The Corporation of City of Kitchener

Downtown Kitchener District Energy System Technical and Financial Analysis – Public Release

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By:

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EXECUTIVE SUMMARY

District Energy provides an opportunity to address the City of Kitchener's goals related to both the transition off fossil fuels and increasing the community's resilience in the face of a changing climate.

The City of Kitchener is a key partner in the ClimateActionWR collaborative of municipalities and non-profits that developed the TransformWR community climate action strategy. TransformWR is based on transformational change to achieve the community's transition off fossil fuels while simultaneously building a more equitable, prosperous, and resilient community. When endorsing the strategy in 2021, Kitchener Council set a community GHG reduction target of 50% below 2016 levels by 2030, and 80% below 2016 levels by 2050. In light of these significant commitments, District Energy (DE) has been identified as an important potential method of addressing GHG emissions from buildings by improving efficiencies and helping businesses and homes to transition to low carbon sources for heating and cooling.

With buildings estimated to contribute up to 50% of the GHG emissions generated in our communities, planning, designing, and thinking about for how buildings generate energy for space heating, space cooling, and domestic hot water will impact our communities for the lifetime of the building – the building energy systems we build today will determine the emissions for the next 50 years and will be challenged to retrofit or change their energy systems or technology.

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, cities around the world are leveraging DE to help meet their GHG emission reduction targets. In Canada, DE is a key component of the GHG reduction measures of cities across the country. Toronto's climate action plan has a significant emphasis on expanding and improving DE, Markham District Energy is adding 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. The reason for this is that District Energy has the potential to substantially reduce greenhouse gas (GHG) emissions by utilizing large-scale, low carbon energy sources to provide heating and cooling not only to new developments, but to existing buildings that may be extremely challenging to retrofit with a stand-alone low carbon solution.

District Energy is also a critical opportunity to address community resilience, especially as the effects of a changing climate will mean Kitchener is expected to experience warmer, wetter, wilder weather in the years to come, even if ambitious global GHG reduction targets are met. The Community Climate Adaptation Plan for Waterloo Region highlights the importance of improving the resilience of energy infrastructure to weather-related disruption (Objective 13).

A District Energy System (DES) consists of three main components:

(1) a central plant that produces heating and cooling energy;

(2) buried piping infrastructure that distribute the thermal energy (i.e., hot and cold water) to connected buildings; and

(3) and energy transfer station at each building.

A DES has numerous benefits. First and foremost, it is more efficient; thermal energy is produced at a central plant, fully overseen by trained operators, rather than at individual buildings with a variety of monitoring and control practices. DE also provides greater flexibility to the maximum amount of users. It can include a variety of fuel sources (e.g., natural gas, electricity, waste heat, process heat, geothermal) and incorporate more over time as the system expands and technology advances. Since these fuel sources are selected to use local energy sources, the DES can increase energy security, stabilize energy prices, and improve community resilience while keeping energy dollars local. While there are challenges to implementation such as significant upfront capital investment, the clear benefits are some of the reasons why DESs have been installed across the world, from college campuses to military bases to indigenous communities, to bustling downtown cores.

Once a thermal grid (district energy network) has been established, low carbon technologies can be easily integrated at scale at the Energy Centre. A thermal grid creates an opportunity to integrate creative energy sources; for example, utilization of waste heat from data centres, hospital, manufacturing process and building cooling systems as the source energy for heat pumps. This is currently being implemented at Markham District Energy and by Enwave within the Greater Toronto Area (GTA). For buildings, this means that after a one-time connection, the benefits of low-carbon initiatives or efficiency improvements at the Energy Centre are automatically gained without any changes required at the building level. For Kitchener, this means that GHG reductions can happen on a large, coordinated scale that would be extremely difficult to achieve by targeting individual buildings.

DES as a Unique Opportunity in Kitchener

The City of Kitchener has an exciting opportunity to develop a world class low-carbon District Energy System in its downtown core thanks to an ideal combination of anticipated development density and availability of an easily accessible low-carbon source. Kitchener is uniquely situated on an aquifer (separate to the City's drinking water source) that can be used as a renewable energy source for a large portion of the District Energy System's annual heating and cooling energy. This is technically referred to as open-loop geoexchange, this resource is suited to a DES scale solution as there are supply and injection well spacing considerations, interacting effects, and management thermal impacts to consider that make building level solution more challenging.

A district energy system will also provide the downtown core with added resiliency through multiple energy sources including electricity and geothermal heat, with added resiliency from natural gas and back-up on site power generation and the potential for waste heat and new fuels/technologies in the future.

The current proposed densities in the downtown core are sufficient to support a successful DES. However, further growth in the area is possible which would further increase the profitability and GHG emissions in the area. The Ontario government has introduced legislation targeting to build 1.5 million homes by 2031 across the province and increasing the amount of residences served by a DES within the same geographical area only makes the business case stronger. This has happened in other cities throughout Ontario and B.C, and FVB has witnessed this firsthand in Markham, where both density and development expectations have been surpassed, increasing district energy revenue.

Study Purpose

The purpose of this study is to further the work completed in the 2020 district energy pre-feasibility study. Based on new information received and further investigation into available fuel sources, this study provides a more detailed assessment and implementation plan of district energy from a technical and financial perspective in the City of Kitchener. The ownership and marketing aspects of the district energy system are still to be determined.

DES Concept Scenario - Full Buildout Scenario Public + Private Buildings/Development - Financial Analysis, Expected Costs, and GHG Reductions:

This feasibility study identified ~15,000,000 ft² of proposed development in the Kitchener downtown anchored by ~5,000,000 ft² of development of publicly owned lands. This represents three times the anticipated growth in the downtown core compared to the 2020 study, and a DES buildout that is two times the size identified in the 2020 study, resulting in greater GHG reduction potential, increase capital outlay and more infrastructure development. The DES is estimated to have a total heating and cooling demand of ~36 MW of heating and ~40 MW of cooling.

The Bramm Works site was selected as the preferred location for an energy centre for the DES. The geotechnical analysis indicated 15 open loop well pairs with a potential of 15 MW of heating capacity. The DES concept proposed focuses on leveraging the open loop geoexchange potential in Kitchener to provide a large-scale low carbon heating and cooling to a greater number of buildings in a strategic phased plan. This will bring low carbon heating and cooling to more buildings than can be achieved by individual solutions, and provides the flexibility to keep the system up-to-date with changes in energy systems over time. To realize this, a second energy centre is proposed to be incorporated at the northeast end of the system toward the Civic District at a later phase. This strategy will reduce capital cost deployment related to the building out of the energy centre and minimizes the interconnection piping and manifolds related to the open loop wells.

While the financial findings of the study are commercially confidential, the study found that a significant capital investment over thirty years would be required to build the DES. Positive financial return metrics were found and a build out indicates excellent potential for the development of a DES for Kitchener.

> ***Net Present Value (NPV)*** *is the difference between the cash inflows and cash outflows over the project lifetime shown in today's dollars. A positive NPV means that there is a return on the investment. The* ***Internal Rate of Return (IRR)*** *is the annual return anticipated on the initial investment.*

The high-level financial findings do not include any grant/funding which will improve the financial proforma. The environmental benefit of a DES in Kitchener will result in ~26,500 tonnes of reduced emissions annually at full system buildout. The return on equity improves somewhat when a 80%/20% debt equity mix is considered.

The business case for DE assumes the cost of carbon begins at $50/tonne in 2022 increases by $15/tonne per year until 2030 ($170/tonne) and then increases by the Carbon Cost escalation rate of 5% each year after 2030. This analysis is done purely for the calculation of projected revenue, and does not take into account the social cost of carbon (SCC). The current SCC is estimated at $261/ton[1] which represents the economic damage avoided for every tonne of GHG emissions avoided.

> *The* ***social cost of carbon*** *is a measure of the incremental additional damages that are expected from a small increase in GHG emissions or, conversely, the avoided damages from a decrease in GHG emissions. For more information, please visit the link included in the footnote.*

[1] Social cost of greenhouse gas emissions, Government of Canada, Accessed May 2023. https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/social-cost-ghg.html

Based on the current SCC, implementing a low carbon DE has a community benefit of ~$690,000 per year in Phase 1 increasing to ~$6,910,000/year in Phase 5 with a total 30 year projection of $121,000,000 of averted damage to the economy compared to the Baseline scenario.

Ownership Models

There are several different ownership and operation structures for a DES, each with their pros and cons. Three were examined in the pre-feasibility study and are to be further evaluated by the City of Kitchener in terms of their role in the development of DE in Kitchener:

1. 100% municipal ownership by either Kitchener Utilities (KU) or the City of Kitchener
2. A joint venture model between the municipality/KU and a private partner(s)
3. 100% private ownership

The district energy landscape is evolving based on the drive to reduce greenhouse gas emissions quickly and to achieve net-zero emissions by 2050. There are more creative business structures being implemented in the market. Public private partnerships and energy concession agreements are being executed across North America which are contributing to the development and success of district energy systems. Kitchener already has strong local municipal, regional, and utility partnerships which is an exceptional benefit to the development of a new DES.

Next Steps: Critical Success Factors in Advancing DE in the City of Kitchener

FVB recommends the following next steps:

1. **Define the ownership model** and business case, including confirmation of KU/City's role in the DES based on the information known today, and if the preference supports public, private, or hybrid ownership. As part of this, it will be important to understand the funding and grant options available for each model.
2. **Refine the DE concept through detailed schematic design** to improve the capital cost estimates and the connections to the anchor customers.
3. **Develop a draft rate structure** that will be used to obtain anchor/public customer commitments through memorandums of understanding (MOU).
4. **Develop a 'DE Ready'** building standard and a **'DE Corridor'** right-of-way (ROW) standard so that City buildings and infrastructure can easily integrate a District Energy System.
5. **Proceed with developing a dedicated energy centre at the Bramm Works Site** to simplify construction and coordination of surrounding developments. This energy centre will be the anchor of the low carbon DES.

In addition to these next steps, it will be equally important to continue to market District Energy and to work continually to engage all stakeholders in this exciting project.

There should be significant emphasis on the fact that the City of Kitchener has a unique opportunity for a low carbon District Energy System due to the large aquifer that can be leveraged as an energy source. Stakeholders should be identified early and be involved continuously through tours, workshops, and shared experiences, to develop the community of knowledge on energy system transformation. A clear message to the community about the benefits of District Energy and why the City of Kitchener is choosing to pursue it should be developed.

The most significant factor in a successful DES is people. Having strong alignment and drive throughout all internal stakeholders that DE is an important initiative to address climate change and build resilience.

Communication with external stakeholders should be consistent and considerate. A "champion" for DE that can lead the effort and drive decision making can be a huge asset. Engagement with all stakeholders should be early, often, and continuous, and communication must continue even after the first customers are connected.

Education is a large barrier to the uptake of District Energy. Its history, application, utility structure, resiliency standards, etc. are generally unknown to the communities where it would be the most beneficial. With strong partners and stakeholders such as the University of Waterloo and Conestoga College, there is an important opportunity to incorporate a District Energy education component to the first Energy Centre slated for the Bramm site. The proximity of this site to the downtown and civic campuses makes it an ideal opportunity to increase the value of the DES to the community above and beyond the numerous concrete benefits.

The financial results of the DES study are promising for the public sector and potential private partners. Based on the results of this study, FVB recommends that Kitchener move forward with detailed schematic design of the first phase of the district energy system and confirm the ownership structure and complete the test well drill program. The support of district energy by the City and Region through policy, planning, education, and alignment of climate action objectives, along with the completed technical test well drill program and commitment by public anchor customer buildings to connect to the DES will position the City of Kitchener and all potential partners to either develop a new utility business and/or partner with a DES developer.

Business Sense and Economic Development

To Developers, Owners, and Residents:

- Operational and maintenance cost savings
- Stability of energy costs
- Free roof for amenity spaces

To the City, Region, and Community:

- Local economic development
- Creation of long-term, secure employment opportunities Benefits urban densification

Energy Security and Resiliency

To Developers, Owners, and Residents:

- Energy reliability and flexibility
- Less heating and cooling system down-time
- Increased roof top area for solar panels
- Adaptable for unknown future fuels & technologies

To the City, Region, and Community:

- Increased potential for use of renewable sources
- Local energy production
- Lower demand on gas and electricity infrastructure

Sustainability

To Developers, Owners, and Residents:

- Improved air quality and health benefits
- Sustainable image and marketing
- Increased comfort from hydronic heating
- Continuous improvements at the Energy Centre benefit all connected buildings immediately

To the City, Region, and Community:

- Decarbonization pathway for both new and existing buildings
- Reduction of water usage
- Potential synergies with snow melt, storm water

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ACRONYMS

ASHP	Air Source Heat Pump
BAU	Business-As-Usual
COP	Coefficient of Performance
DCS	District Cooling Supply
DCR	District Cooling Return
DE	District Energy
DES	District Energy System
DHS	District Heating Supply
DHR	District Heating Return
DHW	Domestic Hot Water
DPS	Distribution Piping System
ETS	Energy Transfer Station
FVB	FVB Energy Inc.
GFA	Gross Floor Area
GHG	Greenhouse Gas
GHGI	GHG Intensity
GSHP	Ground Source Heat Pump
HEX/HX	Heat Exchanger
HOEP	Hourly Ontario Energy Price
HVAC	Heating, Ventilation, and Air Conditioning
IRR	Internal Rate of Return
KU	Kitchener Utilities
kWt	kilowatt (thermal) – a unit of energy, equivalent to 1 joule per second
kWht	Kilowatt-hour (thermal) – the total energy of using 1 kWt over the course of an hour
LDC	Load Duration Curve
LRT	Light Rail Transit
MWt	Megawatt (thermal) – equivalent to 1,000 kWt
MWht	Megawatt-hour (thermal) – equivalent to 1,000 kWht
NG	Natural Gas
NPV	Net Present Value
OAT	Outdoor Ambient Temperature
ROW	Right-of-Way
SCC	Social Cost of Carbon
SHR	Sewer Heat Recovery
TEDI	Thermal Energy Demand Intensity
TEUI	Total Energy Usage Intensity
WACC	Weighted Average Cost of Capital
WSHP	Water Source Heat Pump

LEXICON

4-Pipe District Energy System (DES): A 4-pipe DES consists of hot water supply/return pipes and chilled water supply/return pipes. Buildings are connected to the distribution network with an ETS consisting of heat exchangers and control valves. Hot water is generally supplied at 85-90°C while chilled water is supplied at 4.5°C.

Ambient DES: An ambient DES consists of supply and return pipes circulating water at an ambient temperature. Buildings are connected to the distribution network via heat pumps that either draw heat from or reject heat to the ambient loop to provide heating and cooling to the building respectively.

Annual Energy: Refers to the total amount of heating and cooling that a building requires over the course of one year, and is measured in kilowatt-hours (kWh) or megawatt-hours (MWh).

Baseline Scenario: For the purposes of this feasibility study, the baseline scenario is where new buildings constructed during the study period are designed to meet current building energy codes and standards and no more. They would implement individual, conventional heating and cooling generation systems. This scenario is used to outline the worst-case scenario from a GHG emission perspective.

Business-As-Usual (BAU) Scenario: For the purposes of this feasibility study, the BAU Scenario is where new buildings are constructed to progressive green development standards, and would implement individual heating and cooling generation systems that would become progressively more sustainable. This scenario is used to determine the potential revenue of the District Energy System through avoided costs to the potential customers.

Diversification Factor: Represents the relationship between the simple summation of the peak demand of the connected buildings and the actual peak demand seen at the Energy Centre. As buildings with different use types, occupancies, and geographical orientations will not necessarily experience their peak demand at the exact same time, the system demand is generally lower than adding the peaks of each building together.

Internal Rate of Return (IRR): this is the annual return anticipated on the initial investment.

N+1 Redundancy: If a system has N+1 redundancy, this means that the system can still provide 100% of the required demand even if the largest piece of equipment is unavailable for use.

Building or System **Temperature Differential (ΔT)**: A building's ΔT refers to the temperature difference between the water being supplied from the ETS and the water being returned to the ETS after it has served the building's hydronic systems. The smaller the ΔT, the larger the amount of flow required to transfer the same amount of energy.

Net Present Value (NPV): this is the difference between the cash inflows and cash outflows over the project lifetime shown in today's dollars. A positive NPV means that there is a return on the investment.

Peak Demand: Refers to the highest amount of instantaneous heating or cooling that a building requires over the course of one year, and is measured in kilowatts (kW) or megawatts (MW).

Social Cost of Carbon: This is a measure of the incremental additional damages that are expected from a small increase in GHG emissions or, conversely, the avoided damages from a decrease in GHG emissions. For more information, please visit the link included in the footnote.

1 INTRODUCTION

Building on the District Energy System prefeasibility study completed in 2020, FVB Energy was tasked to review the technical and financial business case for District Energy (DE) in downtown Kitchener to address climate change by improving energy efficiency and incorporating renewable and/or low carbon technologies.

1.1 DISTRICT ENERGY IN KITCHENER

District Energy (DE) provides a path for large scale action on climate change by addressing thermal energy usage in buildings which represents approximately 45% of GHG emissions produced in Waterloo Region. There is compelling evidence nationally and internationally that the implementation of District Energy in communities can be profitable and sustainable. The development of District Energy Systems (DES) globally has been proven to increase the use of localized renewable and waste energy sources, helping communities around the world increase their resiliency, reliability, and energy efficiency in a sustainable manner. Within Ontario, cities such as Toronto and Markham are relying on district energy to achieve their net zero targets.

There is a unique opportunity to develop a low carbon District Energy System in Kitchener. The City of Kitchener is located above a large aquifer that could be leveraged for reliable, low carbon heating and cooling year-round. Paired with the future development that is anticipated for the downtown core, implementing a DES would allow new buildings to achieve GHG reductions, while also providing a pathway for existing buildings to benefit from low carbon energy in a way they would not be able to at an individual level. Especially implementing open loop geo-exchange energy source, there are spacing, aquifer impact, and interaction considerations that may be impossible on a building scale and requires planning and coordination on a community scale.

This feasibility study will provide an overview of the proposed DE concept in order to evaluate the business case and environmental impact of establishing a DES within the City of Kitchener. This will include the development of the estimated demand and energy requirements of the system and the phasing and implementation of open loop geoexchange, distribution piping, and energy transfer stations. Once the business case is established, sensitivity analyses and risk mitigation strategies will be outlined to fully inform stakeholders about the feasibility of implementation of District Energy.

1.2 ACKNOWLEDGEMENT

The information in this report is based on information and assistance provided by multiple project stakeholders, including City of Kitchener, Kitchener Utilities, the Region of Waterloo, the University of Waterloo, Waterloo Region Community Energy (WREC), Grand River Energy (GRE), and Enova.

FVB and the City of Kitchener would also like to thank the Federation of Canadian Municipalities (FCM) for supporting this feasibility study.

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 4).
- **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 5).

