Royal Drive towards the Mississauga Civic Centre.

The ETS would be installed in the P1 boiler room and be comprised of three heat exchangers, one each for heating, cooling, and domestic hot water.

4.3.2 MISSISSAUGA CIVIC CENTRE

Building Description

The Mississauga Civic Centre (MCC) is a multi-use office complex that opened in 1987. The building includes office space, meeting/event spaces, and other community space. The building has a gross floor area (GFA) of 43,220 m^2 (465,200 ft^2) and has two levels below grade (P1 and P2 parking levels) and twelve levels above grade plus two penthouse levels. At the perimeter of Mississauga Celebration Square, which is located just south of MCC, there are “pods” that have standalone heating and cooling systems. The southeast pod houses the ice rink Zamboni and ice-skating rink refrigeration equipment. The southwest pod is primarily used for storage and access to the parking garage.

MCC heating is provided by four gas-fired boilers, installed in 2014, in the penthouse mechanical room. Variable speed distribution pumps in the penthouse circulate hot water through the building via 250mm diameter risers that run down to the P2 level. The system currently operates at relatively high temperatures (82.2/71.1°C HWS/HWR).

Cooling for the building is provided by ten modular Smardt magnetic bearing chillers located in the penthouse (2008) along with two large wet cooling towers (2018) located on the roof of the penthouse. Air handling unit (AHU) cooling coils throughout the building are equipped with 3-way control valves. There are three small, dedicated AC units that provide cooling to the B1 Computer Room.

Domestic hot water (DHW) is provided by numerous electric hot water tanks distributed throughout the building. The top floors of the building receive domestic hot water from two gas-fired domestic hot water tanks.

District Energy Connection

The proposed DE connection would be through an ETS located in the P2 mechanical room. The existing boilers and chillers in the penthouse would be disconnected from the existing hot and chilled water systems, along with the existing hot and chilled water distribution pumps. The DE connection will provide space heating and space cooling, but will not provide DHW due to the decentralized nature of the building’s DHW systems. New distribution pumps would be installed in the P2 mechanical room alongside the ETS. Several sections of pipe would need to be removed and upsized from the P2 mechanical room up to the third and fourth floor risers.

The DE distribution piping will enter the P2 mechanical room from Princess Royal Drive through the large exhaust shaft at the north end of the mechanical room. The distribution piping will continue through the P1 level of the building in order to serve the Hazel McCallion Central Library.

4.3.3 HAZEL MCCALLION CENTRAL LIBRARY

Building Description

The Hazel McCallion Central Library is a large library and community space that opened in 1987. The P1 level of the building is connected to the P1 level of the MCC. The building has a GFA of 16,354 m^2 (176,034 ft^2) and has two levels below grade (P1 and P2 parking levels) and four levels above grade plus two penthouse levels. The building is currently under renovation, including a new boiler plant and heating system upgrades.

The building has a hydronic heating system served by two new cast iron sectional boilers (2021/2022), which are located in the mechanical penthouse. The boilers serve three hydronic loops with varying supply temperatures. The boilers output hot water at a maximum of 98.9°C (210°F), while the perimeter heating and reheat hot water loops have supply temperatures of 48.8°C (120°F) and 65.6°C (159°F), respectively. There are two small gas-fired rooftop units (100 MBH and 60 MBH) located on the second floor rooftop.

The building's chilled water system is fed from two chillers located in the P2 level chiller room, along with wet cooling towers located on the building roof. The existing chillers are Smardt magnetic bearing units (2008). The chilled water system has variable speed distribution pumps and serves several air handling unit cooling coils equipped with 2-way control valves. There are ten (10) small, dedicated AC units that cool server rooms.

Domestic hot water is provided by three electric hot water tanks distributed throughout the building.

District Energy Connection

The proposed DE connection would be through an ETS located in the P2 chiller room. The existing penthouse boilers and P2 level chillers would be disconnected from the building's hot and chilled water loops. New hot water distribution pumps would be installed alongside the ETS in the P2 chiller room, and the existing chilled water distribution pumps would be re-used. The DE connection would provide space heating and cooling. Due to the building's decentralized DHW systems, DHW would continue to be supplied through electric hot water tanks.

The DE distribution piping would run from the MCC through the shared P1 parking level and into the P2 chiller room. A section of hot water secondary supply and return piping would be required between the heating ETS in the P2 chiller room and the existing 100mm risers located on the P1 level.

5 FINANCIAL ANALYSIS

5.1 LOW CARBON DES CONCEPT CAPITAL COST ESTIMATE

The DES is comprised of energy centers (heating and cooling plants), energy transfer stations in each building, and a distribution piping system connecting these two elements. Each of these assets requires a capital cost to construct, install, and commission. An overview of the capital cost of each component of the Low Carbon DES is shown in Table 17.

Table 17: Low Carbon DES Capital Cost Summary

Low Carbon DES Class D Preliminary (-25%/+50%)	Full Phased Buildout	
	Installed Capacity	Total (2022$)
Heating Plants	138.0 MW	$ 113.7 million
Cooling Plants	31,400 tons	$ 144.8 million
Energy Transfer Stations	85 ETSs	$ 65.7 million
Distribution Piping System	10,840 trench meters	$ 57.6 million
Total DES Capital Cost		**$ 381.8 million**

5.1.1 ENERGY CENTRE

The capital cost that would go towards building and/or expanding the energy centre in each phase is shown in Table 18. A detailed breakdown of each phase and energy centre can be found in Appendix C, including assumptions for soft costs for heating and cooling.

Table 18: Energy Centre Capital Cost Estimate

Energy Centre Capital Cost (2022$)[1] Phase	Heating Capacity (MW)	Heating Plant	Cooling Capacity (tons)	Cooling Plant	Total
Phase 1A	13.0	$ 10,591,000	2,500	$ 31,684,000	$ 42,275,000
Phase 1B	33.0	$ 22,416,000	6,100	$ 43,123,000	$ 65,539,000
Phase 2	27.5	$ 26,133,000	7,800	$ 19,904,000	$ 46,037,000
Phase 3	10.0	$ 2,900,000	4,000	$ -	$ 2,900,000
Phase 4	27.5	$ 26,311,000	4,000	$ 25,056,000	$ 51,367,000
Phase 5	15.0	$ 22,466,000	3,500	$ 22,257,000	$ 44,723,000
Phase 6	10.0	$ 2,837,000	2,600	$ 2,804,000	$ 5,641,000
Total	**136.0**	**$ 113,654,000**	**30,500**	**$ 144,828,000**	**$ 258,482,000**

Note 1: Includes Contractor OH&P, Construction Management, Engineering (6.5%), and Contingency (15%). Does not include taxes.

5.1.2 DISTRIBUTION PIPING SYSTEM

Table 19 shows an overview of the DPS capital cost estimate in each phase. The cost per trench meter (tm) varies based on a variety of factors, including economies of scale, pipe size, and expected coordination required with other utilities and major thoroughfares.

Table 19: DPS Capital Cost Estimate

DPS Capital Cost (2022$)[1] Phase	Trench Length (m)[2]	Main Pipe	Total	$/tm
Phase 1A	770	$ 2,041,000	$ 2,041,000	$ 2,651
Phase 1B	1,950	$ 12,337,000	$ 12,337,000	$ 6,327
Phase 2	2,920	$ 20,971,000	$ 20,971,000	$ 7,182
Phase 3	1,210	$ 5,871,000	$ 5,871,000	$ 4,852
Phase 4	2,570	$ 13,918,000	$ 13,918,000	$ 5,416
Phase 5	860	$ 1,452,000	$ 1,452,000	$ 1,688
Phase 6	560	$ 1,018,000	$ 1,018,000	$ 1,818
Total	**10,840**	**$ 57,608,000**	**$ 57,608,000**	**$ 5,300**

Note 1: Includes Contractor OH&P, Construction Management, Engineering, and Contingency (15%). Does not include taxes.
Note 2: Includes length for main line and branch connections.

The estimated trench length is subject to change once the exact location of the proposed and future developments is known. The length is also estimated based on the chosen buildings for market penetration. Buildings that are connected further away from the energy centres will increase the DPS capital cost. However, buildings that are connected near piping that has already been installed will only require an additional branch connection, reducing the marginal capital cost of connection compared to buildings outside the existing network. The existing DPS infrastructure will act as an ongoing incentive for additional buildings to connect to the DES.

5.1.3 ENERGY TRANSFER STATIONS

Table 20 shows an overview of the ETS capital cost estimate in each phase. For Phase 1A, the ETS capital cost includes full building conversion required for each of the City and Sheridan College buildings. For the other phases, the ETS cost was estimated based on the assumed heating and cooling demand of each building (outlined in Appendix B) and does not include the costs of extensive building conversion, as this would typically be the responsibility of the individual building owners.