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+)

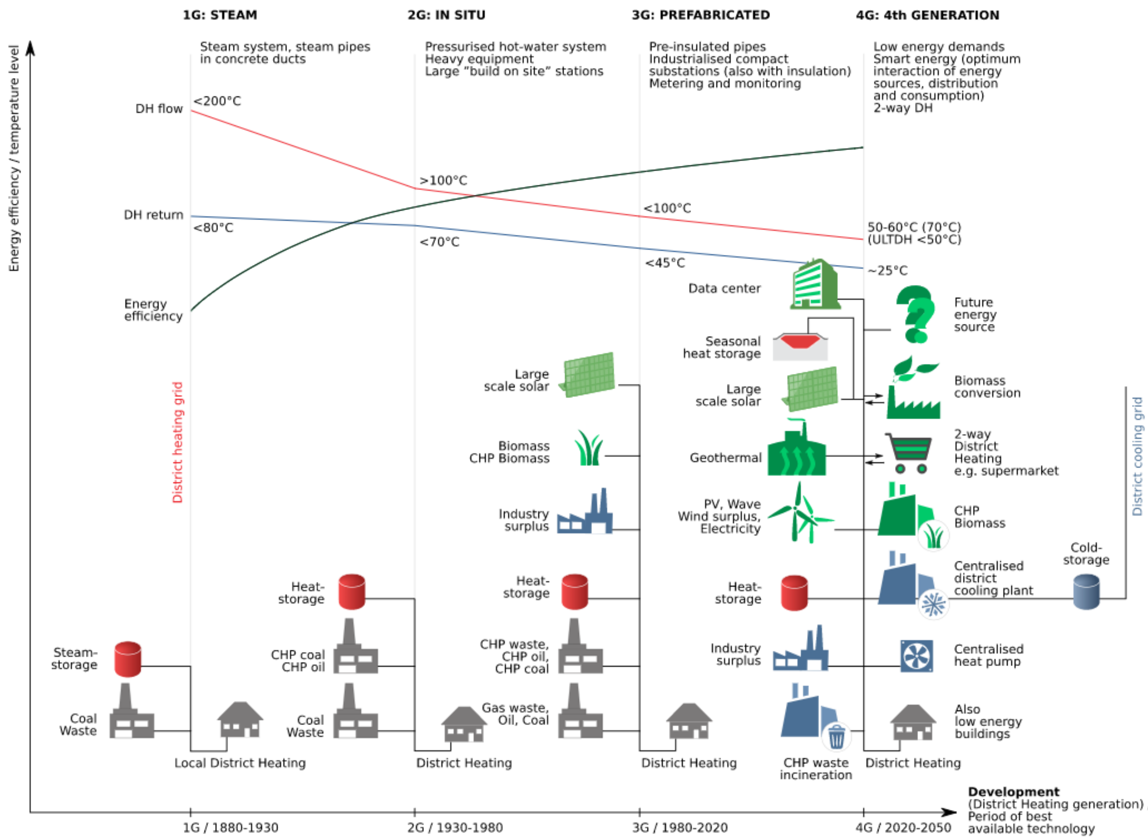

Figure 2: District Energy Evolution[2]

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[3]. 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 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.

[2] Image Source: www.4dh.dk

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

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.

Once a building has been connected to the DES through a one-time connection process, it benefits from all of the above factors while also immediately benefiting from any low carbon initiatives or efficiency improvements implemented at the Energy Centre without any changes required to the building's systems.

Energy Centres can be constructed as stand-alone buildings, or integrated into buildings with other uses. Some Energy Centres can even be integrated into high-rise multi-unit residential buildings. Figure **3** shows some examples of Energy Centres that are currently operational. The Energy Centre at UBC () was constructed to be both visually integrated into the campus, and to educate the community as they pass by. The Bur Oak Energy Centre owned by Markham District Energy (centre) is part of the same building complex that houses a community centre and an above ground parking garage. The Energy Centre at Regent Park (right) cannot be seen from the outside of the building as it is integrated seamlessly into the basement.

Figure 3: Examples of Stand-Alone and Integrated Energy Centres[4]

Figure 4 shows a four-pipe distribution system for hot and chilled water installed in the GTA. Figure 5 shows one of the heat exchangers that forms an ETS located within a building connected to a DES.

[4] Image Sources: The University of British Columbia (left), Google Street View (centre),

Figure 4: Example of a Distribution Piping System

Figure 5: Typical ETS Installation[5]

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.

[5] Image Sources: FVB Energy Inc.

2 REFINED TECHNICAL DESIGN CONCEPT

2.1 STUDY AREA

The study area, shaded in in orange is generally along the King/Charles Street corridor bounded by Weber/Otto Street to the North and the CN Rail line and Victoria Park to the south

The study area is larger than initial District Energy Prefeasibility Study (January 2020) and was chosen to include a large number City/Regional owned lands, especially around the civic district, and forecasted high density development areas. The number of potential customer increased from ~10 to 20 buildings with total forecast development gross square footage approximately three times more than the 2020 study – this was largely due to the increased engagement of the City of Kitchener planning department who are aware of all development submissions and progress.

The DES originally considered the Multi-Modal Hub as the preferred energy centre location but after discussions with the Region it was indicated that the timing and complexity of objectives for the transit hub would not be favorable for housing the district energy centre. With input by the geotechnical consultant, Salas O'Brien, on the technical constraints of the open loop supply and return injection wells and site space requirement, as well as input by the working advisory group, the Bramm Works site was determined to be the preferred energy centre location.

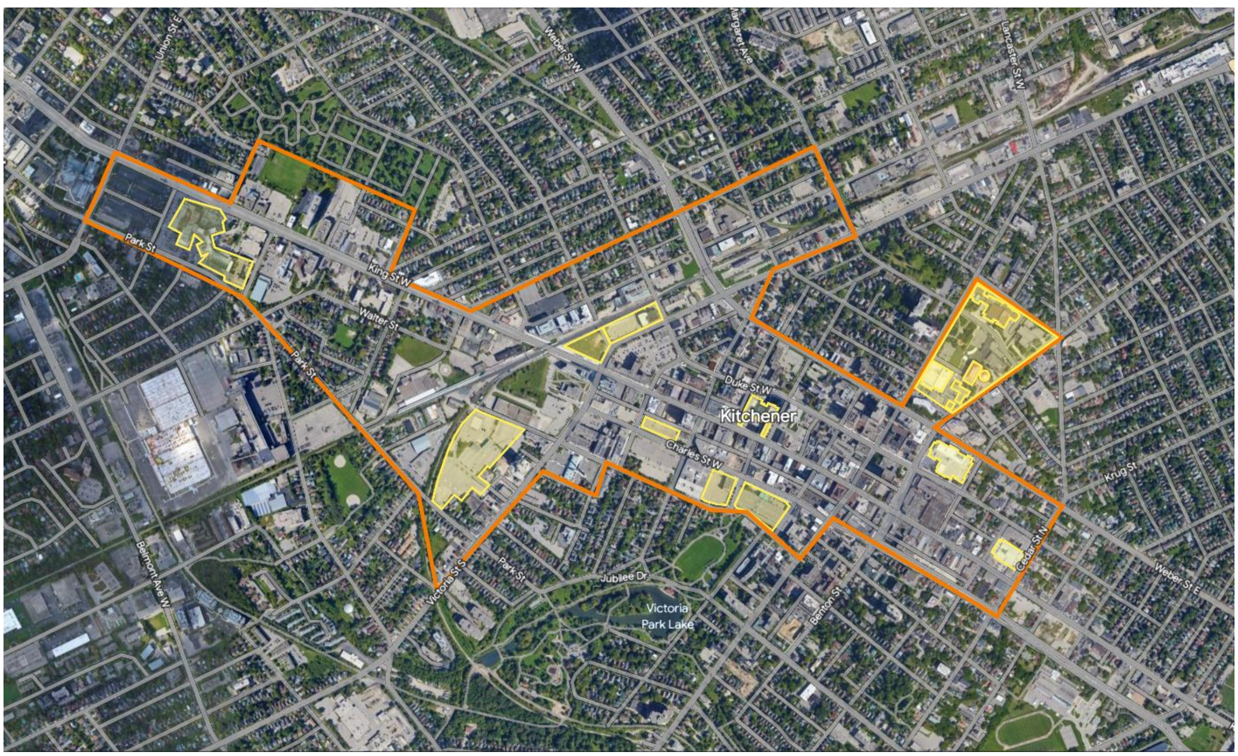

Figure 6: Kitchener District Energy Study Area (Public land is indicated in YELLOW)

In this study area, both existing buildings and new developments were considered for their potential to connect to the new DES. The buildings under consideration are shown in Figure 7, referenced in Table 1. The buildings with coloured outlines were identified as potential customers for the new DES. Hatched buildings represent those that are publicly owned. A full overview map is included in Appendix C.

Figure 7: Overview of Study Area Buildings

Table 1: Overview of Study Area Buildings

Constructed Before 2025		Constructed Before 2034		Construction Date Unknown	
N6	**130 Weber to 175 Wellington**	**N2**	**Google Breithaupt Phase 3**	N1	77 Wellington
N11	**130-142 Victoria S.**	**N3**	**Multi-Modal Hub**	N4	282 Duke to 123 Breithaupt
N12	**Park/Victoria Towers**	**N9**	**Bramm Works Yards**	**N5**	**84 Victoria Cake Box**
N17	**22-26 Charles**	**N10**	**417 King Ziggy's Cycle**	**N7**	**63 Victoria N.**
N18	**1 Charles to 108 Queen S.**	**N15**	**44 Gaukel**	N8	85 Weber to 66 College
N19	**16-20 Queen N.**	**N16**	**15 Charles (Terminal)**	**N13**	**184-200 Victoria S.**
N20	**10 Duke W.**	**N21**	**170 Otto**	**N14**	**54 Water Manulife Lot**
				N22	**115 Benton**
				N23	**39 Church to 73 Benton**
				N24	**Halls and Francis Lot 3**
City/Region Buildings		**Existing Buildings**		**Buildings of Note**	
C2	City Hall	**X1**	**Station Park**	U1	Airboss Rubber Compounding
C3	Theatre	X2	Google Breithaupt Phase 1	U2	Kitchener Waterloo Collegiate
C4	Kitchener Public Library	X3	Google Breithaupt Phase 2	U3	King Edward Public School
C5	Centre in the Square	X4	School of Pharmacy	U4	McMaster U Regional Campus
C6	Kitchener Market	X5	UW Innovation Lab	U5	1 Victoria St S Condo
U10	Ontario Court of Justice	X6	One Hundred Victoria	U6	The Kaufman Lofts
U11	Waterloo Police Central Division	X7	Garment St. Condos	U7	Tannery Event Centre
U12	Region of Waterloo	X8	Glove Box	U8	Manulife Bank
Europro Buildings		X9	195 Joseph Office	U9	Market Square Shopping Centre
E1	Oracle	X10	Cake Box	U13	Enova
E2	50 Queen N.	X11	30 Water N.	U14	Grand River Hospital
E3	22 Frederick	**X12**	**30 Francis**		
E4	The Galleria	**X13**	**305 King W.**		
E5	235 King E.				

2.1.1 SHORTLISTED DES CUSTOMERS & DEVELOPMENT PHASING BUILDOUT

As part of this feasibility study, a subsection of buildings were identified as proposed target customers for a potential DES system in Kitchener. Customers were targeted based on:

- Building / land ownership by City or Regional entity.
- Building size/development >18,500 m² (200,000 ft²)
- City staff comments on likelihood of develops to proceed
- Proximity to energy centre and proposed pipe routing
- New builds are preferred for the shortlist compared to existing buildings due to unknown timing of HVAC replacement, increase cost for retrofit and compatibility with low temperature heating systems

Approximately 1.2 million square meters (12.5 million square feet) of development was identified in the downtown core with the greatest potential to connect to a new DES system. In absence of concrete information on when buildings would be constructed, the system development was assumed to be built out in 5 Phases over the next 25 years starting in 2025 through to 2045. The business case should be adjusted as more data becomes on the timing of developments available through planning or site plan approval submissions.

The developments that were shortlisted for DES connections are shown in Table 2, organized by anticipated connection phase. Once the system is built out, it is recommended that there is ongoing engagement with existing City and Region buildings such that when it is time to replace their mechanical systems, a connection to the DES is considered as an alternative. These potential future customers are not included in the shortlist for this feasibility study as there are greater uncertainties and challenges as to when these buildings would connect to the DES.

The City and Region had identified a number of buildings within the study area:

- City Hall, Kitchener Theatre, Public Library, Centre in the Square, and Kitchener Market
- Kitchen Wilmot Hydro was also identified; it is outside of the study area and ~1.0 km from downtown area
- Region of Waterloo: Courthouse, Museum Wing, Residential Housing 119 College, Residential Housing 74 Church, Waterloo Police Central Division, 150 Frederick

Generally the majority of the City and Regional buildings identified were excluded because they were relatively small < 200,000 m² and/or identified as having a anticipated remaining life between 7-20 years remaining with the exception of City Hall, with planned HVAC replacement in 2025 which was included in the study.

Table 2: Downtown Kitchener DES Target Customers, Phasing, and GFA

Downtown Kitchener DES: Target Customers				Estimated GFA (m²)				
Phase	Connection Year	No. of Buildings	Type	Residential	Office	Retail	Other	Total
1	2025	5	New & Existing	83,400	34,100	500	0	**118,100**
2	2030	6	New	157,000	64,100	29,700	29,700	**255,200**
3	2035	6	New	136,300	80,200	4,200	0	**220,700**
4	2040	7	New	174,800	147,600	3,100	8,000	**320,500**
5	2045	6	New & Existing	269,300	20,800	8,100	19,200	**322,000**
							TOTAL Phase 1+2+3+4+5	**1,236,500**

2.1.2 DISTRICT ENERGY SYSTEM PHASING

For the development of the DES and financial model, the buildings to be connected were divided into five (5) phases, each spanning five years. All phases of the DES are interconnected. A map showing the overview of the phasing and distribution pipe is included in Appendix C.

Phase 1

Phase 1 includes the three new developments and two existing buildings, including City Hall, that has planned major HVAC upgrades in 2025. The connection of City Hall to the DES will demonstrate the City's investment and trust in the DES and will serve as a flagship customer when marketing DES to future buildings.

Phase 2 to 5

Phases 2 to 5 will connect the surrounding existing buildings and new developments. Each phase is divided roughly based on when the new buildings are planned on being constructed, with consideration for the geographic locations of the existing buildings to optimize piping infrastructure.

Market Penetration

Even though the buildings shortlisted for connection were extensively narrowed down from the total available customer base, there is still a risk that not all of the shortlisted buildings will connect to the DES. To account for this risk, a market penetration factor has been assumed for each phase. For the purposes of this study, the market penetration factor is assumed to be ~80% of the buildings/developments GFA identified in Table 2. The exception to this is the new developments on publicly owned lands; it is assumed that 100% of those customers would connect to the DES. In Phases 1-5, of 30 probable developments/buildings, the business case assumes 25/30 will be connected. This could be because some developments may not be built and some may choose not to connect, but there may be other developments not identified that may move forward or additional existing customers that may connect, refer to Section 2.1.3.

Table 3 shows an overview of the phasing buildout after the market penetration assumptions have been applied.

Table 3: Phasing Summary

Phasing Summary	Units	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Connection Year		2025	2030	2035	2040	2045
Buildings Connected	#	4	5	6	5	5
Connected GFA by Phase	m²	91,039	232,461	297,531	189,947	257,936
Cumulative GFA	m²	91,039	323,500	515,122	810,978	1,068,914

2.1.3 FUTURE CONNECTION POTENTIAL

Study Area Buildings

There are new developments that are being designed and constructed at the time of this study (2023) whose heating and cooling equipment will have reached their end of life in 25-30 years. This will provide an opportunity to connect these buildings to the DES rather than replacing the stand-alone equipment. Retrofits will be required for these buildings, but the DES will be well established and will allow for a resilient, competitive option for these buildings. Additional existing buildings may also be included as the system progresses if there is significant interest from the building ownership.

There are a significant number of buildings within the study area (approximately ~10 million square feet) that were excluded from the feasibility study due to the age of their existing equipment, size, hydronic system compatibility with DES, and/or they were identified as low potential for connection or development. These buildings can be approached by the DES entity as potential customers once the ownership and thermal energy services offered is determined to further increase the update of DES in the downtown core. (See Appendix A)

Grand River Hospital

To be conservative the hospital was not included in the initial business case of the DES. The Grand River Hospital is located approximately ~1.3 km from the Bramm Site, where the first district energy centre would be located. The City of Kitchener and FVB Energy met with hospital facilities staff in December 2022. At this meeting, it was conveyed that the hospital recently upgraded the existing steam plant and cooling plant. However the hospital was generally converted to a hot water based hydronic heating system, which bodes well for a hot water district energy connection in the future. Thus, connecting to a future low carbon thermal energy network in downtown Kitchener could be possible in the near future, when the heating and cooling assets near the end of the service life, or earlier if there are GHG reduction goals implemented by the hospital.

The hospital's approximate gross floor area is 662,500 ft^2 . The estimated heating and cooling demand is between 11-16 MW for heating and 1,300-2,500 tons for cooling. These loads could represent over 40% of the system capacity at full build-out.

Hospitals are considered to be excellent customers to connect to a District Energy System for a variety of reasons. First, as they generally require cooling year-round, they can provide a good source of waste heat for optimizing extremely efficient simultaneous heating and cooling systems. They also consume a significant and consistent amount of energy which is ideal from a revenue projection perspective for the DE provider.

From the hospital's perspective, they are also usually very interested in connecting to a DES as it allows them to outsource the most challenging aspects of their building mechanical systems while increasing reliability and resiliency. Hospitals throughout Canada and North America have connected to District Energy Systems, including Markham Stouffville Hospital and University Healthcare Network in Toronto.

Continued coordination and communication with the Grand River Hospital will be essential in order to connect them as a future DES customer. Grand River Hospital should be invited to participate in the external DES stakeholder engagement groups during the development of the low carbon DES in Downtown Kitchener.

University of Waterloo

The University of Waterloo has a newly built Innovation Arena, as well as the existing Pharmacy Building (2007) and Integrated Health Building (2008). These buildings are very close to the Bramm Energy Centre, but would require coordination with the University of Waterloo to connect to the DES. As the buildings have a different load profile and use than the other buildings in the system, they could provide good load diversity to take further advantage of low carbon technology base loading.

2.2 DEMAND ENERGY PROFILES

2.2.1 OVERVIEW

Once the target customer buildings are determined, the DES system energy profiles are calculated. Based on the study area location, building ages and use types, and municipal/regional development plans for current and future building standards, the thermal **peak demand** and **annual energy** requirements are analyzed.