Table 20: ETS Capital Cost Estimate

ETS Capital Cost (2022$)[1] Phase	# of ETS's (kW)	Heating ETS	Cooling ETS	Total
Phase 1A	5	$ 1,582,750	$ 1,582,750	$ 3,165,500
Phase 1B	14	$ 5,260,600	$ 4,849,400	$ 10,110,000
Phase 2	22	$ 7,859,100	$ 8,473,600	$ 16,332,700
Phase 3	11	$ 4,291,400	$ 3,914,300	$ 8,205,700
Phase 4	12	$ 5,971,500	$ 5,426,000	$ 11,397,500
Phase 5	13	$ 4,094,500	$ 4,158,500	$ 8,253,000
Phase 6	8	$ 4,159,000	$ 4,095,000	$ 8,254,000
Total	**85**	**$ 33,218,850**	**$ 32,499,550**	**$ 65,718,400**

Note 1: Includes Contractor OH&P, Construction Management, Engineering (12%), and Contingency (15%). Does not include taxes.

5.2 LOW CARBON DES CONCEPT REVENUE AND EXPENSE PROJECTIONS

The annual cash flow of the DES will be determined by the DE rates charged to each connected building and the operating and maintenance expenses of the DES.

District energy rates are the charges customers pay for the DES service. They are developed to be competitive with the costs a building would incur should it choose to have a stand-alone heating and cooling plant rather than be connected to the DES (also referred to as the "standalone costs"). To estimate the amount of revenue that could be garnered from the DE rates, the standalone costs for each building are estimated and translated into a DES rate structure. For the purposes of this analysis, the standalone case will be the Low Carbon Standalone scenario outlined in Section 3.2.

Customer buildings' standalone costs include the total costs of installing, owning, operating, and maintaining heating and/or cooling in-building systems if they are not connected to the DES.

The self-generation cost can be conceptualized as being comprised of two components:

1. **Annual Operating and Maintenance (O&M) Costs**: this includes fuel, electricity, other consumables, onsite staff time, and maintenance.

2. **Capital Costs**: for new buildings, there are two components: (a) the upfront capital cost to build the space and install the heating and cooling equipment; and (b) the future funds required for equipment replacement.

The estimates for these O&M and capital costs are outlined in the following sections.

5.2.1 LOW CARBON STANDALONE OPERATION AND MAINTENANCE COSTS

Table 21 shows the estimated fixed and variable heating and cooling costs at full buildout if each building had a standalone solution rather than being connected to the DES. The fixed costs are those that do not vary significantly based on energy consumption (e.g., labour, preventative maintenance and repair, insurance). The cost of energy (e.g., gas, electricity) varies based on consumption.

Table 21: Low Carbon Standalone Annual Operating and Maintenance Cost Estimate

Low Carbon Standalone O&M Component	Full DES Buildout (2022 $)
Heating Variable O&M[12]	$ 22,991,300
Heating Fixed O&M[13]	$ 1,461,500
Cooling Variable O&M[14]	$ 7,663,300
Cooling Fixed O&M[15]	$ 1,733,300
DPS and ETS Maintenance	N/A
Carbon Tax	$ 4,476,500

It was assumed that the price for natural gas is an average of $8.45 /GJ across the buildings based on Enbridge's Rate 6 structure as of April 2022. This excludes the federal carbon pricing, which is evaluated separately.

The electricity rate was assumed to be Class B for the individual buildings, with an average cost of $0.18/kWh.

The natural gas boilers for the standalone case are assumed to have a seasonal efficiency of 78%, accounting for those within existing and future buildings. The electric boilers are assumed to have an efficiency of 99% for both space heating and DHW. The chillers are assumed to have an annual

[12] Heating Variable O&M costs include natural gas, electricity, makeup water, chemical treatment, and sewer costs for the condensing boiler, electric boilers, and heat pumps for their contribution to heating.
[13] Heating Fixed O&M costs include major equipment maintenance, insurance, and operator and administration costs.
[14] Cooling Variable O&M costs include electricity, makeup water, chemical treatment, and sewer costs for the chillers, cooling towers, and heat pumps for their contribution to cooling.
[15] Cooling Fixed O&M costs include major equipment maintenance, insurance, and operator and administration costs.

coefficient of performance (COP) of 4.0. For buildings adhering to TGS v3 Tier 3, the ASHPs are assumed to have a COP that varies with the outside air temperature from around 1.5 to 2.8, and are assumed to be operational only when the OAT is higher than -15°C. The GSHPs have a heating COP of 2.4 and a cooling COP of 5.5.

Carbon tax is estimated using Canada's currently forecasted model of $50/tonne in 2022, increasing by $15/tonne yearly until 2030. After 2030, it was estimated that the carbon tax increases at a rate of 2% each year.

5.2.2 LOW CARBON STANDALONE CAPITAL COST

In order to estimate the standalone capital costs, FVB relied on standard $/kW installed metrics for heating and cooling self-generation plants, which have been developed by FVB through years of experience and completed projects. These metrics were tailored based on the size of individual buildings, the expected installed capacity of each building for adequate redundancy, and the TGS v3 tier they are anticipated to meet based on when they are constructed. These capital costs are shown in Table 22.

Table 22: Low Carbon Standalone Capital Cost Summary (2022 k$)

Capital Cost Summary (2022 k$)	P1A	P1B	P2	P3	P4	P5	P6
	2025	2028	2030	2035	2040	2045	2050
Standalone Heating	4,404	16,809	27,677	17,542	30,432	24,374	14,660
Standalone Cooling	7,643	26,302	48,915	24,015	43,591	26,767	19,060
Total Capital Cost	12,047	43,111	76,593	41,557	74,023	51,141	33,720
Cumulative Capital Cost	**12,047**	**55,158**	**131,751**	**173,308**	**247,331**	**298,472**	**332,192**

A breakdown of the equipment capacity and capital cost is provided in Appendix D.

5.2.3 DISTRICT ENERGY RATES

District energy rates are the charges that customers pay for the DES service. The standalone costs determine the district energy rates, which generally include two components:

1. **Energy Charge**: the annual energy charges are based on the annual energy consumption, current utility rates, and the equipment efficiency expected to be achieved in the self-generation scenario.
2. **Capacity Charge**: capacity charges are based on the standard rates applicable to the load for heating and cooling.

Figure 23 shows the relationship between the self-generation and district energy rate structures. District Energy Rate Structure 1 involves an energy charge and capacity charge. District Energy Rate Structure 2 involves a one-time connection fee to cover capital costs, which reduces ongoing rates.

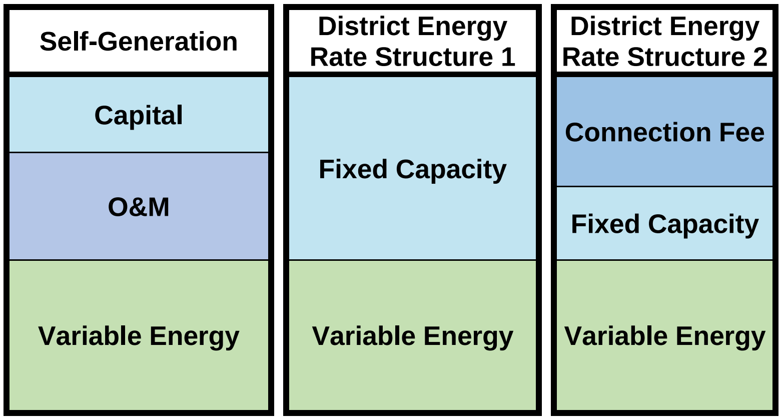


Figure 23: Self-Generation Costs vs. DE Rate Structure

While DE is unregulated in Ontario and – as such – there is not a required rate structure, this rate structure has been used commonly and successfully in DESs across North America, including Markham and Toronto. The split of components allows for a straightforward comparison of the DES rates to the standalone avoided costs, allowing building developers, owners, and managers to understand the cost comparison of the two options.

For the financial analysis, the DE rate structure is assumed to utilize a fixed capacity charge and a variable energy charge structure (Rate Structure 1). The fixed capacity charge was set equal to the standalone fixed costs plus the charge necessary to match the NPV of the standalone capital costs over the 25-year lifecycle of the system. The energy charges are calculated based on the energy consumed and an assumed efficiency for the standalone equipment.

Based on the estimated standalone costs, an indicative DE rate for the first year of connection is presented in Table 23.

Table 23: District Energy Rate Summary for Revenue Estimate

DES Charges	Heating	Cooling
Energy	49.34 $/MWh	64.47 $/MWh
Capacity	109.25 $/kW	160.91 $/kW

The above capacity charges are based on the calculated avoided fixed operation and maintenance costs and avoided capital of the standalone case, and represent the estimated average of the rates charged to each building. These rates will be refined as the design process for the DES continues, detailed feasibility studies are conducted, and there is a better understanding of future developments. These rates serve as a starting point to allow for a financial analysis of the business case, and it is important to consider that these charges are representative of the potential rates only. The actual rate charged to each building will depend on many factors, including the actual standalone design and anticipated composition of the building, as well as financial modelling by the DE owner. The currently estimated rates are higher than traditional rates; however, this is because of the low carbon nature of the DES. As standards for GHG emissions become more restrictive, builders will have to install more costly equipment to meet these requirements. As such, the DES rates remain competitive with the low carbon standalone scenario.

To calculate the thermal revenue in the financial model, the calculated capacity charge is multiplied by the peak heating and cooling demand in each year and the energy charge is multiplied by the total heating and cooling energy for that year. The peak demand and annual energy are calculated by phase in the technical model, and only increase when a new phase comes online.

Based on guidance from the City to use conservative assumptions due to current and future economic factors being volatile, FVB utilized a 3.0% CPI rate as well as a 3.0% capacity charge escalation rate to match predicted inflation. The energy charge will increase in line with actual energy costs, which in this analysis also escalate with CPI. FVB believes that short term inflationary spikes will subside, but long term inflation will be higher than historic trends.[16,17]

5.2.4 DE OPERATION AND MAINTENANCE COSTS

The estimated operating and maintenance costs at full buildout for the low carbon DES are shown in Table 24 and, along with the capital costs, form the expenses incurred by the DES in the financial analysis. As with the standalone case, fixed costs are those that do not vary significantly based on energy consumption (e.g., labour, preventative maintenance and repair, insurance), while variable energy costs change with energy consumption.

Table 24: DE Annual Operating and Maintenance Cost Estimate at Full Buildout

DES O&M Component	Full DES Buildout (2022 $)
Heating Variable O&M[18]	$ 14,858,000
Heating Fixed O&M[19]	$ 1,351,400
Cooling Variable O&M[20]	$ 5,046,600
Cooling Fixed O&M[21]	$ 1,491,700
DPS and ETS Maintenance	$ 357,400
Carbon Tax	$ 1,039,400

It is assumed that the price of natural gas is $7.50/GJ based on Enbridge's Rate 6 structure as of April 2022, excluding federal carbon pricing. The $/GJ price under Rate 6 is anticipated to be lower than in the Low Carbon Standalone option as the billing is for a single, large-use customer.

Electricity cost was estimated based on the Class A rate structure.[22] It is assumed that the natural gas generators would be deployed for peak shaving to reduce the effective electricity price of the plant by reducing the peak electrical demand of the facility on the days when the total demand on Ontario's grid is at its highest. It is assumed that the generators would have to operate for 200 hours to reliably hit all of these peaks with minimal monitoring and prediction. With these peaks reduced, the effective electricity price at full plant buildout is 0.08 $/kWh.

The natural gas boilers are assumed to have a seasonal efficiency of 85% and the electric boilers are assumed to have an efficiency of 99%. The chillers are assumed to have a coefficient of performance (COP) of 4.5. These efficiencies are assumed to be higher than the standalone equipment as the DE

16 "Will Inflation Stay High for Decades?", Wall Street Journal, https://www.wsj.com/articles/inflation-high-forecast-economist-goodhart-cpi-11646837755

17 Statistics Canada, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1810000501

18 Heating Variable O&M costs include natural gas, electricity, makeup water, chemical treatment, and sewer costs for the condensing boiler, electric boilers, and heat pumps for their contribution to heating.

19 Heating Fixed O&M costs include major equipment maintenance, insurance, and operator and administration costs.

20 Cooling Variable O&M costs include electricity, makeup water, chemical treatment, and sewer costs for the chillers, cooling towers, and heat pumps for their contribution to cooling.

21 Cooling Fixed O&M costs include major equipment maintenance, insurance, and operator and administration costs.

22 In the Class A rate structure, the cost of electricity of a consumer is determined by that consumer's draw on the grid during the five (5) hours when the total demand on the grid is the highest. If the consumer's consumption during those hours is limited, savings are achieved year-round compared to the traditional (Class B) electricity price.

equipment has a more stable load with less start-up and shut-down cycles, and will be consistently supervised by professional operators.

The carbon tax is estimated using Canada's currently forecasted model of $50/tonne in 2022, increasing by $15/tonne yearly until 2030 ($170/tonne). After 2030, it was estimated that the carbon tax increases at a rate of 2% each year.

The heat pumps used in the geoexchange system are modelled to have a COP that varies with the hot water supply (HWS) temperature required of the system, which varies based on a reset schedule (see discussion above). Heat pumps have higher efficiencies when the HWS temperature is lower, so the COP varies from 2.0 to 2.4 for heating-only operations and 2.2 to 2.7 for simultaneous heating and cooling operations. The cooling COP is set at 5.0 as the chilled water supply (CWS) temperatures do not change.

The heat pumps in the sewer heat recovery (SHR) system have a heating COP that varies between 2.1 and 3.3, depending on the HWS temperature required with a temperature output of 77°C.

At this stage of the study, it was assumed that the Region of Peel would not charge the DES operator for the use of the wastewater heat recovered; however, this is subject to change as charging for the use of wastewater thermal energy is becoming more common.

5.3 RESULTS OF FINANCIAL ANALYSIS

5.3.1 GENERAL

The financial analysis evaluates the return on capital due to the revenue generated by the DES less the fixed and variable expenses incurred.

5.3.2 GLOSSARY

Key Financial Terms:

- **NPV (Net Present Value)** is the difference between the present value of the benefits of a project and its costs.
- **IRR (Internal Rate of Return)** is defined as the interest rate that sets the NPV of the cash flows of a project to zero.
- **WACC (Weighted Average Cost of Capital)** is the average cost of capital an entity must pay to all its investors, both debt and equity holders.
- The **discount rate** is the interest rate used to determine the present value of future cash flows.

5.3.3 COST OF CAPITAL AND CAPITAL EXPENDITURE ESCALATION

This study does not assume the use of debt financing. The City can potentially raise low cost debt financing for the project, based on its credit rating/profile,[23] with financing costs ranging between 2.6% and 3.5%. Inflationary expectations have risen in recent months[24] and the cost of capital may also rise

[23] https://www.mississauga.ca/city-of-mississauga-news/news/city-of-mississauga-awarded-18th-consecutive-aaa-credit-rating-on-strong-financial-management-and-diversified-local-economy/#:~:text=The%20City%20of%20Mississauga%20has,18th%20year%20in%20a%20row.

[24] https://www.bankofcanada.ca/rates/indicators/capacity-and-inflation-pressures/expectations/

due to geopolitics, capital needs for grid modernization, and increased spending on renewable energy. Based on FVB experience, the DE cost of capital and discount rate is assumed to be 3.0%. Future development of the DES business concept including the Owner/Operator model can further address use of the most appropriate discount rate. In addition, the debt/equity structure can be further explored and an optimal capital structure employed.

While the cost of capital will likely be low, the cost of construction and capital expenditures is likely to rise substantially over the coming years. It is anticipated that material shortages will lead to higher future capital expenditure costs.[25] An era of worker shortages due to shifting demographic trends will further exacerbate cost issues and drive up prices. Based on current industry trends, the capital expenditure escalation rate is assumed to be 5.0%. In other words, the capital cost of new construction is expected to rise more quickly than the standard CPI inflation rate of 3% annually.

5.3.4 FINANCIAL RESULTS

Table 25 presents the results of the financial analysis, using the model and assumptions noted above. These results are indicative of the system at full buildout. The unescalated expenses and revenue represent the costs to operate the system and the anticipated revenue from the buildings connected to the DES. The internal rate of return (IRR) and the net present value (NPV) are metrics that can help determine the business case of a project.

Table 25: Low Carbon DES Financial Results

	Financial (Unescalated)		Financial (Escalated)		Reduced GHG vs. Standalone @ Full Build-Out (tonnes)
Description	Annual Expenses ($/yr) 2022	Annual Revenue ($/yr) 2022	Projected IRR 25 Years (%)	25-Year NPV 3.0% (k$)	
Low Carbon DES	24 million	44 million	8.3%	300 million	28,288 (88%)

The City of Mississauga is a governmental entity and does not justify investment returns over a discount rate (hurdle rate). Regardless, an IRR that falls in the range of 6-8% is considered a good business case for district energy. The following sections will outline how the business case responds to changes in a variety of factors.

25 https://www.theglobeandmail.com/business/industry-news/property-report/article-construction-industry-fears-a-skilled-trades-shortage/

5.3.5 SENSITIVITY ANALYSIS, RISK ASSESSMENT, MITIGATION

Sensitivity to DES Capital Cost

This sensitivity analysis shows the effect on the business case if the capital costs required for the DES, including the costs associated with the energy centre, distribution piping, and energy transfer stations, were to decrease by up to 20% or increase by up to 20%.