> *The **peak demand** refers to the highest amount of instantaneous heating or cooling that a building requires over the course of one year, and is measured in kilowatts (kW) or megawatts (MW). The **annual energy** refers to the total amount of heating and cooling that a building requires over the course of one year, and is measured in kilowatt-hours (kWh) or megawatt-hours (MWh).*

Due to the large number of buildings and development forecast, 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 for peak demand and kWh/m² for annual energy respectively) for each existing building type in the study area. These values are adjusted to account for future building standards when considering the demand and energy profiles of buildings that have yet to be constructed.

For this feasibility study, the thermal demand and energy profiles for each building were developed assuming the implementation of a green building standard in the City of Kitchener. It was assumed this standard would be similar to the Toronto Green Standard (TGS) in that it would implement phased in net zero frame work with decreasing Total Energy Use Intensity (TEUI) and Thermal Energy Demand Intensity (TEDI) targets. The standards would also define progressive maximum building GHGI (GHG Intensity factors). It was assumed that the implementation of these green development standards would be slightly delayed from the City of Toronto, but the TEUI, TEDI, and GHGI targets would be comparable.

The green development standards are estimated to be as follows:

- Phase 1 (2025-2029) will be based on current “Baseline” performance standards.
- Phase 2 (2030-2034) will be based on building performance requirements comparable to TGSv4 Tier 1.
- Phase 3 (2035-2040) will be based on building performance requirements comparable to TGSv4 Tier 2.
- Phases 4 and 5 (2035-2049) will be based on building performance requirements comparable to TGSv4 Tier 3.

All new public, City, and Regional Buildings as welll as Development sites, regardless of phase, are assumed to be constructed to a net zero standard comparable to TGSv4 Tier 3. Existing buildings would perform as per BAU/baseline until any deep retrofits and building envelope improvements are completed.

Table 4 shows the estimated peak demand and annual energy densities assumed by Tier for each building type. Based on the demand and energy targets, we see a decreasing demand and energy use related to heating and an increase in cooling demand and energy from Tier 1 to Tier 3.

Table 4: Demand and Energy Targets by Toronto Green Standard (TGS) version 4 (v4) Tier

Demand and Energy Targets	Baseline		TGSv4 Tier 1		TGSv4 Tier 2		TGSv4 Tier 3		All Tiers
Demand Targets (W/m²)	**Heating**	**Cooling**	**Heating**	**Cooling**	**Heating**	**Cooling**	**Heating**	**Cooling**	**DHW**
Residential (>90%)	50	35	45	30	43	35	41	39	10
Retail	70	60	60	70	50	65	40	60	3.5
Office	60	60	45	50	35	55	31	60	3.5
Civic	65	50	55	55	45	50	31	60	3.5
Energy Targets (kWh/m²)	**Heating**	**Cooling**	**Heating**	**Cooling**	**Heating**	**Cooling**	**Heating**	**Cooling**	**DHW**
Residential (>90%)	70	40	54	30	45	35	34	40	40
Retail	60	50	50	45	25	50	18	64	15
Office	70	105	36	85	25	90	18	110	24
Civic	90	115	75	95	40	100	18	110	24

A summary of the estimated heating and cooling demand by Phase is summarized in Table 5. The estimated combined heating and cooling demand of all of the standalone buildings individually is estimated to be ~45 MW of heating and ~47 MW (13,400 tons) of cooling. Final demand and energy estimated and capacity considerations for future cooling requirements will be assessed during detailed design.

Table 5: Summary of Building Heating and Cooling Demand by Phase

Standalone Summary	Units	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Connection Year		2025	2030	2035	2040	2045
Buildings Connected	#	4	5	5	6	5
Market Penetration						
Connected GFA	m²	91,039	232,461	191,622	295,856	257,936
Residential	m²	57,777	135,898	136,308	174,796	207,461
Retail	m²	260	3,660	4,217	2,285	8,148
Office	m²	33,002	63,174	51,097	118,775	18,581
Other	m²	0	29,729	0	0	23,746
Heating Peak	kW	4,890	9,060	7,520	10,950	12,470
Heating Energy	MWh	9,480	15,790	13,290	18,010	24,260
Cooling Peak	kW	4,020	10,350	8,310	14,080	10,480
Cooling Energy	MWh	5,790	15,020	10,910	20,210	13,330
Cooling Peak	tons	1,140	2,940	2,360	4,000	2,980

2.2.2 DISTRICT ENERGY SYSTEM DEMAND AND ENERGY

The demand and energy used by each building if they are connected to a DES is the same as if they had their own stand-alone heating and cooling systems, also referred to as the business-as-usual (BAU) scenario. However, the peak system demand of the DES will be lower than the simple sum of the building peak demands. This is because there is **load diversity** in the system, meaning that the connected buildings will not necessarily require their peak demand at exactly the same time. Dividing the estimated DES peak demand by the sum of the peak demands of each individual connected building results in what is referred to as the **diversification factor**.

Example of Diversification Factor

If a DES has 3 customers with individual peak demands of 1,000 kW, 1,500 kW, and 2,000 kW, but the DES sees a peak system demand of 3,750 kW, the diversification factor would be:

$$Diversificiation\ Factor = \frac{DES\ Peak\ Demand}{\sum Building\ Peaks} = \frac{3{,}750\ kW}{1{,}000\ kW + 1{,}500\ kW + 2{,}000\ kW} = 83.3\%$$

Diversification factors are critical for correctly sizing DES equipment and allow for a smaller installed equipment capacity at the energy centre(s) while still maintaining the required level of redundancy. Typically, the heating diversification factor ranges from 72% to 85% and cooling diversification factor ranges from 70% to 95%. These values are dependent on the connected building mix including building type, age, use, and location. For example, a university campus with a mix of residences, laboratories, classrooms, and offices would have a higher diversification factor than a condo development.

Based on the projected mix of residential and commercial space in the City of Kitchener, the heating load diversification factor has been estimated to be 82% and the cooling diversification factor has been estimated to be 85%. The resulting cumulative heating and cooling demand for each phase is shown in Table 6.

Table 6: Kitchener DES Estimated Heating and Cooling Demand by Phase

System Buildout	Units	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
System Requirements						
Heating						
New Demand by Phase	kW_t	4,890	9,060	11,730	6,740	12,470
Cumulative System Demand	kW_t	4,890	13,950	25,680	32,420	44,890
Diversified System Demand	kW_t	4,010	11,439	21,058	26,584	36,810
Cooling						
New Demand by Phase	kW_c	4,020	8,798	10,804	8,228	8,908
Cumulative System Demand	kW_c	4,020	14,370	27,080	36,760	47,240
Diversified System Demand	kW_c	3,417	12,215	23,018	31,246	40,154

2.2.3 LOAD DURATION CURVES & MAXIMUM THERMAL SYSTEM DEMAND

Load Duration Curves (LDCs) show the number of hours per year a system is predicted to operate at a specific heating or cooling demand. They are helpful in visualizing the buildout of a system over multiple phases, as well as determining the peak demand, also referred to as the peak load, and base load of a system. The peak load is where the LDC meets the vertical axis, and it can be seen that this load only occurs for a very small number of hours per year before falling rapidly.

Establishing the base load of a system is important for sizing renewable thermal generation equipment such as heat pumps. These types of equipment tend to have a high capital cost per unit of installed capacity. Therefore, it is critical to size this equipment in such a way that they offset the largest possible amount of energy year-round with the lowest possible capacity. In the case of the proposed City of Kitchener system, heat pumps coupled with the open loop geoexchange wells have been sized to meet the year-round base load of the system and displace a large amount of the annual energy in relation to their installed capacity. This maximizes the GHG reduction per dollar of capital spent on equipment.

The progression of the load duration curve by phase for heating is shown in Figure 8. It can be seen that as the buildings are constructed to progressing energy standards, the curve becomes more steep as the need for year-round heating decreases.

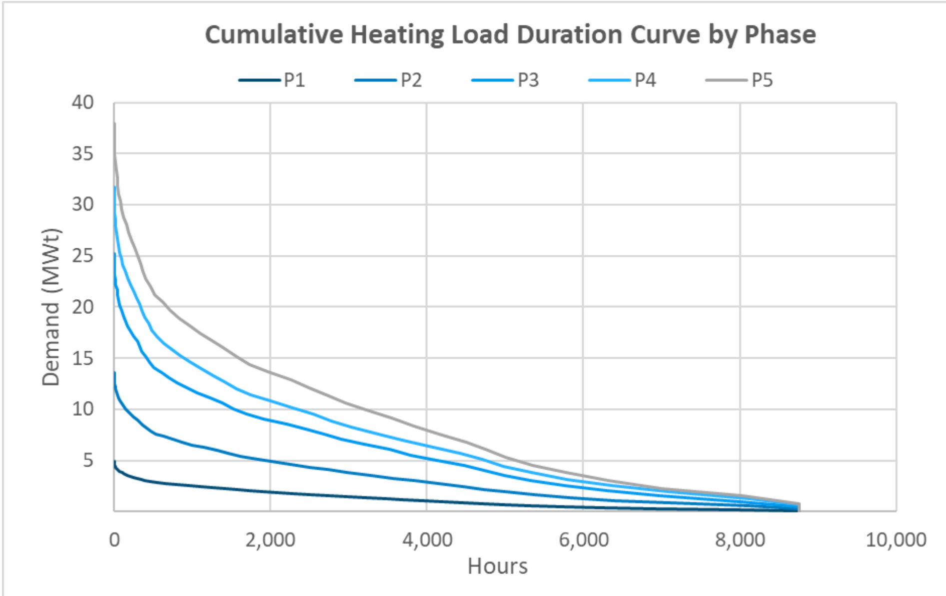

Figure 8: Cumulative Heating Load Duration Curve by Phase

Similarly, the load duration curve for cooling is shown in Figure 9. The peak cooling requirements are expected to increase over time as building envelopes become more airtight.

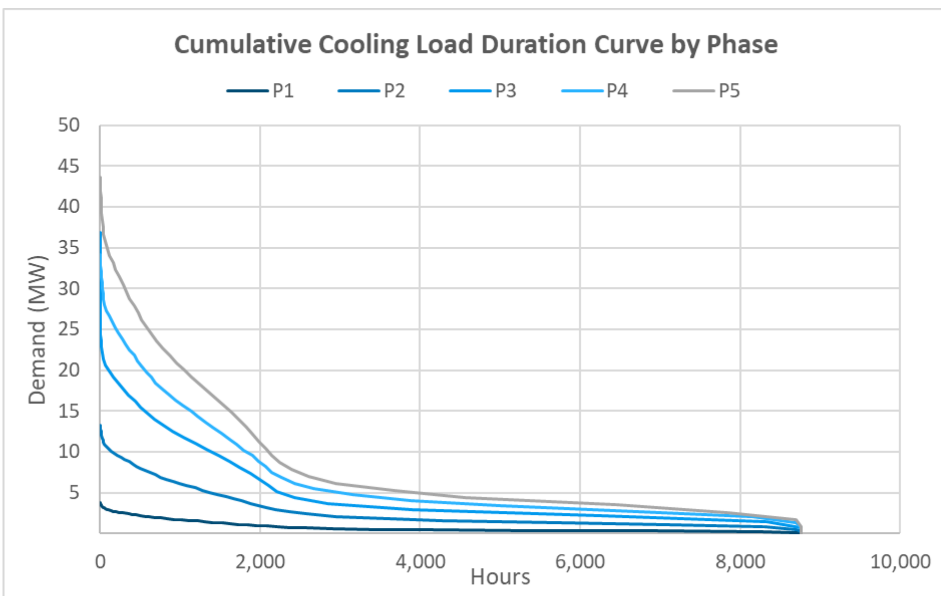

Figure 9: Cumulative Cooling Load Duration Curve by Phase

The corresponding hourly demand for heating and cooling at full system buildout (Phase 5) is shown in Figure 10.

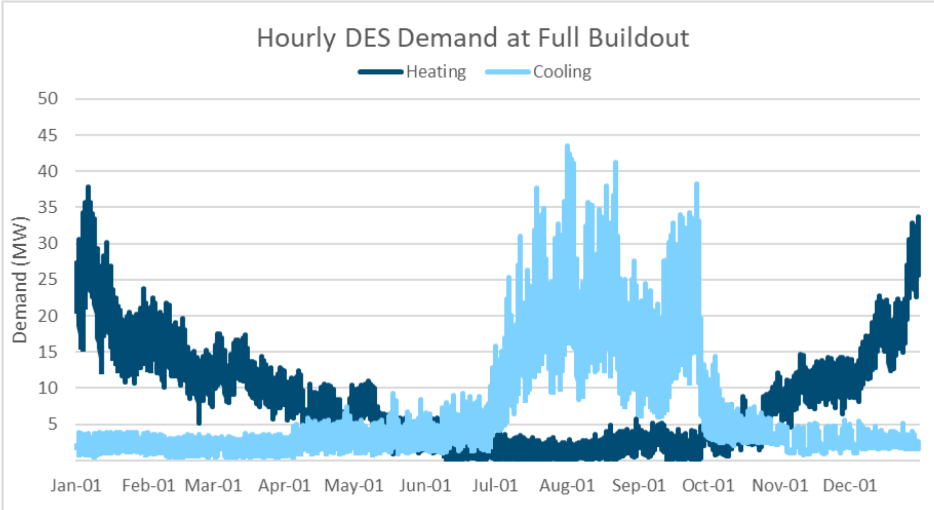

Figure 10: Hourly Heating and Cooling Demand

3 BUSINESS-AS-USUAL (BAU)

3.1 GENERAL

The Business-As-Usual (BAU) scenario is used for comparison and represents what a building would need to do in order to generate heating and cooling if it is not connected to a DES. This includes the capital costs associated with constructing a heating and cooling plant, fixed operation and maintenance costs associated with operating the stand-alone plant, and the electricity and natural gas consumption required. As buildings are unlikely to connect to a DES if it requires a significant cost premium, estimating these BAU costs provide the foundation for developing the DES rate structure (i.e., the rates that buildings would pay the DE provider for the use of the DES energy) that would be competitive to the BAU. These rates are in turn used to estimate the potential revenue of the DES when establishing the business case.

For this feasibility study, the BAU equipment for each building is selected based on its Tier as defined in Section 2.2. The equipment assumed for a building constructed to each Tier is outlined in the table below comparable to the current Toronto Green Standard (Version 4). Existing buildings have been modelled as the “Baseline” energy tier. The stand-alone equipment selected determines the capital cost for the BAU heating and cooling plant, and also dictates the operating costs.

Table 7: BAU Equipment Assumptions by Phase

Phase	Year	Energy Tier	Proposed BAU Equipment
1	2025	Baseline	Natural Gas Boilers Chillers + Cooling Towers
2	2030	Tier 1	Natural Gas Boilers Electric DHW Heaters Chillers + Cooling Towers
3	2035	Tier 2	Natural Gas Boilers Air Source Heat Pump sized to 60% of Peak Heating Demand Chillers + Cooling Towers
4 & 5	2040+	Tier 3	Electric Boilers for Heating and DHW Ground Source Heat Pump + Open Loop Wells sized for full cooling demand
ALL	Existing	BAU	Natural Gas Boilers Chillers + Cooling Towers
ALL	Public	Tier 3	Electric Boilers for Heating and DHW Ground Source Heat Pump + Open Loop Wells sized for full cooling demand

3.2 OPERATING AND MAINTENANCE COSTS

Operating costs for the BAU include variable and fixed costs. Variable costs are costs that vary from year to year as a function of heating and cooling consumption. This includes energy consumption (electricity and gas), as well as water and chemicals. Fixed costs are costs which do not typically vary from year to year and include equipment insurance, maintenance, and plant operation service contracts.

Fuel Cost

Gas consumption by gas boilers and domestic water heaters has been estimated based on the proportion of the building’s heating demand served by gas-fired equipment and an assumed seasonal efficiency of 80%. Gas rates are estimated based on Kitchener utilities rates and vary from $7.70/GJ to $8.20/GJ, excluding carbon tax as this is included separately in the financial analysis.

Electricity Cost

Electricity consumption by chillers, heat pumps, and electric boilers is estimated based on the proportion of heating or cooling served. Each type of equipment and operating mode has an assumed seasonal efficiency or COP. Electricity rates are estimated based on Enova small and large business rates and range from $0.15/kWh$_e$ to $0.20/kWh$_e$ depending on the annual peak electrical demand and electrical consumption from the thermal generation equipment.

Service Contracts / Labour

Boilers, chillers, domestic hot water heaters, and heat pumps require operator attention in order to maintain safe and reliable operation. This is typically accomplished through on-site operators or a service contract for the building HVAC systems, including major equipment and their associated pumps.

Water Treatment Supplies, Water, and Sewer Cost

This includes the cost of water, water treatment chemicals, and equipment operation associated with the treatment process for boilers, heat pump, and cooling towers, including make-up water and discharge to the sewer based on the City of Kitchener's water and wastewater rates.

Major Equipment Insurance Cost

Major equipment insurance is included at 0.15% of equipment and material cost annually.

Equipment Maintenance Cost

The maintenance costs are estimated based on 1.0% of the plant capital and includes yearly preventative maintenance and repair costs that can occur every 7 – 10 years. Maintenance costs assume winterized cooling towers are required for mechanical cooling of the building during the winter.

Reserve Fund

A reserve fund has been included for all residential buildings for heating and cooling plant equipment based on a 20-year replacement life. Replacement costs have been escalated at 2.0% per annum and the reserve fund appreciates at 2.0% per annum.

4 DE LOW CARBON CASE – CONCEPT DESIGN

4.1 OPEN LOOP GEO-EXCHANGE

This study focused on the use of open loop geo-exchange as a heat source. An open loop geo-exchange system uses heat pumps to extract energy from (or reject energy to) briny groundwater in aquifers beneath downtown Kitchener. Using this existing heat source allows the heat pumps to produce significantly more thermal energy than the electrical energy they consume. A supply well paired with an injection well are needed to extract and reinject the groundwater so there are no significant impacts to the area's groundwater flows and quantities.

A desktop study was completed by Salas O'Brien (See Appendix E) to determine the potential locations for the open loop supply and injection wells and the expected yield of each well. Extracting energy from open loop wells consists of installing pairs of supply with submersible pumps and injection (return) wells. The spacing and location of the wells were determined by the expected geological conditions, land use and ownership considerations, and the accessibility of the wells for testing and maintenance.

The feasibility study completed by Salas indicates a potential to extract ~850 kW per open loop well pair based on a flow rate of 31.5 L/s (500 gpm) assuming ambient ground water temperature of 10 °C and a minimum rejection temperature of 4.5°C. Salas O'Brien were tasked to maximize the potential open loop source opportunities to provide 10-15 MW of heating that would provide a base load energy source for a district energy system in the range of 40-65 MW. The intent is for the base load energy source of the district energy system to be the most efficient, low carbon source available, and it is expected to provide ~25% of the system peak demand and ~75% of the annual heating energy use. Figure 11 illustrates the potential well locations identified in the feasibility study. The wells may be located on publicly-owned land, City or Region right-of-ways (ROW), or within private/public property in a landscaped area. The final locations of the wells will be fully coordinated with all stakeholders to ensure that they are located in a mutually amenable location.