Table 26: DES Capital Cost Sensitivity

DES Capital Cost Sensitivity		Financial (Unescalated)		Financial (Escalated)	
Variation	Capital Cost (k$)	Annual Expenses (k$)	Annual Revenue (k$)	Projected IRR 25 Years (%)	25-Year NPV 3.5% (k$)
-20%	305,447	24,145	44,001	11.1%	406,664
-10%	343,628	24,145	44,001	9.6%	353,480
Base	381,808	24,145	44,001	8.3%	300,296
+10%	419,989	24,145	44,001	7.2%	247,112
+20%	458,170	24,145	44,001	6.1%	193,928

At this stage of the feasibility study, there are many elements of the DES concept that are not finalized. In particular, many elements of the existing and new buildings are not known: the locations of the new buildings and mechanical rooms of the existing buildings are among many elements that could influence the actual capital cost. At the same time, access to grants or low-interest loans could reduce the effective project capital and improve the overall business case.

Sensitivity to Electricity Price

This sensitivity analysis shows the effect on the business case if the electricity price is as shown in Table 27. Note that the electricity price is fixed for each phase. The standalone electricity price remains the same at 0.18 $/kWh$_e$.

Table 27: Electricity Price Sensitivity

		Financial (Unescalated)		Financial (Escalated)	
Variation	Electricity Price ($/kWh)	Annual Expenses (k$)	Annual Revenue (k$)	Projected IRR 25 Years (%)	25-Year NPV 3.5% (k$)
-25%	$0.06	19,351	44,001	9.6%	391,790
Base	$0.08	23,579	44,001	8.4%	309,240
+25%	$0.10	27,806	44,001	7.1%	226,691
+50%	$0.12	32,034	44,001	5.7%	144,141
+100%	$0.16	40,489	44,001	2.5%	-20,958

As the proposed Low Carbon DES is largely electrified, there is a certain risk to the business case should the price of electricity change. In particular, the DES concept benefits from the Class A electricity rate by using the peak shaving generators to create a lower effective electricity price for the rest of the year. Should this rate be discontinued or the price of electricity be otherwise changed, the operating expenses of the DES would increase. This risk can be mitigated by using a diversity of fuel sources, as well as heat pumps that have a higher efficiency than electric boilers. It should be noted that, particularly in later phases, the buildings will rely on electricity for heating and cooling even in the standalone scenario, so there would still be relative savings for the DES with the greater system efficiencies.

Sensitivity to Market Penetration / Revenue

This sensitivity analysis shows the effect on the business case if more or less buildings are connected to the system than originally estimated. Phase 1A is not affected as it is assumed that the City and Sheridan buildings will connect. Note that the estimated market penetration in the current financial analysis is 50% of existing and new buildings and 100% of proposed developments.

Table 28: Market Penetration Sensitivity

		Financial (Unescalated)		Financial (Escalated)	
Variation	GFA of All Building Types (m²)	Annual Expenses (k$)	Annual Revenue (k$)	Projected IRR 25 Years (%)	25-Year NPV 3.5% (k$)
-20%	2,974,931	24,145	35,201	4.2%	54,544
-10%	3,346,798	24,145	39,601	6.4%	177,420
Base	3,718,664	24,145	44,001	8.3%	300,296
+10%	4,090,530	24,145	48,401	10.0%	423,172
+20%	4,462,397	24,145	52,802	11.5%	546,048

Note 1: This sensitivity analysis simply multiplies the expected revenue by the % of potential customers. It does not take into account capital cost savings from reduced DPS installations nor savings in later equipment installation phases.
Note 2: Baseline assumption is that there is a 50% market penetration for existing and new buildings. This sensitivity is for overall change in GFA, preserving the ratio of existing & new to proposed & future.

A certain market penetration, or number of customer connections, is required to make a DES viable. If this threshold is not met, the DES will not have enough revenue to cover operating expenses and invested capital. This risk can be mitigated in several ways. The first and most straightforward option is the phasing of capital like shown in this DES concept. By adding capacity throughout the buildout of the system – rather than all at the beginning – the capacity added in later phases can be adjusted to match the actual loads seen on the system. This prevents sunk capital that cannot be otherwise recuperated. Separately, the City has various ways to incentivise existing and new buildings to connect to the DES. This will be expanded on in Section 7.

Sensitivity to Existing Building Rates

This analysis was performed taking a conservative approach to the rates that could be charged to existing buildings. As these existing buildings are largely older condominiums that would have little incentive to connect to the DES for the GHG reduction benefits alone, the rates that make up the revenue were estimated to be in line with the BAU Standalone of natural gas boilers and conventional chillers, as outlined previously in this report. However, as the DES provides a significant amount of GHG reductions, the connection to the DES could be compared financially to what the building would do to meet an equivalent GHG target using a standalone solution. This would result in a higher avoided cost, and therefore the DE rates could be higher and still competitive with the standalone solution. As a sensitivity exercise, the system was evaluated with rates for existing buildings being the same as for new buildings.

When the revenue is adjusted based on this assumption, the business case improves to what is shown in Table 29.

Table 29: Sensitivity to Existing Building Rates

Description	Financial (Unescalated) Annual Expenses (k$/yr) 2022	Financial (Unescalated) Annual Revenue (k$/yr) 2022	Financial (Escalated) Projected IRR 25 Years (%)	Financial (Escalated) 25-Year NPV 3.0% (k$)	Reduced GHG vs. Standalone @ Full Build-Out (tonnes)
Rates in Base Model	24,145	44,001	8.3%	300,296	28,288
Potential Low Carbon Rates	24,145	46,457	11.2%	504,515	13,293

For a fair analysis, this sensitivity shows a reduction in the low carbon DES emissions as compared to the standalone scenario since this case is assumed to include an increase in capital and operating costs in the standalone solution to reduce the GHG emissions of the buildings.

It should be noted that the rate charged to each building will ultimately be determined by the DE provider based on its business model and the willingness of the buildings to connect to the system. This analysis shows the potential revenue.

<u>Sewer Heat Recovery Assumptions and Limitations</u>

In this study, assumptions were made to estimate the available thermal energy from the sewer mains within the Downtown. Prior to detailed design, flow monitors and temperature sensors would need to be installed in the main sewer trunks at the proposed intercept locations to fully quantify values. It may be that flow is not split equally between the two branches, as this study assumes, and heat pumps would need to be reallocated between the plants.

The detailed design process will also involve close coordination with the Region of Peel. This will assist with, among other things, understanding the interaction of the DES with other elements of the wastewater grid, demarcating assets owned and maintained by the Region and the DES owner/operator, and establishing right-of-way agreements and costs for use of the wastewater thermal energy.

5.3.6 PHASE 1A CONSIDERATIONS

One option is to construct a nodal plant for Phase 1A, with other nodal plants built later. If this option is pursued, the first energy centre would be constructed to meet the needs of Phase 1A only, though some capital cost would be allocated for space for Phase 1B equipment. The estimated DES capital cost for Phase 1A is outlined in Table 30.

Table 30: Capital Cost - Phase 1A Only

Low Carbon DES – Phase 1A Class D Preliminary (-25%/+50%)	Phase 1A Buildout Installed Capacity	Phase 1A Buildout Total (2022$)
Heating Plant (includes geothermal)	13.0 MW	$ 10,591,000
Cooling Plant (includes geothermal)	2,000 tons	$ 31,684,000
Energy Transfer Stations	5	$ 3,165,500
Distribution Piping System	770 tm	$ 2,041,000
Total DES Capital Cost		**$ 47,481,500**

There are several limitations on the Phase 1A financial model. The first is that the capital to build a DES is higher than installing low carbon equipment in each of the Phase 1A buildings: the DES costs include all structural and architectural requirements for the construction of a new energy centre. The Phase 1A system would also need piping to connect the buildings, a geo-exchange field, ETSs, and building retrofits. The capital costs for Phase 1A are approximately $47 M (see Table 31).

This is higher than the costs of installing low carbon equipment. Indeed, FVB completed an analysis to determine at a high level what it would cost to reach the GHG emission reduction targets in the CCAP with standalone low carbon equipment in each of the Phase 1A buildings. It was determined that the City buildings would install a combination of heat recovery chillers, air source heat pumps, and electric boilers to provide the majority of the thermal energy, while the Sheridan buildings would likely install a geo-exchange system, leveraging their proximity to Scholar's Green and the adjacent parking lot. In both cases, natural gas boilers and conventional chillers would provide peaking and redundancy.

The difference in capital costs between the BAU Standalone (used in the base analysis) and the 80% Reduction Standalone estimates for the City and Sheridan buildings is shown in Table 31. The estimated capital costs for the low carbon standalone system are approximately $26 M.

Table 31: 80% Reduction Capital Cost Estimate

Capital Cost Estimate	BAU Standalone	80% Reduction Standalone	Incremental $/tonne (1,900 tonne/yr reduction)
Heating Plant	$ 4,397,000	$ 12,975,000	$ 3,668
Cooling Plant	$ 7,643,000	$ 12,563,000	$ 4,405
Total	$ 12,041,000	$ 25,538,000	**$ 8,073**

An updated financial analysis for Phase 1A was completed using the 80% Reduction Standalone scenario avoided costs. The results of this analysis are shown in Table 32. This table shows the expenses and revenue incurred during Phase 1A, as well as the return on investment.