Figure 11: Salas O'Brien Open Loop Well Locations

It can be seen from this study that there are three well nodes. The first is at the 55 Bramm site, the second around the Civic District, and the third in Victoria Park. FVB has not included the six (6) injection and supply wells located in the Victoria Park area as part of the district energy concept as installation of header piping from the wells back to the proposed plant locations would be cost prohibitive. If a third plant were developed nearby, these wells could be integrated into the system at that time. Therefore, nine (9) open loop well pairs will be included in the DE concept.

Well spacing and capacity must be confirmed via a test drill program prior to or in parallel with detailed schematic design of the DES. Minimizing interferences and spacing of the open loop supply and injection wells present challenges to utilizing this energy source as it requires additional interconnection piping in the existing congested utility ROW.

An example of an open loop well installed in Waterloo is shown in Figure 12.

Figure 12: Open Loop Well Installation in Waterloo[6]

4.2 DISTRICT ENERGY SYSTEM CONCEPT

4.2.1 ENERGY CENTRE LOCATION(S)

Two energy centres have been proposed to serve the District Energy System primarily to locate open loop pairs on City/Region land. The first energy centre will be developed at the Bramm Works Yard site in Phase 1, and a second energy centre will be developed in the north west corner of the system within the Civic District in Phase 4. This approach will also phase the capital spending more in line with the proposed building development . A multi-plant approach also offers operational flexibility and additional redundancy, as service can be provided from each end of the DES. Further consultation with the Region will be required to realize this concept. The Phase 1 Plant at Bramm is expected to be 2 storeys with a total GFA of approximately 2,600 m^2. Refer to drawing SK-2243-201 in Appendix C for a plant layout concept. A schematic of the plant concept is also included on drawing SK-2243-102. The Phase 4 Plant within the Civic District is expected to be a 1 storey plant, with a total GFA of approximately 1,450m^2. Refer to drawing SK-2243-202 in Appendix C for a plant layout concept. A schematic of the plant concept is also included as shown on drawing SK-2243-102. In each case, equipment will be installed within each plant as it is required to serve customers as they are added in each phase.

For this feasibility study, it is proposed that the Bramm Energy Centre is a stand-alone, purpose-built structure. While other elements could be integrated into the building, such as an educational centre, having the building separate from any development building allows for the construction of the Energy Centre to be independent of the timing of the Bramm development. That being said, if the construction of the Bramm Energy Centre and the larger Bramm development end up being concurrent, there is an opportunity to integrate the Energy Centre into one of the buildings. This will require design coordination. The cost of a standalone Energy Centre and an integrated one are in the same order of magnitude, though the timing of the cost may be different (i.e., the developer may want a lease agreement).

[6] Image Source: Salas O'Brien

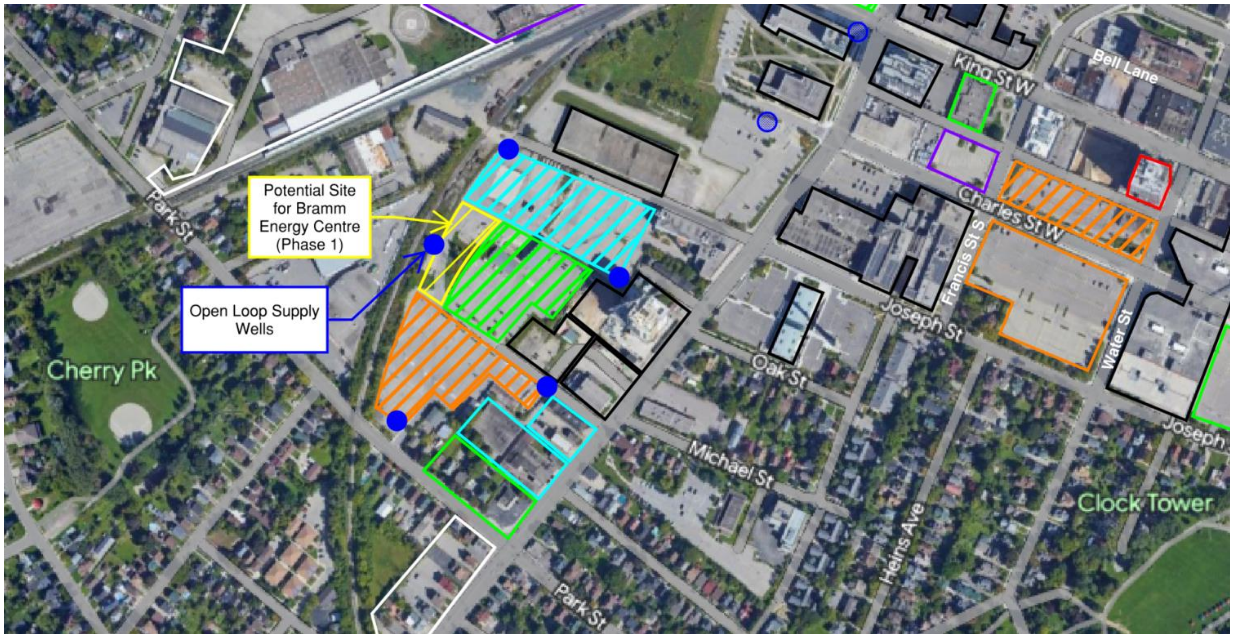

Figure 13: Proposed Bramm Energy Centre and Surrounding Injection Wells

Figure 14: Proposed Civic District Energy Centre Location and Surrounding Injection and Supply Wells

In Figure 13, it can be seen that some of the proposed open loop well locations are located on University of Waterloo (UW) property. This is proposed in order to minimize the geo pipe that is required to cross King Street to access the injection wells. The City of Kitchener will need to engage with UW to determine the feasibility and coordination of these well locations. As shown in Figure 12, the above-ground component of the open loop wells are very small and should not pose any impediment to campus operations, though they will need to be located close to an access point so that they can be serviced.

4.2.2 ENERGY CENTRE PHASING

The proposed phasing for the thermal generation equipment of each of the two DES scenarios is outlined in the below tables. The installed capacity of heating equipment provides **N+1 redundancy** for heating equipment. The installed cooling capacity equipment provides redundancy at a minimum of 66% of peak in Phase 1 and approximately 85-95% at in the subsequent phases. As discussed in Section 2.2.2, the diversified peak demand is the highest demand that will be seen by the system and is the value used for making equipment selections. The cumulative installed capacity is the nominal capacity of the installed equipment. The difference between these numbers indicated the safety factor and level of incorporated redundancy.

N+1 redundancy *means that the system can still provide 100% of the required demand even if the largest piece of equipment is unavailable for use.*

Natural gas generators have been included in the phasing to provide resiliency in the event of disruption to power and can also be used for electricity peak shaving with a Class A electricity rate.

Table 8: Energy Centre Heating Equipment

Energy Centre Heating Equipment Added by Phase							
Phase	Diversified Peak Heating Demand (MW)	Cumulative Installed Capacity (MW)	New Capacity Added in Phase	New Open-Loop Heat Pump Capacity (MW)	New Electric Boiler Capacity (MW)	New Natural Gas Boiler Capacity (MW)	Plant Housing Equipment
1	4.01	7.85	7.85	0.85	3.5	3.5	Plant 1: Bramm
2	11.4	16.55	8.7	1.7	3.5	3.5	
3	21.1	25.25	8.7	1.7	3.5	3.5	
4	26.6	34.95	9.7	1.7	4	4	Plant 2: Civic District
5	36.8	40.65	5.2	1.7	4	0	

Table 9: Energy Centre Cooling Equipment

Energy Centre Cooling Equipment Added by Phase						
Phase	Diversified Peak Cooling Demand (MW)	Cumulative Installed Capacity (MW)	New Capacity Added in Phase	New Open-Loop Heat Pump Capacity (MW)	New Electric Chiller Capacity (MW)	Plant Housing Equipment
1	3.4	4.0	4.0	0.5	3.5	Plant 1: Bramm
2	12.2	15.6	11.6	1.0	10.6	
3	23.0	27.2	11.6	1.0	10.6	
4	31.2	36.3	9.1	1.0	8.1	Plant 2: Civic District
5	40.1	45.4	9.1	1.0	8.1	

Table 10: Energy Centre Generators

Energy Centre Generators			
Phase	Cumulative Installed Capacity (MWe)	New Capacity Added in Phase (MWe)	Plant Housing Equipment
1	0	0	Plant 1: Bramm
2	0	0	
3	3.0	3.0	
4	3.0	0	Plant 2: Civic District
5	6.0	3.0	

At full buildout, the generators can support approximately 75% of the peak heating demand through the use of natural gas boilers, heat pumps, and some electric boilers. They can also support approximately 50% of the peak cooling demand. Compared with most individual building systems that would have minimal heating capacity and no cooling capacity in the event of an extended outage, this is a significant benefit for a DE connection.

4.2.3 DES ENERGY PRODUCTION BY TECHNOLOGY

The contribution of each type of equipment to the energy production of the DES is shown in the following graphs. For heating, the base load is served primarily by open loop geoexchange, with the electric boilers included when required. The natural gas boilers are only used during times of peak demand or as emergency backup. The effective area under the curve highlighted by each technology indicates the relative energy contribution of that equipment. Similarly for cooling, the open loop geo provides the base load while electric centrifugal chillers make up the required generation during times of higher demand.

Part of the efficiencies of a DES is the ability to provide simultaneous heating and cooling. When the system requires both hot water and chilled water, the heat pumps can extract heat from the chilled water network and inject it into the hot water network. This is extremely efficient as both heating and cooling are provided to the system for one unit of energy input. Simultaneous heating and cooling primarily occurs during the summer when domestic hot water is still needed by the buildings but space cooling is the primary system requirement. In the following graphs, the simultaneous heating and cooling is shown as only occurring during part of the year to reflect this.

The contribution of each type of equipment to the heating generation in the first and last phase of project buildout is shown in Figure 15. In this figure, “Sim. Geo” represents simultaneous heating and cooling provided by the geoexchange heat pumps, while “Heat Geo” represents the heat pumps extracting heat from the open loop system.

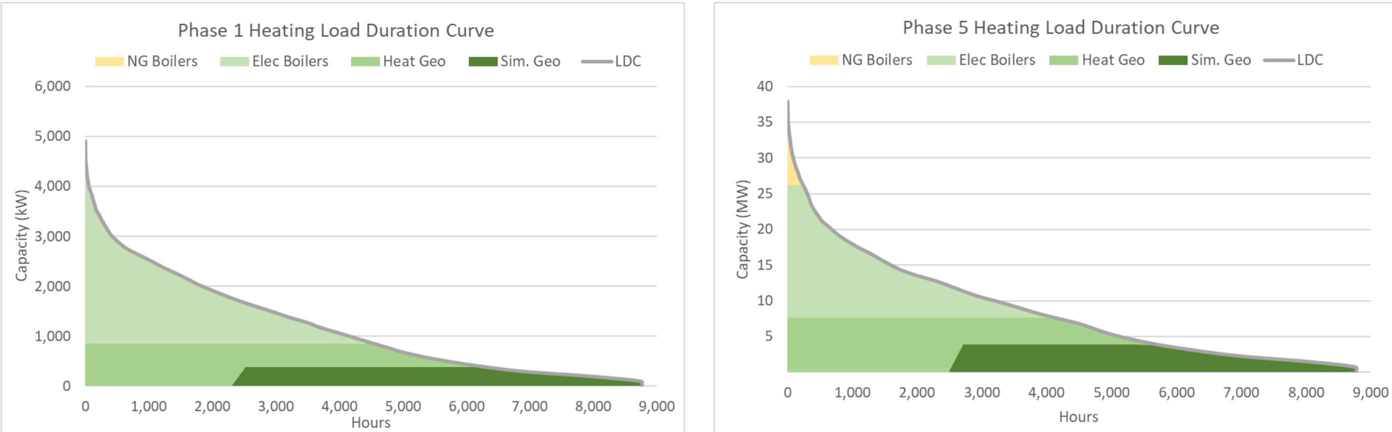

Figure 15: Heating Generation by Equipment Type

The contribution of each type of equipment to the cooling generation in the first and last phase of project buildout is shown in Figure 16. Because the cooling demand is expected to increase over time due to tighter building envelopes, the cooling peaking equipment will have to contribute more significantly over time than in the heating generation scenario. Similar to heating, simultaneous heating and cooling is represented by “Sim. Geo” while “Cool Geo” represents energy injected into the open loop system.

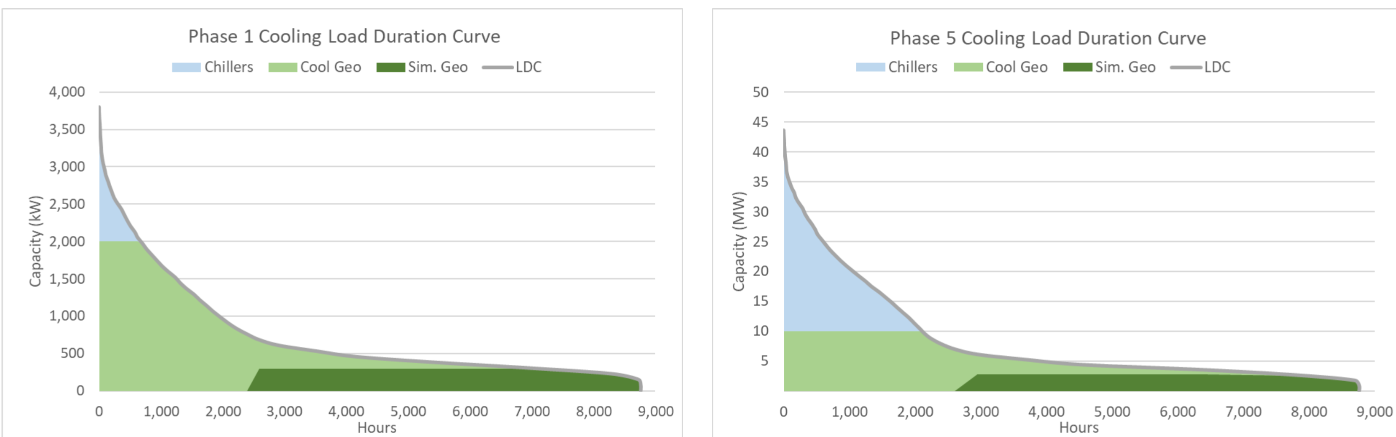

Figure 16: Cooling Generation by Equipment Type

4.2.4 AMBIENT VS. 4-PIPE SYSTEM

Table 11 and Table 12 on the following pages provide a brief description of the benefits and drawbacks of a 4-pipe DES compared to an ambient DES.

*A **4-pipe DES** consists of hot water supply/return pipes and chilled water supply/return pipes. Buildings are connected to the distribution network with an ETS consisting of heat exchangers and control valves. Hot water is supplied at 85-90°C while chilled water is supplied at 4.5°C at peak (see Section 4.2.5).*

*An **ambient DES** consists of supply and return pipes circulating water at an ambient temperature. Buildings are connected to the distribution network via heat pumps that either draw heat from or reject heat to the ambient loop to provide heating and cooling to the building respectively.*

Kitchener has good load diversity with the mix of residential, office, and civic space targeted for connection which is vital for a successful ambient system. However since the system is targeting the connection of existing buildings and has the space for a large energy centre, it is recommended that a 4-pipe system is pursued. This will allow for minimally invasive retrofits into existing buildings, and allow for consolidated maintenance of all thermal generation assets. In addition, as the DES will be providing energy to a mix of private and public customers, a 4-pipe system allows for more reliable metering and customer billing than an ambient system, which is crucial for a successful business case.

Table 11: Pros and Cons of a 4-Pipe DES

4-Pipe System	
Pros	**Cons**

- Plant operators can oversee all equipment at one location and respond quickly.
- **Economies of scale for plant equipment and less total installed heat pump capacity required.**
- Equipment maintenance is restricted to the confines of the energy centre allowing for cost improvement measures.
- **More efficient operation overall due to single plant control with ongoing supervision, technology phasing for peaking, and single heat pump stage.**
- Complementary technologies such as thermal storage and solar PV can be used at the energy centre to further reduce GHG emissions.
- No heating and cooling generation equipment required in the buildings means mechanical rooms can be smaller. More real estate is available for parking, green roofs, amenity space and potentially more saleable area.
- Potential for electrical peak shaving to reduce DE electricity costs with generators/solar PV at the main energy centre.
	- **4 pipes required**, which leads to:
	  o Larger trench widths
	  o More piping material installed
	  o Higher costs for the distribution system
	- **More space is required at a single location for the energy centre.**
	- Higher supply temperatures for heating means that pre-insulated pipes are required and central heat pump selection is slightly more limited

Applications	**Notes**
- Well suited for all district energy systems. - Best for DESs planning to connect existing standalone buildings due to the minimal space required within the individual buildings and higher hot water supply temperature potential.	- New 4-pipe greenfield DESs are being designed with low hot water supply distribution temperatures to maximize the efficiency and contribution of heat pumps and limit the amount of top-up required of peaking equipment.

Table 12: Pros and Cons of an Ambient DES

<table>
<tr><th colspan="2">Ambient System</th></tr>
<tr><th>Pros</th><th>Cons</th></tr>
<tr><td>- Only 2 pipes required, which leads to:
  o Smaller trench width
  o Less upfront capital cost
  o Less total pipe material installed
- Ambient temperatures mean that materials such as HDPE can be used for the distribution piping, and insulation is not required.
- Less space is required at a single energy centre.</td><td>- Fewer economies of scale with distributed generation centres means a higher overall capital cost.
- Increased overall system maintenance costs
- Increased building-side monitoring and on-site operator requirements.
- Servicing is more difficult if heat pumps are owned by DES and/or less control over system if heat pumps are owned by buildings.
- Low delta-Ts with the ambient loop:
  o Difficult to measure the contribution by the low-carbon sources due to low delta-Ts of the ambient loop (<5°C, often 2-3°C)
  o Thermal metering for billing is an issue – low delta-Ts cause calculation issues with the flow & temperature energy meter
  o Larger heat exchangers are required if there is a desire to isolate the building systems from the ambient loop, which is often the case
  o Significantly larger pipes and pumping requirements
- More mechanical space required overall based on distributed heat pump plants and energy transfer stations
- Higher electricity costs at the individual buildings
- Increased electrical infrastructure requirements at each buildings to support large heat pumps, including backup generator requirements for essential heating loads</td></tr>
<tr><th>Applications</th><th>Notes</th></tr>
<tr><td>- Best results would be expected on university campuses or similar institutions where the billing of individual buildings for use of the DES is not required and there is high load diversity between buildings.
- If a system has a chilled water loop and a steam loop and is wanting to move the system away from steam, conversion of the chilled water loop to an ambient loop would reduce the upfront capital costs, site disruption, and construction schedule compared to installing new hot water distribution piping infrastructure.</td><td>- Some sort of central plant is still commonly required to ensure that the temperature of the ambient loop does not fall above maximum temperature or below the minimum temperature.
- Existing systems that FVB has looked at often include additional heating generation equipment within the connected buildings, which results in the following:
  o More heat is rejected to the loop than is extracted from it, which requires additional heat rejection equipment feeding the loop such as cooling towers
  o The DE provider is not able capture the entire load that could be provided to the connected building, reducing the revenue potential and the GHG reduction potential of the system.</td></tr>
</table>

4.2.5 DISTRIBUTION PIPING SYSTEM: THERMAL GRID LAYOUT

The distribution piping system (DPS) is a critical component of a successful district energy system as it establishes a thermal grid between the Energy Centres and all connected buildings. In the case of the proposed City of Kitchener DES, the DPS will have three separate components:

(1) District Heating
(2) District Cooling
(3) Geoexchange Loop Open Loop Wells and Interconnection Piping Manifold

District heating and cooling supply and return pipes are installed in a common trench and provide heating and cooling service to all connected customers. The geoexchange loop piping will interconnect the open loop supply and injection wells with the Energy Centre. Geoexchange loop piping may be installed in a common trench with the heating and cooling piping where it is advantageous (e.g., similar routing). In this case, it will be installed underneath of the cooling pipes. However, in most cases, it will be installed in its own dedicated trench. Geoexchange loop piping must be installed below the frost line to avoid freezing.

In key areas, isolation of the distribution system will be required to facilitate connection of future customers, construction phasing, or future expansion. The DES owner/operator will have to consider where the system isolation points will be located and whether to employ direct bury valves or installation in pre-fabricated concrete valve chambers.

Distribution piping installation projects require significant planning prior to execution, and design and coordination must begin well before service is required. It is best practice to coordinate with all utilities, municipal works, and road construction well in advance of the required service dates. All stakeholders must be informed of planned DE infrastructure over the next 1 to 5 years.

New buried infrastructure in an existing downtown core is always challenging whether it is in Toronto, London, Windsor, Montreal or Kitchener but generally technical solutions and compromises can be found. The actual DPS route determined during detailed design may differ than the concept route considering or based on:

1. Final plant and proposed customer locations.
2. Existing congestion factor vs. longer alternate route.
3. Consultation with all utility stakeholders.
4. Synergy and timing with other proposed electrical or utility expansions.
5. Planned renewal / re-building on existing municipal infrastructure or roadway or sidewalks.
6. Relocation of existing infrastructure.
7. Construction of the DPS in two separate trenches vs. a combined trench.
8. Acquisition of land and easements to facilitate installation of new infrastructure.
9. Review of exceptions to minimum clearances.

The distribution piping has been phased to delay the outlay of capital as late as possible, while also ensuring that all piping that is installed in early phases are adequately sized to meet the full buildout requirements. Pipe sizing must consider all future loads as replacing sections of undersized piping is challenging and costly. The estimated trench meters shown in Figure 11 are summarized in Table 13 that forms the basis of the capital cost estimate.

Table 13: DPS Trench Meters by Phase

Phase	Trench Meters
1	2,080 m
2	890 m
3	445 m
4	1,065 m
5	885 m

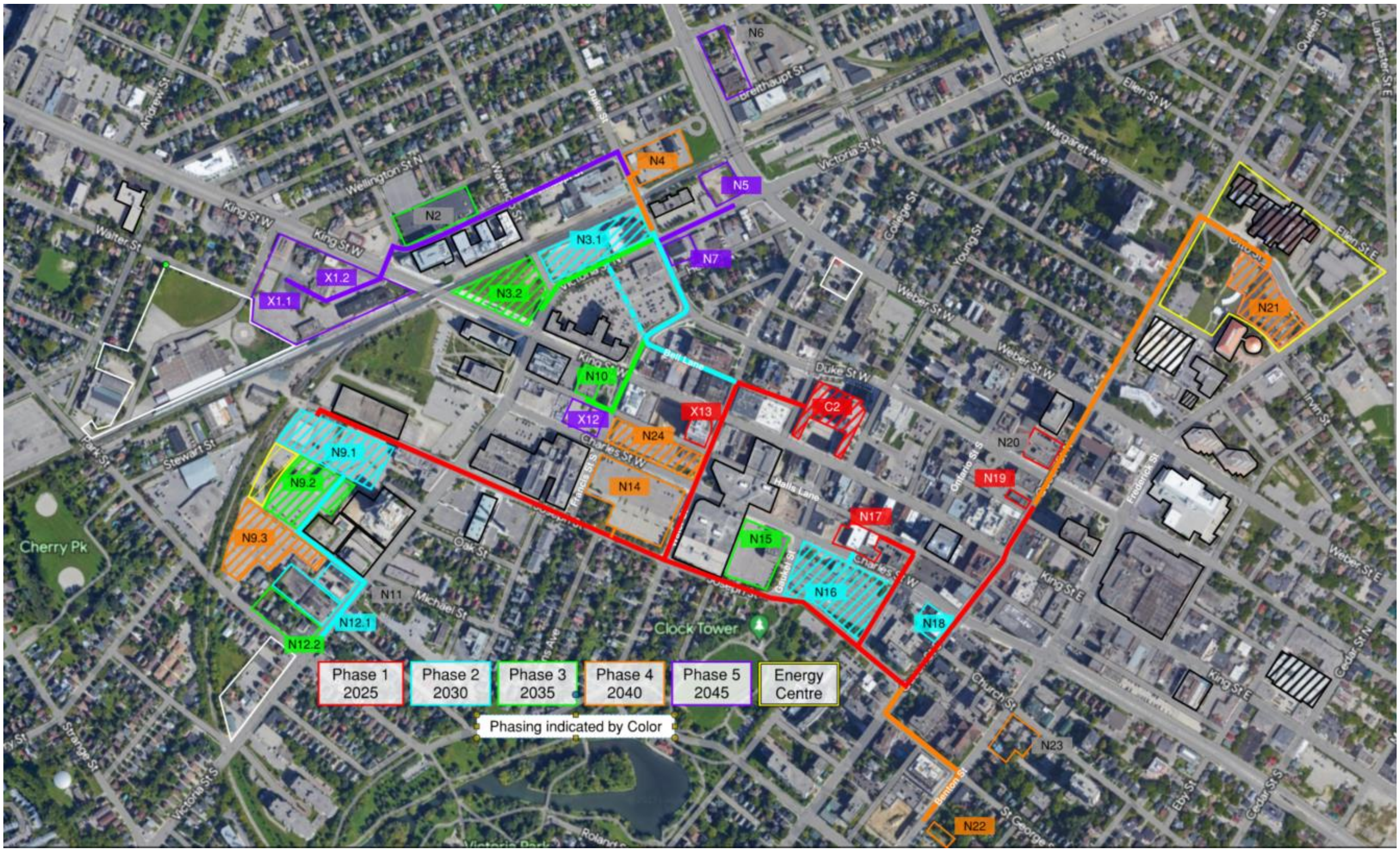

Figure 17: Kitchener Distribution Piping Phasing Map

Piping Layout and Configuration

Distribution piping will be installed within the right-of-way (ROW) wherever possible and shall be treated as a utility. Distribution piping is primarily installed using open trench methods, where a trench 2.0m to 4.0m across is excavated to the installation depth (generally 1.2 to 3.0m, depending on configuration), piping is installed on sand bedding and then backfilled and reinstated. The DPS routing indicated on the phasing plan has been selected to avoid sensitive or particularly challenging roads as identified by City of Kitchener staff. Construction phasing can be used to minimize open lengths of trench and road closures. It is also possible to design and install DE piping in conjunction with other utility infrastructure upgrades in the area to provide project synergies and potentially decrease the cost of installation.

In some areas, the use of open trench methods of construction may not be permitted, such as where piping must cross the existing light rail transit (LRT) tracks or other highly sensitive areas. In these cases, trenchless technologies can be used to minimize disruption. Generally, routing the piping to avoid the need for trenchless crossings is preferable, as trenchless construction costs over three times that of open trench construction. There are several LRT track crossings which may require trenchless construction (e.g., Phase 1: Charles and Queen, Duke and Queen, Water and Charles, Phase 2: Bell Lane and Francis, Phase 3: Francis and King).

Distribution piping can also be installed in various configurations to reduce its footprint within the ROW. Preferably, heating and cooling pipes will be installed in a common trench in a 1 x 4 configuration, such that the heating and cooling supply and return pipes are installed next to each other horizonally (i.e., with the same invert elevation) on sand bedding. This is the most cost effective piping configuration. Alternatively, the piping can be installed in a stacked 2 x 2 configuration such that the cooling pipes are installed in the trench first, backfilled with sand bedding, and the heating pipes are then installed on top. This method requires deeper trench excavations but reduces the piping footprint within the ROW. An example of where a stacked configuration would be preferable due to space constraints is along Joseph Street west of Victoria Street South, where heating, cooling and geoexchange piping must be installed. In this case, a 3 x 2 configuration is proposed, with the geoexchange loop piping installed on the bottom of the trench, followed by the cooling pipes and heating pipes as shown in Figure 18 .

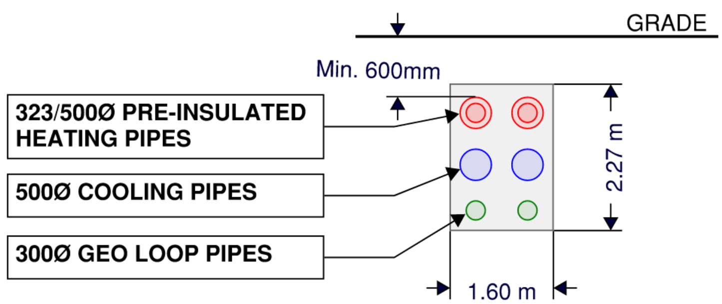

Figure 18: Proposed 3 x 2 DPS Installation on Joseph Street

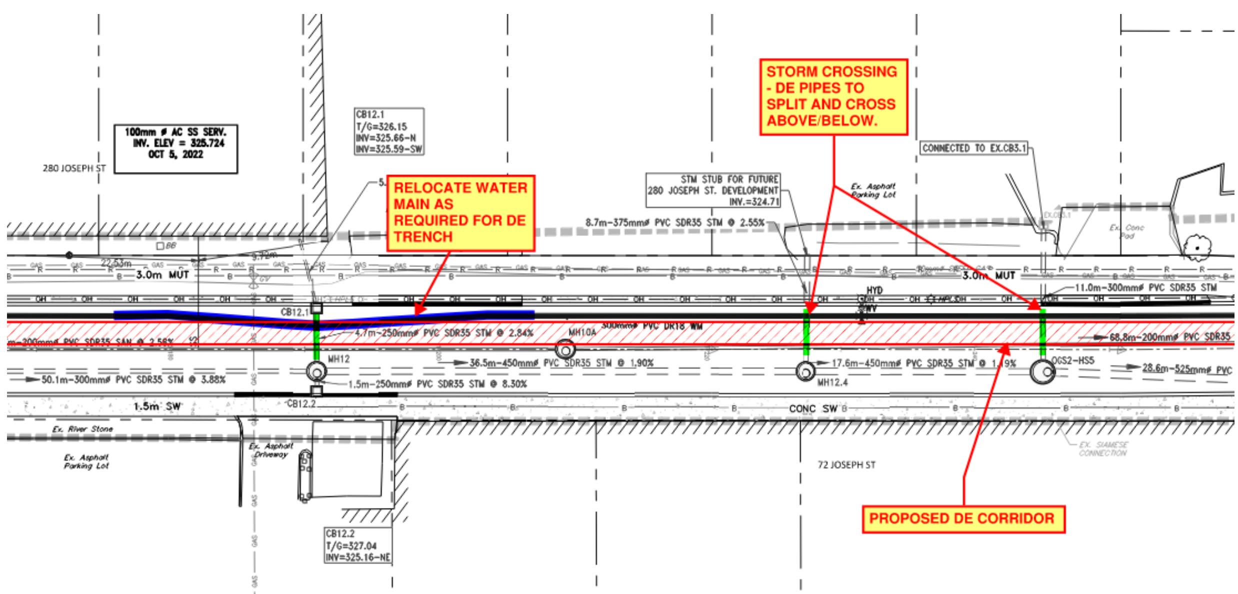

Figure 19: Proposed DE Trench (1.60m Wide) on Joseph Street, West of Victoria

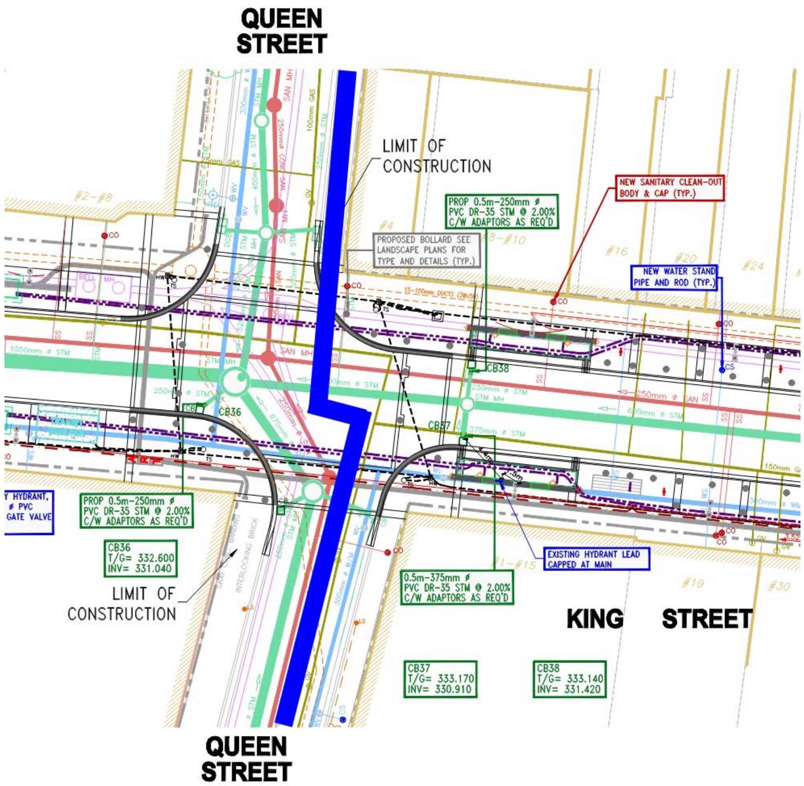

Figure 20: Proposed DE Trench (1.50 m wide) Queen & King

Integrating DE DPS Into New Streets

As with any buried utility installation, integrating district energy distribution piping into a street is simplest when it is included in the original design of the ROW. Streets which will be redeveloped or are new should, at minimum, provide consideration for future DPS piping to be installed by leaving an open corridor within the street, preferably within the asphalt. This will allow for the simplest integration and design of future DPS piping into the street, avoiding complex and exceptionally deep installation to avoid other utilities.

Further, defining "utility crossing zones" within boulevards should be considered and is a mutually beneficial way of extending service from the street to customers. A "utility crossing zone" is a vertical section below grade through which utility mains cannot be installed, but all utilities may use this space to cross each other at intersections or service connections.

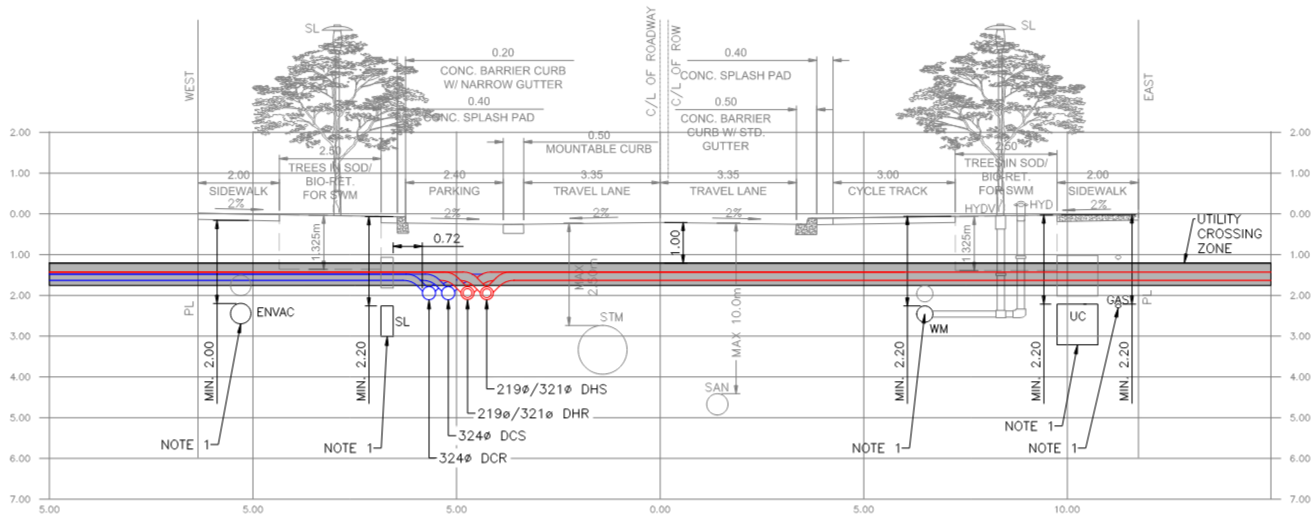

Figure 21: Utility Crossing Zone Example – 1 x 4 Piping Configuration (Grey Area)

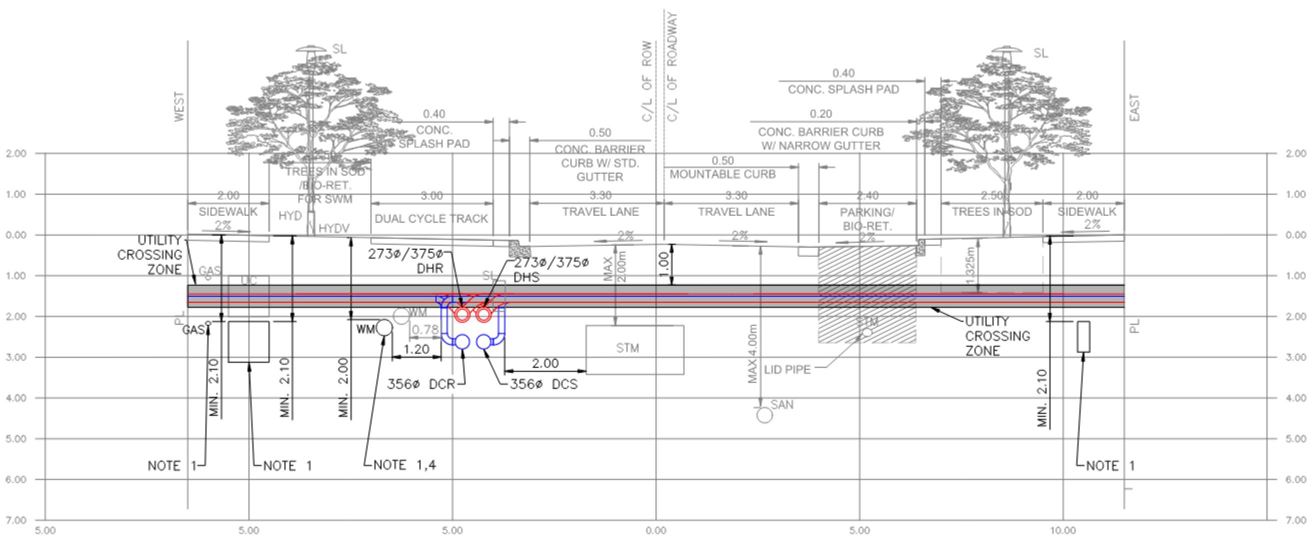

Figure 22: Utility Crossing Zone Example - 2 x 2 Piping Configuration (Grey Area)

Utility Crossings and Parallel Installations

The design of DPS will be coordinated with all utility stakeholders to ensure that required clearances are observed, where feasible. DE piping systems offer greater flexibility in terms of routing than storm and sanitary sewers as it is a pressurized system, allowing for the use of vertical bends as required to avoid utilities. However, main lines with large pipe sizes offer less flexibility due to the amount of space that they occupy, and the size of fittings used to make directional changes. In some cases, reduced minimum clearances between DE pipes and utilities will be required when routing through congested roads and intersections. These will be coordinated with the affected utilities on a case-by-case basis to reach an agreement on the best approach to ensure that the existing utility will not be damaged during construction or because of the proximity of DE infrastructure.