Table 32: Financial Analysis Results - Phase 1A Only

	Financial (Unescalated)		Financial (Escalated)		Reduced GHG vs. 80% Red. @ Full Build-Out (tonnes)
Description	Expenses (k$/yr) 2022	Revenue (k$/yr) 2022	Projected IRR 25 Years (%)	25-Year NPV 3.0% (k$)	
Phase 1A Only (80% Reduction Standalone)	1,142	2,016	3.8%	5,962	-274

Phase 1A does not result in as good of a business case as the larger system buildout. This is in large part due to the increased capital required for a low-carbon solution (i.e., geo-exchange), compared to the avoided cost of capital for the existing equipment. The DES capital cost also takes into account the costs of constructing additional space that would be available for the subsequent installation of equipment as the DES expands. Note that, in this analysis, the GHG reductions from a low carbon standalone solution are slightly higher than the DES, as the DES uses natural gas boilers and generators to achieve significant electricity cost savings under the Class A rate structure.

There are also ways that capital costs could be decreased. For example, the layout of the plant could be adjusted in the detailed design process, possibly reducing the capital cost. In addition, if the Phase 1A plant could be integrated into the plans for the construction of a new building (e.g., at the South Sheridan parking lot), there would be synergies that would reduce capital costs (e.g., building construction, architecture, and site servicing). This would have a positive impact on the Phase 1A business case.

FVB conducted a business case analysis for the City of Toronto with regards to a new DES in the Etobicoke Civic Centre (ECC) Precinct. This analysis modelled the CapEx and OpEx required for individual buildings to meet varying versions and tiers of the Toronto Green Standard instead of using natural gas boilers and electric chillers, and showed the economic competitiveness of a long-term low-carbon DE solution when compared to the cost required for individual buildings to meet the TGS.

An additional economic consideration is that, while the IRR for Phase 1A is low, the flexibility to expand this system to serve near-term growth and future initiatives is high. This will dramatically increase the economic return. The low carbon DES also allows for a significant reduction in GHG emissions from both existing and future buildings.

5.3.7 LOANS AND GRANTS

Another element that will have an impact on the business case is the funding available for the project. There are currently a number of funding sources available to municipalities. These include federal grant programs, Canada Infrastructure Bank (CIB), The Atmospheric Fund (TAF), and the Federation of Canadian Municipalities (FCM), which are providing grants and low-interest loans to fund projects that reduce GHG emissions.

The effect of these loans and grants on the business case is varied depending on the cost of capital and when the funds are injected into the project. Any low-cost capital will, however, improve the business case and aid implementation of the project, so it is recommended that the City of Mississauga continue to pursue funding opportunities. It should also be noted that having the municipality as a partner in the DES allows for a greater number of funding opportunities compared to if the DES was solely owned and operated by a private entity. This is addressed in more detail in Section 7.

Canada Infrastructure Bank

One funding source of particular note is the Canada Infrastructure Bank (CIB). CIB investment allows for the build out of the DES on a larger scale and a more expedited basis. CIB's innovative financing terms take into account the number of new and existing connections to the system over time and can have terms of up to thirty (30) years at a rate as low as 1.0%. They have historically provided significant funding for GHG reductions achieved through DE projects.

FVB ran a scenario that assumed that 43% of Phases 1A, 1B, and 2 are financed by the CIB with terms of thirty (30) years at a rate of 1.0%. The amount of CIB funding that may be available and the terms are unknown at this time, but – based on FVB's experience – these estimates are in line with recent project financing by the CIB. When this scenario is run, the low interest financing increases IRR from 8.3% to 11.5%.

5.3.8 ADDITIONAL OPPORTUNITES, BENEFITS, AND SYNERGIES

There are additional opportunities that the City of Mississauga could leverage to expand and improve the DES.

Snow Melt

A DES, with hot water travelling through buried pipes, provides unique opportunities to melt snow on public sidewalks and in courtyards. The heat from the water returning to the energy centre would be used, requiring minimal energy. This would also improve the DES efficiency, as it would reduce the temperature of the water returning to the energy centre.

Waste Heat Recovery

As the system is built out, there will be more opportunities to leverage sources of waste heat, such as data centres that require cooling year-round. This would increase the amount of simultaneous heating and cooling and the overall efficiency of the DES. One potentially significant source of waste heat in Downtown Mississauga is the Square One Mall. If it undergoes a renovation, it could connect and provide waste heat to the DES.

System Redundancy

A non-financial benefit of a DES is the increased redundancy in heating and cooling. This redundancy comes from the distributed energy centres, a combination of natural gas and electricity (leveraging geothermal or wastewater heat) as fuel sources, and emergency/peak shaving generators installed in most plants.

Scaling

The DES concept outlined in this report is not the end-state of the system. There is significant potential to connect the buildings that are not part of the estimated 50% market penetration. The incentive to connect will increase as DE infrastructure is installed and the system proves its reliability. As heating and cooling equipment in the DES reaches its end-of-life, the old equipment can be replaced with new equipment that has a larger capacity, effectively increasing the DES's capacity with a minimal increase in equipment footprint. Additional energy centres could be constructed in new buildings as needed, or existing buildings could be retrofitted to accommodate an energy centre. Eventually, the system could be expanded outside of the Study Area. The proposed DES could also be connected to other DESs and waste heat sources.

Table 33 outlines some additional benefits and synergies of a DES that are not necessarily captured in a financial model or GHG reduction analysis.

Table 33: Benefits and Synergies of a DES

	To Real Estate Developers, Building Owners, and Residents	To the City / Region
Business Sense & Economic Development	• O&M cost savings, deferred capital costs • Stabilized energy costs • Alternative income stream, waste fuel sources • Architectural opportunities with a free roof for amenity space	• Returns on investment, local economic development • Job creation, risk mitigation • Infrastructure asset • Increase urban densification and planning
Energy Security	• Energy reliability and flexibility • Increases efficiency and conservation • Reduces impact from loss of heating and cooling that can affect productivity • Increases roof top area available for Solar PV electricity generation	• Increases potential for uptake of renewable energy sources • Increases energy security and resilience with local energy production and future proofing • Fuel flexibility • Lower demand on existing gas/electricity infrastructure • Reduced electrical peak demand • Supports micro-grid strategies for backup power
Environmental and Other	• Green image/marketing, environmental stewardship/leadership • Opportunity for green roofs • Increase comfort from hydronic heating and possibly radiant floor heating • Improved air quality + health benefits	• Reduces GHG emissions • Improves air quality • Can reduce water usage in cooling systems • Promotes energy awareness • Potential synergy with storm water reduction strategy • Snowmelt strategies reduce salt usage

Additional Benefits for Developers

DESs provide a number of additional benefits to developers. This is illustrated by Hotel X Toronto, which connected to the Exhibition Place DES (Figure 24[26]). Without the need for cooling towers, the hotel was able to add more amenities to its roof, including a pool, a large athletic facility (with tennis and squash courts), and a cocktail bar. These are all revenue-generating amenities that would not have been possible if the building required a stand-alone boiler / chiller / cooling tower system.

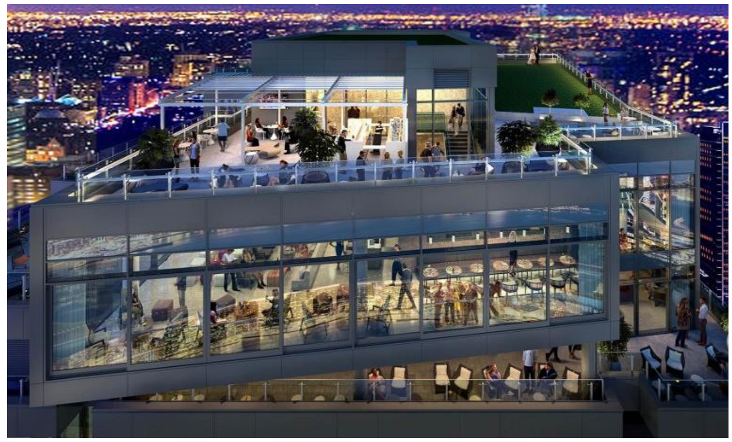


Figure 24: Hotel X Rooftop Amenity Rendering

For residential buildings, the rooftop space still provides benefits even if they are not monetized. This includes a reduction in noise around the building and the potential to add green roofs – which can provide a pleasing visual as well as a reduction in reflective heat radiation and an increase in carbon sequestration.

In Toronto, an incentive allows for a building to repurpose its mechanical penthouse floor area for residential or amenity use without penalty if the building installs a low-carbon thermal energy system. Both The Well – Building C and buildings in Mirvish Village repurposed their mechanical room space into additional residential and amenity space with this incentive. In another project, the applicant is realizing an additional 3,720 m² on a 92,900 m² project of saleable GFA with the City of Toronto's support. Since cooling towers can impede the allowable building height, another floor plate or more for example could be added to the development when cooling towers are removed. This is a major benefit of district energy.

It is recommended that, regardless of the ownership model chosen, the City of Mississauga review its bylaws and zoning to allow developers additional saleable or amenity usable floor area if they do not install boiler/chiller/cooling towers, but connect to a low carbon DES instead.

Interim Energy Centres

Occasionally, temporary or interim energy centres (IEC) are installed to connect the first customers of a system before a permanent energy centre is constructed. Typically IECs are very simply constructed, and are often prefabricated before being transported to site. The intent is that the equipment within the IEC can be eventually re-located to the permanent energy centre and the site on which the IEC is installed can be returned to its original condition with minimal effort. Examples of IECs are shown in Figure 25. While simply constructed, they do not necessarily have to look it – the installation at UBC (left) has wood cladding and the IEC on the right, installed in Oval Village, is covered in colourful artwork.

[26] Source: Stephen Jacobs Group

Figure 25: Interim Energy Centres at UBC (left) and Oval Village (right)

For the City of Mississauga, IECs could be used to start the transition of the City and Sheridan buildings to a DESwhile plans for the permanent energy centre are being finalized. This possibility will be explored in more detail during the detailed design for Phase 1A.

6 ENVIRONMENTAL BENEFITS

6.1 GHG EMISSIONS COMPARISON BETWEEN STANDALONE AND DES

GHG emissions were calculated for BAU Standalone, Low Carbon Standalone, and Low Carbon DES. A comparison of each of the standalone scenarios to the Low Carbon DES is presented in Table 34 and Table 35. The emissions are calculated based on the total cumulative natural gas and electricity consumed in each phase, using the emission factor of 50.1 kg CO_2/GJ (180 kg CO_2/MWh) for natural gas[27] and The Atmospheric Fund (TAF)'s hourly average emission factor (AEF) for electricity, which varies hour-by-hour according to Table 9 but has a daily average of 30.5 kg CO_2/MWh_e.

It should be noted that Table 34 is for illustrative purposes only, comparing the worst-case scenario (where the buildings are not constructed to more aggressive building standards) to the best case scenario (where the buildings are constructed to progressive GDS standards and are connected to the low carbon DES).

Table 34: Annual GHG Emissions of BAU Standalone Compared to Low Carbon DES

Phase	Cumulative BAU Standalone GHG Emissions (tonnes/year)	Cumulative Low Carbon DES GHG Emissions (tonnes/year)	Reduction (tonnes/year)	Reduction (%)
1A	2,980	610	2,370	80%
1B	15,870	4,550	11,320	71%
2	30,620	5,100	25,520	83%
3	38,790	5,500	33,290	86%
4	51,300	6,230	45,070	88%
5	57,590	6,300	51,290	89%
6	65,990	7,750	58,240	88%

Table 35 shows the GHG emissions of a low carbon standalone scenario compared to a low carbon DES, where buildings in both scenarios are constructed to the same standards.

Table 35: Annual GHG Emissions of Low Carbon Standalone Compared to Low Carbon DES

Phase	Cumulative Low Carbon Standalone GHG Emissions (tonnes/year)	Cumulative Low Carbon DES GHG Emissions (tonnes/year)	Reduction (tonnes/year)	Reduction (%)
1A	2,980	610	2,370	80%
1B	15,860	4,550	11,310	71%
2	23,930	5,100	18,830	81%
3	25,350	5,500	19,850	78%
4	27,070	6,230	20,840	77%
5	27,640	6,300	21,340	77%
6	36,030	7,750	28,280	78%

These tables show that a low carbon DES could play an important role in the City meeting its GHG emission reduction targets.

27 Source: National Inventory Report, 2020 Edition.

6.1.1 ALIGNMENT WITH CITY OF MISSISSAUGA GOALS AND TARGETS

The City of Mississauga's Climate Change Action Plan includes a goal of reducing GHG emissions 40% below 1990 levels by 2030 and 80% by 2050. A low carbon DES allows for a significant reduction in GHG emissions corporately and in the community for both existing and future buildings. The electricity-based equipment was chosen to offset as much natural gas use as possible, within the constraints of the available space in the Downtown area and maintaining a positive business case.

In Phase 1A, connecting the three City buildings to the DES reduces their combined emissions by 1,650 tonnes annually.

6.1.2 FUTURE ELECTRICITY GRID EMISSIONS

The Ontario grid is changing every year, with some low carbon generation technologies such as wind and small modular reactors (SMRs) being added and some nuclear facilities being phased out. As the composition of the grid changes, so does the amount of GHGs emitted from the grid. TAF has estimated future average emission factor (AEF) values out to 2040 for the Ontario grid based on current projections for technology implementation and use. According to "A Clearer View on Ontario's Emissions" dated November 2021, TAF expects that there will be an increased reliance on natural gas to produce electricity over the next 20 years, which will gradually increase the AEF (see Table 36 below).

Table 36: AEF Projections from TAF

Average Emission Factors (Daily Average) for Future Grid Electricity from TAF					
Year	g CO_2/kWh$_e$	Year	g CO_2/kWh$_e$	Year	g CO_2/kWh$_e$
2025	87	2030	94	2035	86
2026	82	2031	86	2036	94
2027	88	2032	84	2037	94
2028	81	2033	86	2038	101
2029	86	2034	83	2039	98

Table 37 presents the estimated GHG emissions for the Low Carbon Standalone case and Low Carbon DES case if the AEF for grid electricity increases at the rate currently projected by TAF.

Table 37: GHG Emissions Based on Projected AEFs from TAF

Phase	Cumulative Low Carbon Standalone Future GHG Emissions (tonnes/year)	Cumulative Low Carbon DES Future GHG Emissions (tonnes/year)	Reduction (tonnes/year)	Reduction (%)
1A	3,150	1,000	2,150	68%
1B	16,780	6,880	9,900	59%
2	26,560	10,000	16,560	62%
3	29,030	12,130	16,900	58%
4	32,800	16,770	16,030	49%
5	34,610	18,030	16,580	48%
6	44,310	22,510	21,800	49%

While the reductions are less than with the current electricity grid, the future of Ontario's grid is not set in stone, and there are both pressures and incentives to decrease emissions from electricity generation. Additionally, the DES still allows for GHG reductions compared to the Low Carbon Standalone case through an overall reduction in energy and electricity consumption.

7 DES OWNERSHIP MODELS IN CANADA

DESs in North America and worldwide have used variations of three different ownership models:

1. Public: a public entity like the City maintains ownership
2. Private: a private entity receives a concession or is the outright owner
3. Hybrid: a combination of the above models. Includes joint venture (JV) and split ownership

In Canada, the approximate breakdown of DES ownership is:

- 30% Institutions
- 20% Publicly Owned
- 20% Privately Owned
- 30% Other – Crown/First Nations/Cooperative/Hybrid

Whether it is a public entity, an agency or corporation of a public entity, a Joint Venture (JV), or a private company, **an identified and credible DES owner is essential**. Prospective customers will want to know the DES owner's precise plan for ownership and operating structure, or at least the most likely option, if it is not firmly established at the time marketing activities commence. This is because customers, who will be signing long-term agreements, will need to understand exactly who they can rely on to deliver this essential service.

In considering the suitability of each of the three ownership models, the City should take into account the following factors:

- **Management capacity and DE experience**: is the City willing to allocate internal management staff and is it interested in entering the DE utility business?
- **Risk/Reward**: what is the City's comfort with risk? Or risk aversion?
- **Access to capital or cost of capital**: is there willingness to raise all or any part of the necessary capital? Involvement of private capital tends to be more costly. Public ownership may mean access to government grants and incentives that help to improve the business case and return on investment.

The following table provides a summary of the pros and cons of various ownership models that have been used in Canada. In many cases, DESs have transitioned from a publicly owned or joint venture ownership model to private ownership. Each model has its benefits and challenges.

Table 38: Ownership Model Pros/Cons

	100% Public	Hybrid	100% Private
Pros	• Access to low cost financing • Comfortable with long term agreements, guaranteed ongoing municipal partnership • Access to government grants and incentives • Alignment with other City departments and levels of government	• Combines private DE experience & capital with City advantages, such as access to government grants	• Private sector assumes all risk, is most motivated, minimizes government interference • Create environment for the DES to succeed through experience, available capital, and mitigation of risk • Realize socio-economic and environmental benefits without using City's own limited financial resources
Cons	• Limit on available capital for large infrastructure project • Insufficient management capacity (internal resources) • No DES experience	• JV complexity with resultant demands on management time • Split ownership found to inhibit growth in Windsor example	• DES projects may not meet private return/risk curve without government assistance • Financial return requirements could inhibit motivation to expand or spend maintenance dollars • Private sector objectives for the system may not align with those of the City (e.g., maximizing GHG reductions, providing additional community benefits)

7.1 EFFECTIVENESS AND ABILITY TO SUPPORT SUCCESSFUL IMPLEMENTATION OF THE PROJECT

There are many factors that impact project success. Chief among these is the ownership and operation models employed. Other factors include the ongoing support and motivation of the proponents, engagement of local champions, system control, efficient governance, cost of capital, risk, expertise, marketing, and many other factors. Value will only be generated from the DES if it is built, not just studied. From experience, FVB is well aware that DE implementation is challenging.