Distribution Piping Materials

Installing distribution piping through an urban centre presents many challenges and is expensive. As a result, selecting appropriate piping materials is critical to the longevity of the system. Piping materials should provide a minimum service life of 50 to 70 years.

A variety of different piping materials are available for distribution systems, each with distinct advantages and disadvantages. The largest number of available options is for heating piping, where a variety of pre-insulated piping products are available. Pre-insulated steel piping has historically been the most commonly used material due to its longevity, pressure, and temperature ratings. However, with low temperature district heating systems, polymer based piping materials such as PEX and PE-RT become a viable alternative. These piping systems are generally easier to install than pre-insulated steel and simpler to design due to reduced need for thermal expansion compensation. They do, however, present limitations on maximum operating temperature and pressure. Table 14 presents several options along with several key parameters. FVB has assumed that the hot water distribution network in the City of Kitchener will be pre-insulated steel, though there is an opportunity for cost savings by using PEX for smaller branches to customer buildings.

Table 14: District Heating Piping Material Options

Material[1]	Pipe Size Range (Nominal)	Max. Intermittent Operating Temp. (°C)	Max. Continuous Operating Temp. (°C)	Max. Pressure at Max. Continuous Temp. (psi)	Expected Service Life (Years)
Steel	20Ø – 600Ø	140	120	363	50+
Cross-Linked Polyethylene (PEX)	20Ø – 150Ø	95	80	87	70
Reinforced PEX	32Ø – 150Ø	115	95	232	70
PE-RT	50Ø – 600Ø[2]	82	82	100	100
Fiberglass Reinforced Plastic (FRP)	25Ø – 1000Ø+	107	107	225	15 – 25

Notes:
1. All options listed are for full bonded, factory preinsulated piping systems.
2. PE-RT maximum size in DR11 wall thickness is 600Ø. For thicker walls, maximum size is lower, and for thinner walls, maximum size is greater.

Cooling distribution piping is generally not insulated and typically sees relatively minor thermal losses due to the small temperature gradient between the chilled water inside of the pipes and the ground temperature. The most commonly utilized chilled water piping materials are fusion bonded epoxy (FBE) coated steel piping and HDPE. FBE steel piping is paired with cathodic protection to offer adequate service life, while HDPE does not corrode and has a design life of up to 100 years. HDPE is a less robust material than steel in the event of errant excavations near the pipes, however when installed with tracer wire for detection and proper datalogger butt fusion methods, provides a long lasting and quick to install solution. Further, the inherent flexibility of HDPE piping can be used to make directional changes as required to correct elevation or to avoid nearby utilities.

The geoexchange loop piping is most similar to chilled water distribution piping; however, it operates at temperatures even closer to the ambient ground temperatures, negating the need for thermal insulation. HDPE is most commonly used for these piping systems due to the long service life and ease of installation.

Sizing Distribution Piping

Distribution pipe sizes are a function of several factors including:

- Temperature differential between supply and return piping
- Maximum allowable fluid velocity (and allowable pressure drop)
- Distribution network pressure at design load
- Differential pressure required to service the most remote customer.

The supply and return temperatures of the distribution system are the most critical factors when designing a distribution system. These temperatures are defined by the thermal generation technologies at the energy centre(s) and the customer building design. The proposed City of Kitchener DES will utilize low-carbon thermal generation technologies, and therefore the maximum heating supply temperature will be 85 °C. Customer buildings must be designed to utilize low temperature hot water and to return water at the lowest possible temperature. By returning a low temperature, the temperature differential between the supply and return is maximized, allowing a larger amount of thermal energy to be transmitted through a given pipe size.

Distribution System Temperatures

The district heating and cooling distribution systems will employ a temperature reset schedule which will modulate the supply temperature of the heating and cooling systems as a function of outdoor air temperature. In most heating systems, lower supply temperatures result in higher equipment efficiencies and lower thermal distribution losses. This is especially true when providing heat using heat pumps. The coefficient of performance (COP) of a heat pump decreases as the hot water temperature it is required to generate increases, therefore, it is desirable to maintain the hot water supply temperature as low as possible for the majority of the year when a heat pump is being used to provide the baseload heating.

The opposite is true for cooling systems, where a lower chilled water supply temperature generally results in a lower COP, while a higher chilled water supply temperature provides a better COP. This is again thanks to operation with a lower temperature lift.

Table 15: District Heating and Cooling Temperatures

	Supply Temperature	Return Temperature
District Heating	85°C	45°C
District Cooling	4°C	14°C

Figure 23 and Figure 24 present example temperature reset schedules for the district heating and cooling systems, respectively. It is important to note that conditions where the heating system is operating at the maximum supply temperature of 85°C will occur for a very limited number of hours per year. Figure 25 presents a temperature duration curve and it can be seen that in 2022, Kitchener-Waterloo experienced outdoor ambient temperatures of less than -15°C for only ~200 hours. Combining the reset schedules shown in Figure 23 and Figure 24 with the temperature duration curve shown in Figure 25, the annual average heating supply temperature would be approximately 68°C.

Likewise, the outdoor ambient temperature exceeded 25°C for approximately 500 hours in 2022, meaning that for the remainder of the year, the district cooling supply temperature would be warmer than 4°C. In 2022, the target chilled water reset schedule would have resulted in an annual average chilled water supply temperature of ~6.4°C.

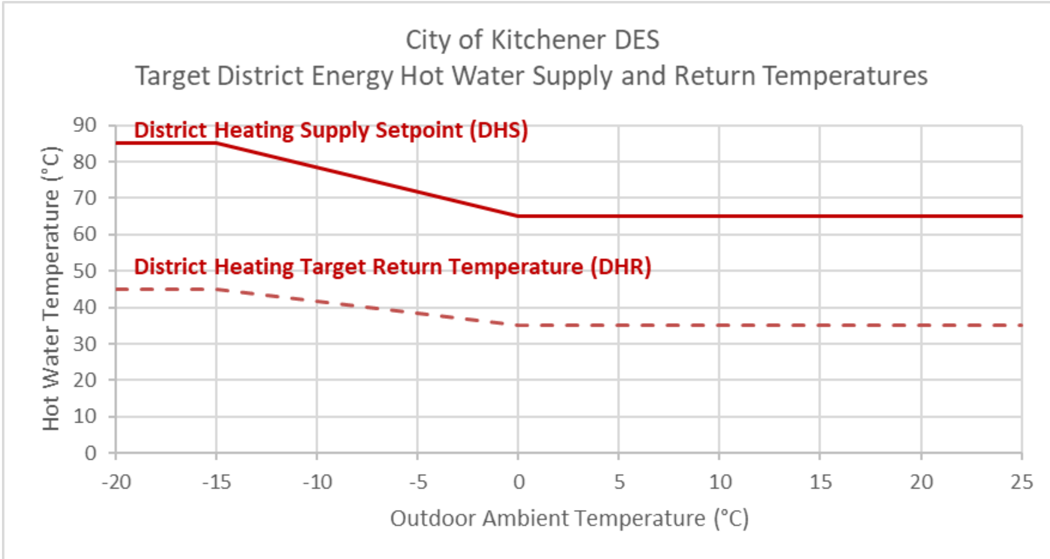

Figure 23: Target District Heating Reset Schedule

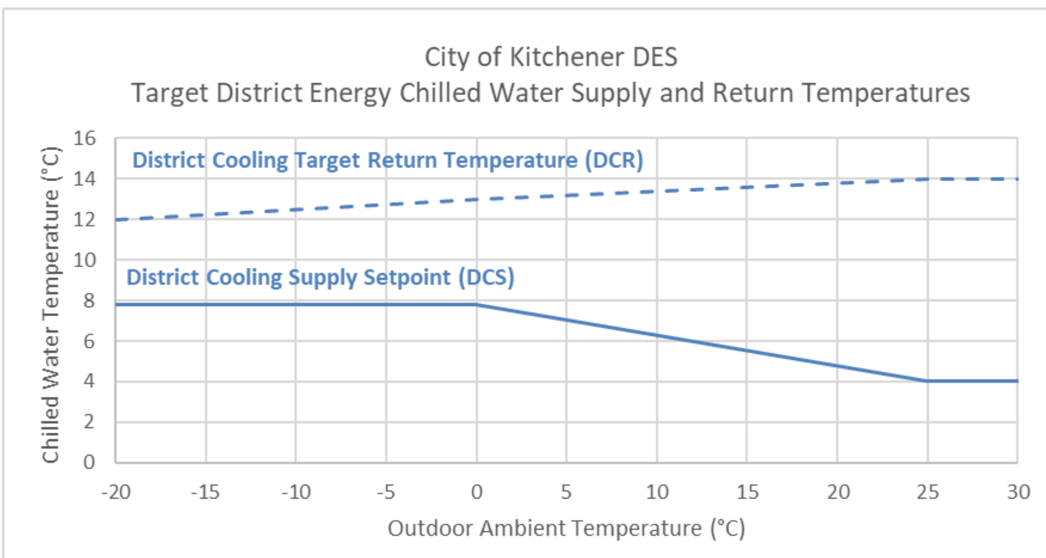

Figure 24: Target District Cooling Reset Schedule

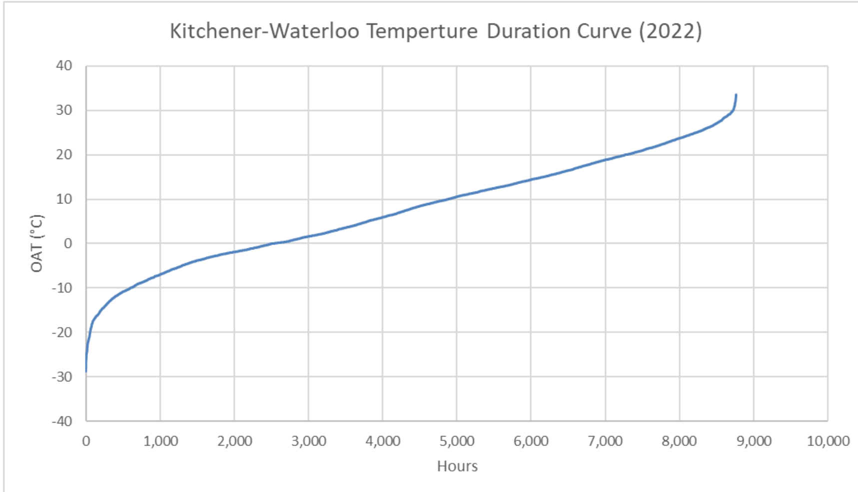

Figure 25: Temperature Duration Curve - Kitchener-Waterloo (2022)

4.2.6 CUSTOMER CONNECTIONS: ENERGY TRANSFER STATIONS

Energy transfer stations (ETS) are the demarcation point between the district energy utility and the building hydronic heating and cooling systems. Energy to the end user is measured using thermal energy (BTU) meters to CSA C900 which is an adoption of the European standard for energy metering used in district energy system in Europe and commercial systems here in Canada, similar to other utilities for billing purposes.

Generally, ETS are comprised of multiple heat exchangers to hydraulically separate the district heating and cooling systems from the customer buildings' space heating, space cooling, and domestic hot water systems. These heat exchangers provide a pressure break between the building and district energy system, and also ensure that the district energy system is not contaminated by poor water quality in connected buildings. The DE owner or operator is responsible for proactively contacting building owners to ensure that they are aware that a competitive district energy heating and cooling solution is available in their area.

An ETS includes:

- District heating and cooling supply and return pipes.
- Heat exchangers (HX) to transfer heat from the DES to the building's hydronic heating, cooling and DHW systems.
- Controls to regulate the flow required to meet the buildings heating demand and maintain the desired building supply temperature.
- Energy meters to monitor and measure the energy used by each building for billing and system optimization.
- Isolation valves on the primary and secondary sides of the HX to facilitate maintenance.

A typical ETS includes three heat exchangers, one for space heating (brazed plate), one for space cooling (plate and frame) and one for domestic hot water heating (double walled plate and frame). Figure 26 shows an example of a heating and DHW ETS constructed on a skid.

Figure 26: Space Heating and DHW ETS Skid[7]

Figure 27 shows an 11 MW heating and 2.8 MW cooling ETS installed in a multi-unit residential building. The chilled water heat exchanger is partially hidden behind the column. The heating heat exchangers occupy approximately 200 ft² of floor area. The pipes shown here will connect directly to the building's secondary hydronic system. This image also shows the typical demarcation point between the DES provider and the building's HVAC systems.

Figure 27: Heating and Cooling ETS in Multi-Unit Residential Building[7]

New customer buildings should be designed in such a way that they are "DE Ready," meaning that the mechanical rooms and secondary systems of the building are design to interface optimally with an ETS. The ETS is ideally located in a basement mechanical room, generally one level below grade along an exterior wall facing the street from which district energy service will be provided. This minimizes the length of distribution piping branches and the need to run interior distribution piping through building spaces.

Buildings should also have heating and cooling systems designed to minimize the heating return water temperature and maximize the cooling return water temperature. FVB recommends that a document outlining

[7] Image Source: FVB Energy Inc.

specific requirements for "DE Ready" buildings be prepared and provided to all developers and building designers within the DES area. The DE owner or operator must have ongoing conversations with the developers and designers to ensure that the design is DES compatible.

The space required for an ETS will be dictated by many factors such as the heating capacity, number of heat exchangers (for redundancy or for multiple loops), heat exchanger type, available room height, and building secondary hot water temperatures. Table 16 presents how different factors impact the size of an ETS, assuming that the design heating load is fixed.

Table 16: Factors Influencing ETS Size

Factors that Increase ETS Size	Factors that Decrease ETS Size
• Large number of heat exchangers/loops • Increased redundancy (N+1, duty/standby, oversizing) • Small building side **ΔT** • Low ETS room height • Use of plate and frame heat exchangers (space heating) • Installation of submetering on ETS • Installation of mixing valves for multiple temperature circuits off of a single HX	• Minimal number of heat exchangers • Low redundancy • Large building ΔT • High ETS room height • Use of brazed plate heat exchangers

*A building's **ΔT** refers to the temperature difference between the water being supplied from the ETS and the water being returned to the ETS after it has served the building's hydronic systems. The smaller the ΔT, the larger the amount of flow required to transfer the same amount of energy.*

4.2.7 ESTIMATED UTILITY REQUIREMENTS

As the DES concept includes heat pumps, electric chillers, and electric boilers, a significant amount of electrical infrastructure will be required. This will have to be coordinated with Enova Power Corp. (Enova). The amount of electricity need in each phase is shown in Table 17.

Table 17: Electrical Infrastructure Requirements by Phase and Energy Centre

Electrical Infrastructure Required	Units	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
By Phase	kW_e	6,400	9,000	9,000	8,900	8,900
Cumulative	kW_e	6,400	15,400	24,400	33,300	42,200
Total Bramm Energy Centre	kW_e	24,400				
Total Civic District Energy Centre	kW_e	17,800				

It should be noted that the peak instantaneous demand seen on the electrical grid will be less than the infrastructure requirements shown due to the offset operation of the chillers and the electric boilers. The implementation of the DES also results in lower summer electrical peaks for the connected buildings as they do not have to operate their own chillers.

4.2.8 PERMITTING & REGULATORY

TSSA & Operating Engineers

The Technical Standards and Safety Authority's (TSSA) Operating Engineers (OE) Safety Program registers, inspects, and regulates the safety of plants in Ontario. All components of the DES will be designed and registered for TSSA compliance. Due to the size of the equipment within the Energy Centres, trained and certified operating personnel will be present 24/7 to ensure the system is operating efficiently and safely.

Permit to Take Water, Air Noise Modelling, ECA etc.

It was determined that compliance with these items will be deferred to the schematic design stage.

5 FINANCIAL ANALYSIS

5.1 GENERAL

5.1.1 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.

5.1.2 GENERAL ASSUMPTIONS

Table 18 outlines the escalation assumptions used in the financial model.

Table 18: Escalation Assumptions for Financial Model

Escalation Assumptions	
Current Year	2023
CPI Escalation Rate	3.0%
Natural Gas Cost Escalation Rate	3.0%
Electricity Cost Escalation Rate	3.0%
CapEx Escalation Rate	5.0%
Maintenance Cost Escalation Rate	3.0%
Weighted Average Cost of Capital	4.0 %

5.2 DE: LOW CARBON REVENUE AND EXPENSE PROJECTIONS

5.2.1 REVENUE

Revenue for each of the two scenarios has been derived from the BAU analyses completed as described in Section 3. The BAU determines the amount of capital that each building would need to spend in order to establish a heating and cooling plant within the building, as well as the annual operating and maintenance costs of the plant.

Using the avoided capital and O&M costs from the BAU, District Energy rates were established such that the annual cost to the building would be equal to BAU. Note that the rates for district energy services are intended to be competitive, not necessarily cheaper than what the building would have done. This allows for a successful business case and recuperation of capital, while still giving the buildings the added benefits of resiliency, available space, simplified operations, and continuous improvements that DE provides.

Typical thermal services contracts are signed between the DE service provider and the customer, outlining the rate structure, term of the agreement, responsibilities of each party, cancellation clause, escalation, etc. Thermal Energy Services Agreements (TESA's) are typically for 20+ years in term and final rates are typically negotiated on an individual basis with each customer to provide a service strategy and redundancy level that meets the building's needs.

Alternatively, the DES utility may choose to structure a set rate structure for all customers; this approach is less common in commercial DES systems in operation.

The district energy rates are comprised of two components and follow either District Energy Rate Structure 1 or District Energy Rate Structure 2 illustrated in the figure below showing the relationship between the BAU costs and the DE rates. 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, thus reducing ongoing rates.

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** - The Capacity Charges are based on the standard rates applicable to the load for heating and cooling.

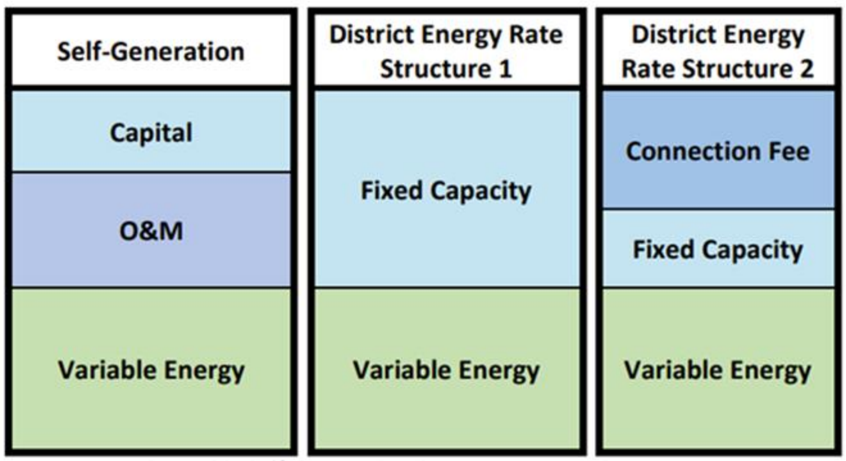

Figure 28: District Energy Rate Structure

For the financial analysis, a blended rate of all buildings has been determined and modelled as Structure 1 using a fixed capacity and variable energy rate to provide a conservative approach to revenue due to delayed return on capital. Applying upfront connection charges will improve the business case.

5.2.2 EXPENSES

The expenses for the DES will include variable costs such as for natural gas and electricity consumption, along with fixed maintenance costs for the upkeep and repair of the equipment. A full cash flow is included in Appendix D.

5.2.3 BUSINESS CASE

The results of the financial model with the DES and BAU cases described in this report is shown in . The analysis is shown for each Phase of the project. The result show that if Phase 1 of the project is built serving only the Phase 1 targeted customers, the project will have a negative IRR and NPV. The business case become positive with the development of the system in Phase 2.

The financial result are commercially confidential, but shows a positive return on investment.

Net Present Value (NPV) *is the difference between the cash inflows and cash outflows over the project lifetime shown in today's dollars. A positive NPV means that there is a return on the investment. The* ***Internal Rate of Return (IRR)*** *is the annual return anticipated on the initial investment.*

The DES financial results exclude debt financing in the case where the City of Kitchener and/or Kitchener Utilities may review opportunities to raise capital. The analysis also excludes any available grants or funding available to municipalities for low carbon and energy saving measures

5.3 SENSITIVITY ANALYSIS, RISK ASSESSMENT, MITIGATION

5.3.1 SENSITIVITY ANALYSIS

A sensitivity analysis was performed on the financial results to account for various factors that may change over the course of the DES buildout: capital, electricity price, and revenue. In the following tables, “Base” represents the assumptions used to calculate the overall financial results.

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 energy centre, distribution piping, and energy transfer stations, were to decrease by up to 20% or increase by up to 20%. The IRR varies between +2.4% and -2.0% with a variation in capital of -20% and + 20%.

At this stage of the feasibility study, there are many elements of the DES concept that are not finalized, which could result in changes to the capital costs. In particular, many elements of the existing and new buildings are not known, and 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

As the proposed Low Carbon DES is largely electrified, there is a certain risk to the business case should the price of electricity increase. 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, and the use of 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 BAU scenario, so there would still be relative savings for the DES with the greater system efficiencies.

The sensitivity analysis is commercially confidential but shows the effect on the business case. The electricity price increases and decreases the DES projected expenses by approximately +/-20% with projected IRR fluctuating between +0.6% and -0.8%.

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 or if estimated BAU cost assumptions are not realized. Note that the estimated market penetration for the current financial analysis is 80% of private buildings and 100% of public buildings and that there will be new and other opportunities that continue to arise as well as disappear. A reduction in revenue by 10% reduces the projected IRR by 1.4% based on a full buildout scenario.

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.

Sensitivity to Carbon Price

This analysis assumes that the carbon tax will continue along the plan outlined by the Government of Canada, meaning it will reach $ 170/tonne by 2030. However, this analysis does not include the **social cost of carbon**. The Government of Canada estimates this to be $261/tonne in 2023[8]. As the social cost of carbon represents the cost to society of every additional tonne emitted, it is possible that the carbon tax is increased to this amount in the future.

> *The **social cost of carbon** is a measure of the incremental additional damages that are expected from a small increase in GHG emissions or, conversely, the avoided damages from a decrease in GHG emissions. For more information, please visit the link included in the footnote.*

A carbon tax reduction to $100/t reduced IRR by 0.1% and an increase in the carbon tax to 300$/t improves IRR by 0.4%.

5.3.2 RISK ASSESSMENT

Customers/Revenue:

The most significant risk in the establishment of a new DES is the potential that customers assumed to connect in the business case do not connect to the system. The City of Kitchener is well positioned to mitigate this risk as a significant portion of the customers targeted for connection in this feasibility study are publicly-owned buildings and developments. However, this risk can be mitigated further by engaging potential customers early on in the development of the DES through planning and signing memorandums of understanding (MOUs) with potential customers to ensure that these customers are prepared to connect to the system when the time comes. Developing policy and incentivizing connection to the district energy system are also good mitigation strategies.

Cost:

The DES Owner/Operator must consider their soft costs and reasonably contingency allowance for unknow factors. Project budgets must be managed to make decisions throughout the project development to keep project costs within budget. Cost estimates are updated and refined through each design stage, schematic, detailed, tender (i.e. 33/66/99 design development stage) to ensure project scope (i.e. quality and time) are in line with the project budget.

Construction:

Construction risks with respect to the DPS piping installation and congestion. Various route can be reviewed during detailed design considering congestion vs. length. Early schematic design engagement and circulation with all utility groups as well as roadway reconstruction is required to understand plans for new, renewal, expansion of infrastructure projects to identify synergies and conflicts.

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[8] Social cost of greenhouse gas emissions, Government of Canada, Accessed May 2023. https://www.canada.ca/en/environment-climate-change/services/climate-change/science-research-data/social-cost-ghg.html

Daylighting and locates can be completed during the schematic design stage to identify and design all utility crossings.

Technical:

Another risk in the development of this low carbon system is the uncertainty surrounding the open loop wells. Test wells should be completed very early in the DES process to gain a better understanding of the thermal capacity available from the open loop wells to see if additional low carbon sources are required to meet the City of Kitchener's GHGI targets for the DES.

5.3.3 LESSONS LEARNED FROM DE IN CANADA

While there are many stories of DE operating successfully and profitably in Canada, there have also been cases where systems have not reached their potential. The lessons learned from these systems include the following:

- People. The most significant factor in a successful DES is having strong alignment and drive throughout **all** internal stakeholders. Messaging to external stakeholders should be consistent and concrete. A "champion" for DE that can lead the effort and drive decision making can be a huge asset. Engagement with all stakeholders should be early, often, and continuous, and this messaging must continue even after the first customers are connected.
- As DES rates are designed to be competitive with BAU, developers will typically not connect unless there are other incentives to do so. Successfully implemented incentives include a streamlined building application process if the building is designed to connect to District Energy (ex. Markham) or achieving a higher building standard if the building is designed to connect to District Energy (ex. Toronto).
- Having firm customer commitments is essential before investing the capital cost for infrastructure. If it is uncertain if customers will connect, there is a risk of oversizing the DES equipment and not being able to recuperate the cost of capital through revenue. Anchor customers should sign memorandums of understanding (MOUs) with the DES provider before any construction begins.
- Anchor customers should be a substantial load for the system, and located near other buildings that would benefit from a connection to the DES, such that the infrastructure installed to serve them will be the foundation to connect future customers.
- As DES rates are designed to be competitive with BAU, developers will typically not connect unless there are other incentives to do so. Successfully implemented incentives include a streamlined building application process if the building is designed to connect to District Energy (ex. Markham) or achieving a higher building standard if the building is designed to connect to District Energy (ex. Toronto).
- A balance between the Capacity Charge and the Energy Charge is recommended to create revenue certainty for the DES that is not tied to weather conditions or commodity costs. The DES rates should escalate based on CPI to remain competitive over the lifetime of the system.

5.3.4 FUNDING OPPORTUNITIES

Canadian Infrastructure Bank (CIB)

The Canadian Infrastructure Bank (CIB) aims to support the achievement of ambitious, portfolio-scale GHG reduction goals. The CIB does not provide grants, but makes investments through loans, credit, and equity investment. Financing is variable based on the project size and the GHG reductions achieved, but the CIB has proven interest in low carbon district energy by funding systems such as Markham District Energy and Enwave.

Federation of Canadian Municipalities (FCM) Green Municipal Fund (GMF)

The FCM provides both grants and loans to municipalities that are striving to implement GHG reduction plans. For District Energy Systems, they can provide grants up to 15% of the loan, and loans of up to $10 million. They also provide grants to support the retrofit of municipal facilities.

Low Carbon Economy Challenge (LCEC)

The LCEC is part of the Low Carbon Economy Fund (LCEF). It leverages Canadian ingenuity to reduce GHG emissions and generate clean growth by providing approximately $500 million to a wide range of recipients. The amount of funding varies based on project size and ownership model (e.g., 25% for private sector and 40% for municipal governments). Applications are expected to reopen in 2023.

Southwestern Ontario Development Fund

The Southwestern Ontario Development Fund provides support for projects and investments to businesses, municipalities, and not-for-profit organizations for economic development in southwestern Ontario. It can provide up to 50% of eligible project costs for a maximum grant of up to $1.5 million for community economic development projects.

5.4 ADDITIONAL OPPORTUNITES AND BENEFITS

5.4.1 ADDITIONAL OPPORTUNITES

In establishing a DES, the City of Kitchener opens the door for additional opportunities that could provide additional benefits to the community.

Snow Melt

A DES with hot water travelling through buried pipes provides unique opportunities to melt snow on public sidewalks and building courtyards. The residual heat in pipes that remains after a building’s heating requirements are satisfied is still enough to provide low temperature heat to snow melt systems while improving the temperature differential and overall system efficiency of the DES.

Waste Heat Recovery

As the DES is built out, there will be more opportunities to leverage sources of waste heat throughout the downtown, such as data centres and industrial facilities that require cooling year-round. This would increase the amount of simultaneous heating and cooling potential and therefore increase the overall efficiency of the DES. A potentially significant source of waste heat could be the Airboss compound.

System Redundancy

A significant benefit of a DES is the increased redundancy in heating and cooling for connected buildings compared to those that have a stand-alone system. The energy centres use a combination of natural gas and electricity, leveraging geothermal heat, as fuel sources for diversity. The energy centres are also constructed to N+1 redundancy, meaning that they can still provide 100% of the heating load required even if the largest piece of installed equipment is not available for use. Trained operators consistently monitor the generation equipment as well as the energy being transferred to buildings. Additionally, emergency and peak-shaving generators will be installed in the energy centres, which will become increasingly relevant as more extreme weather events are predicted due to climate change.

Scaling

The DES concept outlined in this report is not necessarily the end-state of the system. Once the DES is established, it becomes significantly less cost-intensive to connect additional customers if they are close to the existing piping infrastructure. As heating and cooling equipment in the energy centres reaches its end-of-life, the old equipment can be replaced with new equipment with larger capacities, effectively increasing the system capacity for an incremental capital cost. Additional energy centres could be constructed either within buildings or on available land. In the future, the DES could even expand outside the boundaries of the study area.

5.4.2 BENEFITS: ENVIRONMENTAL, SOCIAL, ECONOMIC

Table 19 gives an overview of the various benefits that District Energy can provide to both external stakeholders and to the City of Kitchener and Region of Waterloo.

Table 19: Benefits of District Energy

	To Real Estate Developers, Building Owners, and Residents	To the City, Region, and Community
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 and Resiliency	• 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 • Adaptable for unknown future fuels and technologies	• 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
Sustainability and Environmental	• Sustainable image/marketing, environmental stewardship/leadership • Opportunity for green roofs • Increase comfort from hydronic heating and possibly radiant floor heating • Improved air quality + health benefits • Continuous improvements at the Energy Centre benefit all connected buildings immediately	• Reduces GHG emissions in both new and existing buildings • 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

5.4.3 TEMPORARY 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 29. 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.

For the Kitchener DES system, there is potential to collaborate with the University of Waterloo to house a temporary energy centre in their School of Pharmacy building which has been identified as having usable heating capacity and space for additional chillers. This could potentially improve the Phase 1 business case and delay the timing of the Bramm Energy Centre.

Figure 29: Interim Energy Centres at UBC (left)[9] and Oval Village (right)[10]

5.4.4 RELIEF DISTRIBUTION PIPING FOR ADDITIONAL RESILIENCY

Buried DES infrastructure is extremely resilient, particularly for hot water systems such as the one being proposed for Kitchener. The two Energy Centres also provide good redundancy for a significant amount of the system. If increased resiliency is desired, additional pipes could be constructed down Victoria St. between Joseph St. and the Multi-Modal Transit Hub to create a loop through the downtown area. This was not proposed in the feasibility study as Victoria St. is a regional road and it was understood that construction along this street would be challenging and capital intensive, and the system is expected to be extremely resilient even without this loop. That being said, if the University of Waterloo buildings would like to connect to the DES in the future, it may be worth extending the branch piping across King St. W to get that additional system resiliency for an incremental capital cost (Figure 30).

[9] Image Source: The University of British Columbia
[10] Image Source: FVB Energy Inc.

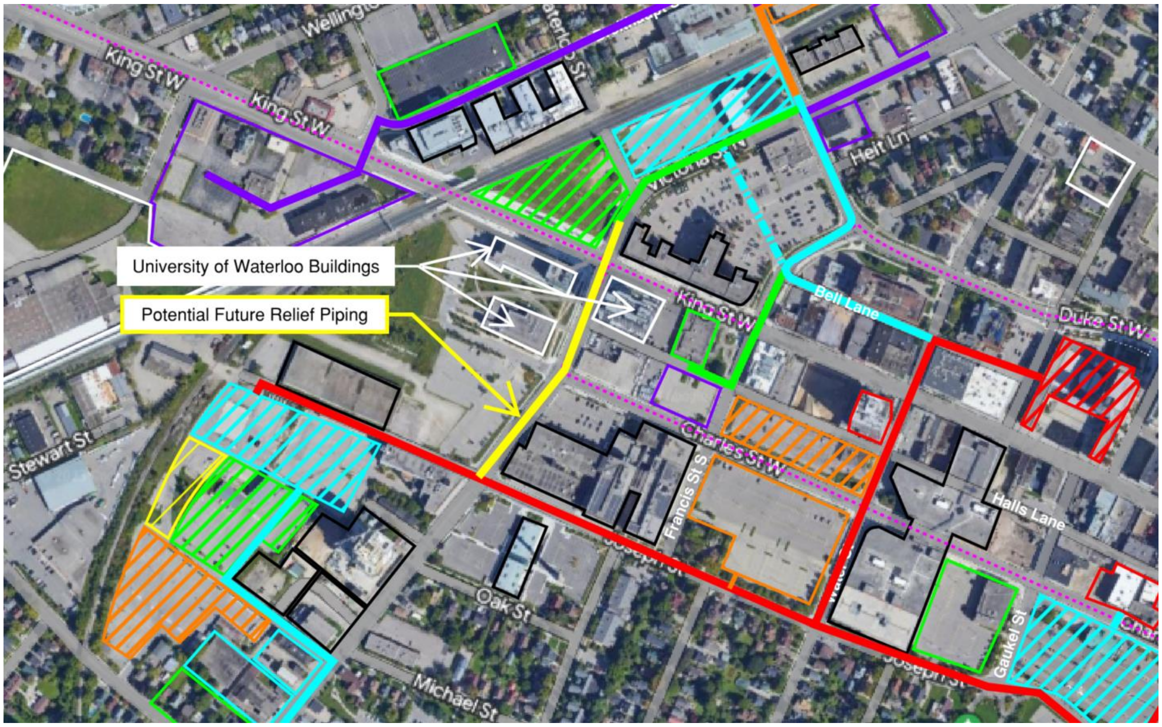


Figure 30: Potential Future DPS Addition

6 ENVIRONMENTAL ANALYSIS

6.1 EMISSION FACTOR ASSUMPTIONS

The emission factors used in this feasibility analysis are taken from the National Inventory Report 1990-2020: Greenhouse Gas Sources and Sinks in Canada (2022). While there are various predictions for the future emissions of the Ontario electricity grid, these were not factored into this feasibility-level analysis and should be evaluated further during detailed design.

Table 20: GHG Emission Factor Assumptions

GHG Emission Factors by Fuel Type	
Natural Gas	50.1 kg CO_2e/GJ
Electricity	30 kg CO_2e/MWh

6.2 BASELINE GHG EMISSIONS

FVB developed a baseline GHG scenario assuming that all connected buildings are built to current 2022 building codes (National Energy Code/Ontario Building Code), minimum standard energy efficiency, in absence of any local green development standard or net zero framework. These buildings would have a self-generation heating and cooling plant with equipment as per Table 21. This baseline scenario is the reference case to which the BAU and DE scenarios will be compared. The resulting baseline GHG emissions are shown in Table 22.

Table 21: Baseline BAU Equipment

Phase	Year	Energy Tier	Proposed BAU Equipment
All	-	BASELINE	Natural Gas Boilers – 80% Seasonal Efficiency Chillers + Cooling Towers – Seasonal COP of 4.0

Table 22: Baseline GHG Emissions

Standalone Summary	Units	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Totals
Connection Year		2025	2030	2035	2040	2045	**-**
Buildings	#	4	5	6	5	5	**25**
Total GFA	m^2	91,039	232,461	297,531	189,947	257,936	**1,068,914**
Annual GHG Emissions	tonnes	2,851	6,203	7,866	5,274	7,979	**30,173**
GHGI	kg/m^2	31.3	26.7	26.4	27.8	30.9	**28.2**

6.3 BAU GHG EMISSIONS

FVB has assumed that for the BAU varies throughout the project development in anticipation of new green development standards. The proposed developments are constructed to the Tiers outlined in the Demand and Energy Section: i.e. BAU (2025), Tier 1, Tier 2, or Tier 3. The allowable GHGI's for each building are provided in Table 23.