In many cases, DESs have transitioned from a publicly owned or joint venture ownership model to private ownership. Often, the municipal component of ownership or operation is exercised through a wholly-owned corporation, which may be a holding company.[28] For example, Markham District Energy is one of several corporations owned by Markham Enterprises, which is wholly owned by the City of Markham. Similarly, Hamilton Community Energy is one of several corporations owned by Hamilton Utilities, which in turn is wholly owned by the City of Hamilton.

While a variety of ownership structures have been utilized across Canada, the majority of large DESs brought into service in the past 30 years in Canada have required 100% municipal ownership. There are several reasons for this, including that municipalities:

- Are not motivated solely by profits, but by other values as well (e.g., decreased air pollution, job creation)

[28] For the purposes of this discussion, the terms "municipal," "City," "District," and "Town" include wholly-owned municipal corporations, agencies, or commissions.

- Have a long-term interest in the health of the community
- Have the ability to encourage or mandate connection of customers
- Have access to capital at relatively low costs
- Have the willingness to take business risks that cannot offer high internal rates of return (IRR)

DES marketing is key to the success of the system, and municipal owners have several key marketing advantages over a private DES owner. This includes the ability to mandate connection on publicly-owned land, mandate connection anywhere in the city through a bylaw, commit to connecting municipally-owned buildings (e.g., Windsor, Sudbury, Markham, Hamilton, Revelstoke, Strathcona County, Calgary), and encourage DE connection during the development approval process (e.g., Markham).

If there is no way that the City could contribute the required equity investment, after all recourse to potential funding sources is exhausted, then the 100% municipal ownership model would not be the most effective way to proceed and alternatives would need to be explored.

If the City wants to involve a partner who could contribute capital and operating expertise, then it can likely negotiate more favourable terms after having accomplished the most important step: assembling heat load (i.e., customers).

There are several examples of hybrid models that have been successful. This model may suit the City's needs, where the City is interested in part ownership to initiate the system and then hold that interest for as long as needed to meet City goals (e.g., local economic development, GHG emission reductions). Many JVs have moved, or are moving, to a single ownership. If a joint venture is pursued, it is recommended that the City has specific voting rights and agreements in place to enable options of selling the system after a certain amount of time or once objectives have been achieved. This allows for some reduction of risk to the City, while enabling the City to focus on its objectives.

For the DES in the Downtown, Phase 1A aims to connect City and Sheridan College buildings. It may, therefore, make sense for the City to take the lead in developing the system, so as to maximize benefits and minimize system costs. However, there is a private DES being developed concurrently in Mississauga and, as such, involving a private DES owner/operator in the development of Phase 1A may allow for additional project synergies.

7.2 CITY OWNERSHIP

If the City decides to own all or part of the DES, it could do so through an existing City corporation or by establishing a new one. Using a municipal corporation allows for more efficiency, as it streamlines the procurement process. In addition, if the City owns the DES directly, this may result in the DES being subject to rules and restrictions that apply to the City's overall operations.

Further, a municipal corporation provides flexibility to raise capital as needed through selling shares (i.e., bringing in a partner). It is generally preferred that there is no cross-subsidization between the DES and other City operations; however, the governance structure must allow the DES manager to access funds to meet obligations during the early years of operation when the net operating revenue of the DES will be weak.

Several DESs that have been developed over the past 30 years have built and operated their systems without private partners or operators. In the case of Markham and Hamilton, local electric distribution utilities were initially involved. This provides the benefits of a utility management structure during development and construction. However, being a minor and therefore relatively low-priority department in a non-DE utility is not preferred over the long term. As a result, Markham and Hamilton split off the DES as separate wholly-owned corporations run by dedicated staff with DE experience.

Table 39: Pros & Cons of Different City Governance Models

	Deliver DE Directly through the City	Create and Deliver DE through a Subsidiary Corporation	Initially Deliver DE Directly with the goal of creating a Subsidiary Corporation
Pros	• Simple to establish and maintain • Minimizes additional human resource planning and staffing • Allows for efficient granting of permits for district energy infrastructure installation based on synergies of City departments. • No additional tax planning considerations • Ability to apply for grants under provincial Grants Statute	• Separate, skills-based Board of Directors with delegated authority over decision making and operations allows for quicker implementation • Can utilize an unanimous shareholder declaration (USD) to remove certain powers from the Board of Directors • Can achieve similar City tax benefits as other municipal organizations • Access to low-cost CIB debt to fund CapEx and growth • Frees up reserves and borrowing capacity to fund other priority projects • Provides flexibility to consider monetization strategies in the future that are available to corporations • If the corporation meets the definition of a government business enterprise (GBE), the City can present the debt off-balance sheet by using the modified equity method	• Speed and simplicity to establish • Minimizes additional human resource planning and staffing • Allows for efficient granting of permits for district energy infrastructure installation based on synergies of City departments. Subsidiary Corporation can be an asset and financing vehicle with all staff and operations retained in the City and delivered to the DE Subsidiary Corporation pursuant to a services agreement • No additional tax planning considerations • No additional financial reporting considerations • Ability to apply for grants under provincial Grants Statute • Can negotiate agreement for low-cost CIB debt to fund CapEx and growth (with the future Subsidiary Corporation as the borrower) • Timelines for setting up and obtaining approvals for the Subsidiary Corporation align with the DE planning and build out
Cons	• Council control over decision making and operations can increase time for implementation. • City retains financial exposure and legal liability regarding contracts and agreements • Potential for perception that taxpayers are subsidizing the DES for the benefit of select users • Requires funding from reserves or direct City borrowings, which puts debt on the City's books	• Takes time, resources, and approvals to establish • Council delegates authority over decision making and operations • Requires additional human resources planning and staffing • More removed from City departments that grant permits for DES infrastructure installation, which can increase application time • Local government corporations are not entitled to apply for or receive grants under the provincial Grants Statute, though still eligible for federal grants	• Takes time, resources, and approvals to establish • Council delegates authority over decision making and operations • Requires additional human resource planning and staffing • Local government corporations are not entitled to apply for or receive grants under the provincial Grants Statute once the subsidiary corporation is created

7.3 COST OF CAPITAL AND RISK

Municipal ownership allows for lower cost of capital but higher risk, primarily due to financial exposure and legal liability from contracts.

Involvement of private capital increases the cost of capital, but mitigates the amount of risk as the private partner may contribute management skills that can help avoid negative outcomes.

The extent of risk reduction is proportional to the percentage of private ownership: as the percentage of private ownership increases, the risk to the City decreases. A 100% private ownership model does not, however, remove all risk from the City; if the DES becomes problematic for any reason, the City may be pressured to own and operate it. The optimal level of private ownership must take into account the cost of capital and other City goals, including how much influence the City wants to have on the direction of the DES and the achievement of social and environmental targets.

If a partner is included, the desired role of the partner should be used to determine the optimal timing of involvement. For example, if the private partner has a high level of expertise in the design and construction of DES facilities, it makes sense to have them participate early to take on some of the construction risk. In contrast, if the private partner is chosen for their DE management skills, it may make sense to involve them later in the development cycle (e.g., after system design).

7.4 RECOMMENDATION FOR OWNERSHIP

There are benefits and drawbacks to each of the three ownership models presented, and there are many factors specific to each individual DES that drive the final recommendation for that system. As part of the Phase 1A detailed design stage, the three models presented should be evaluated in greater quantitative detail in order to make a final recommendation.

8 RECOMMENDED PATHWAY

Next Steps: Critical Success Factors in Advancing DE in the Downtown

The development of a successful DES requires one or more anchor customers to start, and the City and Sheridan buildings provide this opportunity. It is important to keep in mind, however, that coordination with stakeholder groups and rigorous planning will be required to continually and sustainably grow and develop the DES beyond this initial phase. FVB recommends the following next steps:

1. Explore the development of a City of Mississauga standard for new buildings to be 'DE Ready' so that if DES in the Downtown moves forward, connecting the building will be feasible without having to complete a substantial retrofit to the building. This could be incorporated into the refresh of the Green Development Standards (GDS) for the City. (Timeline: Immediate. To be analyzed in conjunction with the refresh of the GDS).
    a. As the DES is implemented and becomes a facet of the Downtown, options that require new buildings with multiple towers or significant thermal demand to connect to the DES should be explored. Alternatively, providing incentives to developers to connect to the DES – such as what is currently being done in the City of Toronto – should be investigated.

2. Further develop the Phase 1A design to further optimize the energy centre, distribution piping, and energy transfer station design, system costs, and coordination between this phase and the other DE phases. (Timeline: In the short term). This would include:
    a. Schematic design of the first energy centre and building connections, along with refined capital costing
    b. Presentation of an updated business case that would evaluate the presented ownership models in greater quantitative detail
    c. The development of a detailed economic comparison report that present the avoided cost of the standalone solution required for the Phase 1A buildings to achieve their 80% GHG reduction target. This economic comparison report could be used to form the basis of Thermal Energy Service Agreements with the three City buildings, Sheridan buildings, and new developments near the proposed Phase 1A energy centre.

3. Develop a detailed drawing of the DE corridor for municipal roads and rights of way so, when new developments are being considered, there is consideration for DES infrastructure(Timeline: In the short term). In addition, this detail could be used for coordinating utility upgrades in areas where there could be synergies to install DE infrastructure to facilitate an existing or future DES.

4. Continue engagement with all relevant stakeholder group(s), including internal stakeholders (e.g., Building, Development & Design, Facilities & Property Management), Downtown landowners, developers, utilities, and other levels of government. Engage and educate the public about DE opportunities in the city and their benefits for GHG emission reductions, reliability, and resiliency (Timeline: Ongoing).

Provided all major stakeholders work together cohesively, there is an opportunity for the City of Mississauga to develop a world class low carbon thermal energy network in the City's Downtown that will make a significant contribution to the City meeting its GHG reduction targets.

The following are recommended resources:

- FVB Energy's Website: www.fvbenergy.com
- United Nations Environment Programme: District Energy In Cities Initiative: www.districtenergyinitiative.org
- International District Energy Association (IDEA): https://www.districtenergy.org/topics/district-heating
- Centre for Community Energy Transformation: https://www.brampton.ca/EN/residents/GrowGreen/Pages/CCET.aspx

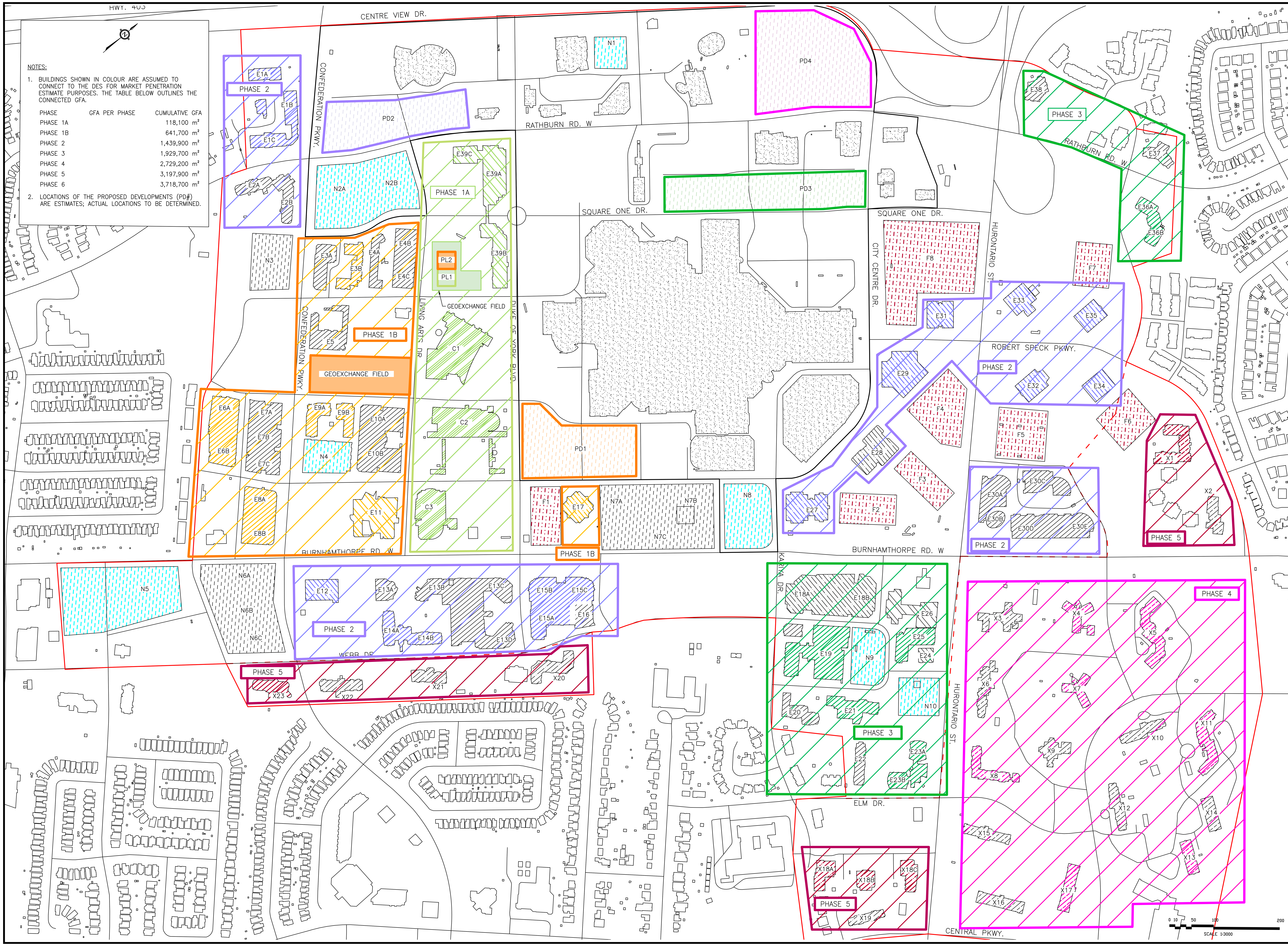
9 APPENDICES

APPENDIX A STUDY AREA OVERVIEW AND PHASING

Drawings are attached at the end of this document and are not included in the document page count.

Drawings List:

1. SK-1244-302: Study Area Overview with Phasing and Market Penetration



NOTES:

1. BUILDINGS SHOWN IN COLOUR ARE ASSUMED TO CONNECT TO THE DES FOR MARKET PENETRATION ESTIMATE PURPOSES. THE TABLE BELOW OUTLINES THE CONNECTED GFA.

PHASE	GFA PER PHASE	CUMULATIVE GFA
PHASE 1A		118,100 m^2
PHASE 1B		641,700 m^2
PHASE 2		1,439,900 m^2
PHASE 3		1,929,700 m^2
PHASE 4		2,729,200 m^2
PHASE 5		3,197,900 m^2
PHASE 6		3,718,700 m^2

2. LOCATIONS OF THE PROPOSED DEVELOPMENTS (PD#) ARE ESTIMATES; ACTUAL LOCATIONS TO BE DETERMINED.

LEGEND

- EXISTING RESIDENTIAL WITHIN MAIN STUDY AREA
- EXISTING RESIDENTIAL WITHIN EXTENDED STUDY AREA
- EXISTING OFFICE WITHIN STUDY AREA
- EXISTING OTHER USE WITHIN STUDY AREA
- EXISTING CITY-OWNED BUILDING
- NEW DEVELOPMENT WITHIN STUDY AREA
- FUTURE DEVELOPMENT OF EXISTING BUILDING
- NO ANTICIPATED DES CONNECTION

- STUDY AREA BOUNDARY
- EXTENDED STUDY AREA BOUNDARY
- SQUARE ONE DISTRICT BOUNDARY

CONNECTION PHASING:

- PHASE 1A (2025) – CITY + SHERIDAN
- PHASE 1B (2028) – EXISTING & PROPOSED
- PHASE 2 (2030) – EXISTING & PROPOSED
- PHASE 3 (2035) – EXISTING & PROPOSED
- PHASE 4 (2040) – EXISTING & PROPOSED
- PHASE 5 (2045) – EXISTING & FUTURE
- PHASE 6 (2050) – NEW

ENERGY CENTRES:

- PL1 PLANT 1 (2025) GEOEXCHANGE
- PL2 PLANT 2 (2028) GEOEXCHANGE

THE LOCATIONS OF PLANT 3 (PL3), PLANT 4 (PL4) AND PLANT 5 (PL5) TO BE DETERMINED THROUGH FURTHER STUDIES AND COORDINATION WITH STAKEHOLDERS.

THIS DRAWING IS A CONCEPT AND DOES NOT REPRESENT FINAL RENDERINGS OF ALL NEW DEVELOPMENTS.

STAMP:

CONCEPTUAL

REVISIONS

DATE	REMARKS	NO.	INIT.
AUG 31/22	ISSUE FOR DRAFT REPORT	D	N.P.
JUN 28/22	ISSUE FOR CLIENT REVIEW	C	N.P.
APR 19/22	ISSUE FOR DRAFT REPORT	B	N.P.
APR 01/22	ISSUE FOR CLIENT REVIEW	A	N.P.

CLIENT:

MISSISSAUGA

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PROJECT TITLE:

MISSISSAUGA DE STUDY

SHEET TITLE:

STUDY AREA OVERVIEW WITH PHASING AND MARKET PENETRATION

DGN: M. BROWN	SCALE: AS SHOWN
DWN: M. BROWN	JOB NO.: 221244
APPR: N. PIDGEON	DATE: SEP 2021

DWG NO.: SK-1244-302