Table 23: Greenhouse Gas Intensity Limits

Greenhouse Gas Intensity Limits				
GFA Type	**BAU GHGI (kg/m^2)**	**Tier 1 GHGI (kg/m^2)**	**Tier 2 GHGI (kg/m^2)**	**Tier 3 GHGI (kg/m^2)**
Residential	20	15	10	5
Retail	20	10	5	3
Office	20	15	8	4
Community	20	15	10	5
Effective for Phase[1]	20	15	8.3	4.7
Minus Plug Loads[2]	18.4	13.4	6.7	3.1

Note 1: Effective for Phase is a weighted average of the GHGI for the phase based on the GFA of each building type in that phase.
Note 2: Plug Loads include lighting, elevators, secondary-side building pumps, and other electrical loads that are not associated with the DES. These factor in to the total GHGI limit for a building so must be taken into account when calculating the GHGI limit for the DES. It is estimated that the plug loads create 1.6 kg/m^2 of CO_2 for each phase based on standard electricity use factors and the Ontario electrical grid emission factor.

The BAU scenario GHG emissions are significantly lower than the baseline BAU due to buildings performing to a higher standard than in the GHG Baseline, with lower energy consumption and integration of electrified heating technologies to reduce emissions. Ultimately, the BAU offers a GHG emissions reduction of 78.9% when compared to the baseline as shown in Table 24.

Table 24: BAU Low Carbon GHG Emissions

BAU Summary	Units	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Totals
Connection Year		2025	2030	2035	2040	2045	**-**
Buildings	#	4	5	6	5	5	**25**
Total GFA	m^2	91,039	232,461	297,531	189,947	257,936	**1,068,914**
Annual GHG Emissions	tonnes	2,178	1,453	980	227	1,515	**6,353**
GHGI	kg/m^2	23.9	6.3	3.3	1.2	5.9	**5.9**
GHG Reduction vs. Baseline	%	23.6%	76.6%	87.5%	95.7%	81.0%	**78.9%**

6.4 DES GHG EMISSIONS

The comparison of the DES emissions to the baseline emissions are shown in Table 25. The combination of the progressive development standards and the low carbon DES using open loop geoexchange and electric boilers creates a GHG emission reduction of 88% compared to the baseline.

Table 25: Annual GHG Emissions Comparison to Baseline

Phase	Baseline GHG Emissions (tonnes/year)	Low Carbon DES GHG Emissions (tonnes/year)	Reduction (tonnes/year)	Reduction (%)
1	2,851	201	2,650	93%
2	9,054	976	8,078	89%
3	16,920	2,267	14,653	87%
4	22,194	2,593	19,601	88%
5	30,173	3,684	26,489	88%

While it is essential for cities to implement a Green Development Standard to ensure that new buildings are built such that they limit the amount of GHGs that are emitted, a DES can actually reduce the amount of GHG emissions rather than limiting new emissions. Existing buildings that are constructed to previous standards would generally have a very difficult time implementing stand-alone low carbon thermal generation equipment due to the size and technical complexity of the equipment. A connection to a DES can allow an existing building to gain the low emission factor of the DES with the majority of the renovations contained within an ETS room while actually decreasing the system complexity for building operators.

Due to the impact of providing low carbon energy to existing buildings, the DES would provide a GHG emissions reduction of 42% compared to simply implementing a GDS for new buildings.

Table 26: Annual GHG Emissions Comparison to BAU

Phase	Aggregated BAU GHG Emissions (tonnes/year)	Aggregated Low Carbon DES GHG Emissions (tonnes/year)	Reduction (tonnes/year)	Reduction (%)
1	2,178	201	1,977	91%
2	3,631	976	2,655	73%
3	4,611	2,267	2,344	51%
4	4,838	2,593	2,245	46%
5	6,353	3,684	2,669	42%

Table 27 shows the cumulative Low Carbon DES GHG emissions over the 30-year project timeframe, compared to the Baseline and BAU emissions. It is important to note that while this analysis was done on a 30-year timeframe, the DES is expected to remain operational for much longer than this and the cumulative savings will only increase past the timeframe of this analysis.

Table 27: Cumulative GHG Emissions and $/tonne

Scenario	Cumulative 30-year GHG Emissions (tonnes)	Cumulative Avoided Emissions with Low Carbon DES (tonnes)
Baseline	526,600	463,300
BAU	133,500	70,100
Low Carbon DES	63,300	-

Recalling the discussion of the social cost of carbon in Section 5.4.1, these avoided emissions result in $18 million in averted damage compared to the BAU scenario, or $ 121 million compared to the Baseline scenario.

7 OWNERSHIP MODELS

7.1 OVERVIEW

Variants of three ownership models have been used by DES's worldwide and in North America:

1. Public – the City maintains ownership
2. Private – concessions or outright ownership by private entity
3. Hybrid – including joint venture (JV) or split ownership, a combination of the above models

In Canada, approximate breakdown of DES by ownership model is roughly:

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

Determination of the preferred, viable Owner/Operator model and governance is a prerequisite to developing a DES. There must be an entity with a clearly defined structure that will be responsible for the project, raise financing and enter service agreements with customers, whether it is the City/Region itself, an agency or corporation of the City/Region, a Joint Venture (JV) or a totally private company.

An identified and credible DES Owner is essential for effective marketing. 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 activity commences. This is because customers are expected to sign long-term service agreements naturally need to understand exactly who their counterparty would be and who they can rely on to deliver this essential service.

The suitability of each of the three ownership models depends on 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 (degree of 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 have access to government grants and incentives that help to improve the business case and return on investment

Strengths and weaknesses of the other options are highlighted by a SWOT analysis in Table 28.

Table 28: Ownership Models - SWOT Analysis

	100% Public	Hybrid	100% Private
Strengths	• Access to low cost financing. • Long term agreement, stable partner. • Access to government grants. • Alignment with other City Departments and levels of government	• Combines private DE experience & capital with City advantages, such as access to senior government grants	• Private sector assumes all risk, is most motivated, minimizes government interference
Weaknesses	• Available capital for large infrastructure project. Management capacity (internal resources) and • No DES experience	• Joint Venture (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
Opportunities	• Meets other goals and objectives in addition to business case such as sustainability, economic development, resilience. • Leadership Synergy with other municipal projects and objectives	• Monetize City advantages; sell out when DES established, using cash to seed another DES project, maximizing socio-economic and environmental values • Leverage industry experience	• Create environment for the DES to succeed • Realize socio-economic and environmental values without using City's own limited financial resources
Threats	• Risks: cost overruns, performance issues associated with construction, commissioning and O&M costs. • Market penetration • Nuisance complaints	• Disputes due to different goals • Relationship and RFP process scrutinized for fairness	• Concessions inhibit motivation to expand or spend maintenance dollars

7.2 100% PUBLIC OWNERSHIP

Many successful DES system start-ups have begun with 100% Public Ownership. Table 29 outlines three different types of private ownership models seen with examples of each.

Table 29: Public Owner/Operator Models

Model	Description	Examples
1	• 100% municipal ownership and operation directly (through the engineering services department)	• Southeast False Creek (SEFC) NEU; • Strathcona County • City of Surrey • Prince George • City of North Vancouver
2	• 100% municipal ownership and operation, through a subsidiary corporation or existing public utility	• Markham District Energy; • Hamilton Community Energy; • City Calgary's Enmax; • City of Richmond Alexandra DEU; • Lonsdale Energy Corp. • Lulu Island Energy Company
3	• 100% municipal ownership with private sector operation	• Revelstoke Community Energy • Regent Park Energy Inc.

7.3 100% PRIVATE OWNERSHIP

Private DE systems have been proven to work in Canada with the largest district energy utilities[11] being entirely privately owned. Some of the DES's may have begun as publicly owned or joint venture owned systems and transitioned to private ownership. Table 30 outlines two models that have been successfully implemented, along with examples.

[11] The qualifier "utility" is to distinguish this business model from campus systems owned by universities, industries, the military or other government organizations.

Table 30: Private Owner/Operator Models

Model	Description	Examples
4	• 100% private ownership and operation – commercial utility model	• Enwave (Toronto, London, Charlottetown, Windsor, Chicago, Los Angeles, Houston, New Orleans, Seattle, Las Vegas, Portland) • Creative Energy (Formerly Central Heat) • Corix (University, Dockside) • Sudbury District Energy (Toromont) • Cornwall District Energy • Energir Urban Heating and Cooling (Veolia North America – Montreal) • River District Energy
5	• 100% private ownership – campus systems by real estate developers	• Mirvish Village, Toronto – West Bank + Creative Energy in Toronto • Drake Landing Solar Community, Okotoks - • La Cite Verte, Quebec City – SSQ+

7.4 HYBRID

There are several examples of hybrid models that have worked because they suited specific local requirements at the time. This is a pattern that might fit the City's situation where the City may be interested in a part ownership position in order to initiate the project and then hold that interest for as long as it proves useful to ensure expansion to meet City goals for local economic development and GHG reduction. Many of these joint ventures have moved, or are moving, to a single owner position as shown in Table 31; the split ownership model is the least favorable option.

Table 31: Hybrid Owner/Operator Models

Model	Description	Examples
6	JV between a municipality and a private sector company (the private sector company may provide operating expertise)	• Toronto Community Housing / Corix (now 100% public) • City of Subury / Toromont (now 100% private) • Oval Village Richmond – LIEC / Corix
7	Split ownership and operation, the municipality owning and operating the distribution systems with private sector owning and operating Energy Centre	• Windsor District Energy / Enwave

8 RECOMMENDATIONS AND NEXT STEPS

8.1 RECOMMENDATIONS

Based on the results of this feasibility study, the City of Kitchener has an excellent opportunity to establish a low carbon District Energy System in the downtown core. The unique geology of aquifers beneath the City allow for the use of open loop geoexchange, which can be used reliably year-round for both heating and cooling resulting in a GHG reduction of 88% compared to the baseline i.e. projected emissions should buildings continue to be constructed to current energy and emission requirements and install individual heating and cooling solutions. Two energy centres on publicly-owned land create good phasing of capital and allow for significant system redundancy. It is highly recommend that the City of Kitchener pursue the establishment of a state-of-the-art District Energy System in the downtown core.

8.2 NEXT STEPS

1. **Refine the ownership model,** business case, and develop business plan and marketing strategy including confirmation of KU/City's role in the DES based on the information known today.

As part of this, it will be important to understand the funding and grant options available for each of the private ownership, public ownership, and private or hybrid ownership models. Discussions between the City of Kitchener, the Region of Waterloo, and the various utilities should be held in a structured environment. Joint venture discussions with district energy providers and other private firms that could be interested in having an equity partnership in the DES should also be pursued. Infrastructure investment firms should be solicited to provide structures in which they would be amenable to partnering with the City, and what debt/equity they are open to providing.

2. **Refine the DES concept through detailed schematic design**, including any project phasing and loads, capital, and O&M costs.

This will including developing constraints for the stand alone energy centre on the Bramm site and the connections to the anchor customers. It should also include further defining the locations of each of the open loop geothermal wells in the ROWs, public lands, park lands, and green spaces.

3. **Develop a draft rate structure** that will be used to **obtain anchor customer commitments** through memorandums of understanding (MOU).

The more detailed technical design will allow for greater certainty on the business case and the capital recovery required. The rates will be evaluated for competitiveness with BAU.

4. **Develop a 'DE Ready'** building standard **and a 'DE Corridor'** right-of-way (ROW) standard.

This will allow for new buildings and infrastructure projects to be constructed in a manner that is complementary to DE infrastructure and will minimize the work required to connect these new buildings to the DES, as well as streamline the coordination required for the pipe installation in new developments. Providing incentives to developers to connect to the DES – such as what is currently being done in the City of Toronto and the City of Markham – should be investigated.

5. **Proceed with developing a dedicated energy centre at the Bramm Works Site**
Building an energy centre at the Bramm Works site in a dedicated building is preferred and simplifies construction and coordination of the surrounding developments. This energy centre will be the anchor of the City of Kitchener low carbon DES, and the system will grow outwards throughout the downtown core.

In addition to these next steps, it will be equally important to continue to market District Energy and to work continually to engage all stakeholders in this exiting project. There should be significant emphasis on the fact that the City of Kitchener has a unique opportunity for a low carbon District Energy System due to the large aquifer that can be leveraged as an energy source. Stakeholders should be identified early and be involved continuously through tours, workshops, and shared experiences, and a clear message to the community about the benefits of District Energy and why the City of Kitchener is choosing to pursue it should be developed.

Education is a large barrier to the uptake of District Energy. Its history, application, utility structure, resiliency standards, etc. are generally unknown to the communities where it would be the most beneficial. With strong partners and stakeholders such as the University of Waterloo and Conestoga College, there is an important opportunity to incorporate a District Energy education component to the first Energy Centre slated for the Bramm site. The proximity of this site to the downtown and civic campuses makes it an ideal opportunity to increase the value of the DES to the community above and beyond the numerous concrete benefits.

A significant factor in the successful development of a DES is having a “champion” at the City and Region who can lead the effort both internally and externally. Having someone who understands DE and its benefits well can help all parties understand what can be done to limit the barriers to implementation, and help internal and external stakeholders along the pathway to implementation.

Site tours to successful District Energy Systems in Toronto and Markham should be arranged to create greater familiarity with how these systems are integrated into a community.

The Grand River hospital should be asked to participate as they represent a large heating and cooling potential which could assist with connecting additional customers as new buildings or developments are built east on King Street from the Bramm site.

8.3 THE ROLE OF THE CITY AND REGION IN DISTRICT ENERGY

8.3.1 LEAD BY EXAMPLE: MUNICIPAL & REGIONAL BUILDINGS

- Connect all municipal and regional buildings and mandate connection of all buildings constructed on public lands. Focus should be on new City/Regional developments with review of existing buildings in line with capital replacement or deep retrofit plans.

8.3.2 LEAD BY EXAMPLE: PUBLIC BUILDINGS – PROVINCIAL, FEDERAL, UNIVERSITIES

- Connect with provincial, federal, including institutional and hospital partners and public entities on the goals for District Energy.

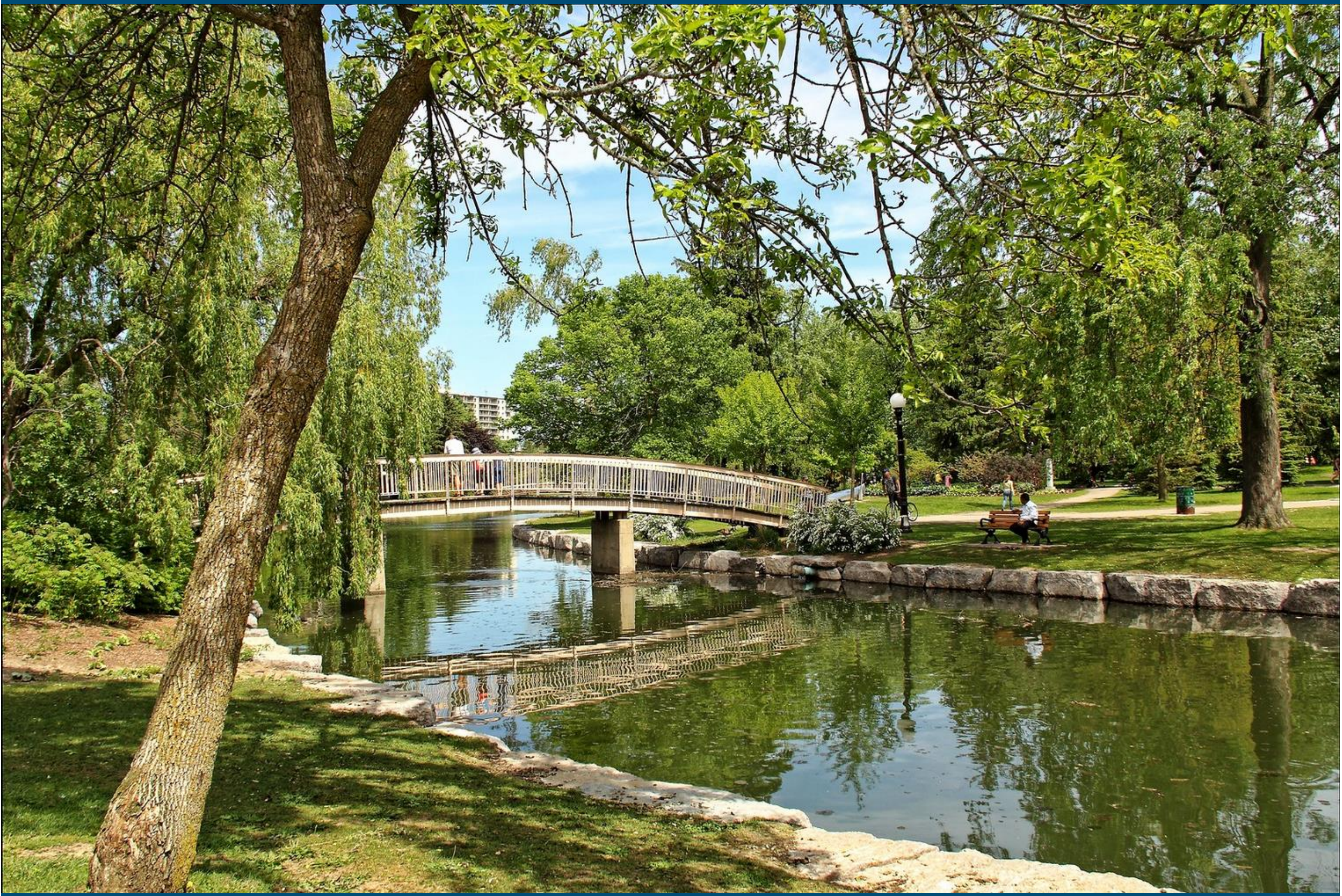
8.3.3 LAND/POLICIES/EASEMENTS/ETC.

- Green standard incorporating policy and language to require considering proposal to connect to DE, i.e. could include mandatory connection in DE zones, DE readiness, proof of alternative low carbon measure
- Incentive to connect
- Revamp right-of-way standard details to accommodate DE piping and reduced separations

- Options for routing piping within Region/City lands or underground garages outside of ROWs
- Options for locating open loop wells on public landscaped areas in the Civic, Bramm, Multimodal Hub areas contingent with permitting

8.3.4 EDUCATE: ALIGNMENT OF CITY AND REGIONAL GROUPS

- Create learning opportunities and alignment of goal on climate action initiative including district energy.
- Understanding the purpose and requirements for all city departments with respect to district energy: roads, infrastructure, parks trails, planning, policy, snow clearing, etc. to identify synergies, impacts and potentials.



Thompson, Sue. Flickr, June 2 2014.

APPENDIX A – SUMMARY OF BUILDINGS WITHIN STUDY AREA

Removed for public release.

APPENDIX B – BAU CAPITAL/OPERATING COSTS

Removed for public release.

APPENDIX C – LOW CARBON DISTRICT ENERGY CONCEPT DRAWINGS

Removed for public release.

APPENDIX D - CASHFLOW AND FINANCIAL MODELLING

Removed for public release.

APPENDIX E - SALAS O'BRIEN GEOTHERMAL REPORT